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Review of Bambara Groundnut (*Vigna subterranea* (L.) Verdc.) Production in Sub-Sahara Africa

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INTRODUCTION

Most human food requirements are provided by fewer than 20 crop species. There remains a vast repository of many hundreds of underutilised species that have been grown locally for centuries and which contribute to the food security of the world's poorest people. Many of these crops are cultivated in hostile, tropical environments by small-scale farmers without access to irrigation or fertilizers and with little guidance on improved practices and feasible alternatives. Any attempts to improve their germplasm or management practices depend on local experience and resources since most agricultural scientists and breeders have ignored or actively discouraged the cultivation of indigenous underutilised crops. The few efforts that have been made to evaluate these species by conventional methods have been slow and labour-intensive and research funds have rarely been directed to multidisciplinary research on such crops of unknown potential. Furthermore, because many of these crops are grown for subsistence, little effort has been made to genetically or agronomically improve them or assess their nutritional, processing and economic potential. A major limitation of most research on underutilised crops is that, because of inadequate funding, it is confined to a single aspect, e.g. breeding, of the particular species in question. The lack of a multidisciplinary effort or comprehensive published literature on any particular underutilised species means that any research that is done may duplicate that being done elsewhere with no increase in overall knowledge or understanding of the crop in question. The lack of an overarching strategy for the improvement of different underutilised crops discourages the development of general principles that can be applied across species. This piecemeal approach reduces both the effectiveness of research on each underutilised species and the collective influence of those advocating greater efforts to increase agricultural biodiversity.

If there is to be an increase in agricultural biodiversity and a broader basis to food security policies, there is an urgent need to coordinate research on underutilised crops within a general and robust methodology that:

- Disseminates recommendations to growers and advisors on management practices and end uses.
- Defines physiological attributes and responses to environmental factors so that the agro-ecological requirements of each crop can be determined.
- Identifies how knowledge and understanding gained on any particular species can rapidly be applied to increase our understanding of other underutilised crops.

One such crop is Bambara groundnut (*Vigna subterranea* L. Verdc), which is an indigenous grain legume grown mainly by subsistence women farmers in drier parts of sub-Saharan Africa. The crop has advantages over more favoured species in terms of nutritional value and tolerance to adverse environmental conditions. In much of Africa, Bambara groundnut is the third most important legume after peanuts (*Arachis hypogaea*) and cowpea (*Vigna unguiculata*) (Sellschop, 1962). The crop has a number of production advantages in that it can yield on poor soils with little rainfall as well as produce substantial yields under better conditions. It is nutritionally superior to other legumes and is the preferred food crop of many local people (Linnemann, 1990; Brough and Azam-Ali, 1992). Bambara groundnut is a rich source of protein (16-25%) and its seeds are valued both for their nutritional and economic importance. The seeds command a high market price, with demand far outweighing supply in many areas (Coudert, 1982). However, despite these important attributes, the agro-ecological and genetic potential of Bambara groundnut have not yet been fully realised nor its full economic significance determined. The crop is still cultivated from local landraces rather than varieties bred specifically for particular agro-ecological conditions or production systems.

Recently, scientists in Africa and elsewhere have begun to accumulate agronomic and physiological knowledge about the crop and to link this with the indigenous knowledge and perceptions of farmers. Between 1992 and 1996, the University of Nottingham, UK, co-coordinated a major European Union (EU) project to assess the agro-ecological potential of Bambara groundnut. This programme linked field experiments in the United Republic of Tanzania, Botswana and Sierra Leone with experiments and analysis at Nottingham and Wageningen University in the Netherlands. The objectives of the EU bambara groundnut project were to:

- Define sites and seasons for Bambara groundnut cultivation in the United Republic of Tanzania, Botswana and Sierra Leone.
- Produce a validated, mechanistic model of Bambara groundnut to predict total biomass and pod yield in contrasting soil and atmospheric environments.
- Identify attributes associated with the ability to produce yields under semi-arid conditions.
- Recommend management practices to stabilise crop yields under rain fed conditions.
- Outline a methodology for applying a similar approach to rapidly assess the potential of other underutilised species.

Bambara groundnut has become less important in many parts of Africa because of the expansion of peanut production. In recent years there has, however, been a renewed interest in the crop for cultivation in the arid savannah zones. Bambara is a popular crop because of its tolerance of drought and the ability to produce a reasonable yield in poor soils.

Constraints associated with Bambara groundnuts production includes, lack of education on the values of the crop, scarcity or in availability of germplasm, pests and diseases. This has contributed to unpopularity and low production of the crop.

Uses: Bambara groundnut is primarily grown for human consumption, but it has other uses as well. The seeds of the crop make it a complete food, with sufficient and well balanced quantities of carbohydrate, protein and fats (Oliveira 1976; Linnemann, 1987). On average the seeds contain 63% carbohydrate, 19% protein ad 6.5% oil. The gross energy value of Bambara groundnut is said to be greater than that of other common pulses such as cowpea and pigeon pea (FAO, 1982).

In countries such as Angola and Mozambique, boiled salted seeds are often served as appetizers. Commercial canning of Bambara groundnuts in gravy is a successful industry in countries such as Zimbabwe and Ghana.

Bambara groundnuts can be eaten in many ways. Immature pods can be boiled and consumed as snacks. However, at maturity the seeds become harder and require boiling for long time. Seeds can be pounded into flour and used to make stiff porridge (Nsima). Roasted seeds can be boiled, crushed and eaten as relish (*chipele*). Recently, a trial of Bambara groundnut milk was carried out which compared its flavour and composition with those of milks prepared from cowpea, pigeon pea and soybean (Brough *et al*., 1993). Bambara groundnut was ranked first and its lighter colour was preferred. This crop may also be used as animal feed. The haulm was found to be palatable (Doku and Karikari, 1971a) and the leaves were reported to be rich in nitrogen and phosphorous and hence suitable for animal grazing (Rassel, 1960).

Table 1: Weaning food recipes

Ingredients	Proportion (%)
1) Finger millet	70 (most nutritious)
Bambara groundnut	25
Amaranthus (dry leaf powder)	5
2) Finger millet	70
Bambara groundnut	30
3) Sorghum	70
Bambara groundnut	25
Amaranthus (dry leaf powder)	5
4) Sorghum	70
Bambara groundnut	30

Studies were undertaken in Kenya by the Kenya Energy and Environment Non Governmental Organization (KENGO) of the Bambara groundnuts as a substitute ingredient for peanut in weaning foods. Researchers worked on traditional recipes provided by several collaborating women's groups and developed four new recipes. Nutritional analysis of the new recipes was carried but no palatability tests were done (Table 1).

Other than culinary uses, Bambara groundnuts have medical uses as well. The Luo tribe in Kenya use Bambara groundnut for cure of diarrhoea. When water from boiled maize and Bambara groundnut mixture is drunk it treats diarrhoea (Goli *et al*., 1991). Leaves can be mixed with those of *Lantana trifolia* L. and pounded and water added to make a solution which can be used to wash livestock or as an insecticide.

The other virtue of Bambara groundnut is that it is a low-cost, dependable farm resource, which grows in harsh environments where many other crops fail. For Africa, the crop offers various benefits;

- An ideal subsistence crop
- A good rotation crop
- A good backstop for hungry times
- A promising commercial resource

It is also among the easier legumes to grow: burying its fruits in the soil, it keeps them safe from the myriad of flying insects that devastate or destroy cowpea, common bean, soybean and other legumes that heedlessly wave their tastiest parts in the air! Other than requiring open sunlight and light, loose soil within which to bury its pods, Bambara tolerates widely dissimilar substrates, including infertile ones. Some observers swear it "prefers worn-out soils"! The crop thrives in laterite, the reddish acidic soil that is toxic to many crops and is the curse of tropical agriculture.

MATERIALS AND METHODS

Bambara groundnut is an annual legume with a compact well-developed taproot system with short (up to 20 cm long) lateral stems on which leaves are borne. Leaves are trifoliate (±5 cm long). Flowers are typically papilionaceous and are borne in a raceme on long, hairy peduncles, which arise from nodes.

Plants may either be bunch or they may be spreading. Bunch types are usually self-pollinated while the spreading types are usually cross-pollinated by ants. Pods form underground, where they are protected from pests and herbivores. Pods may be about 1.5 cm long, round or slightly oval shaped and wrinkled with usually one or sometimes 2 seeds. Unripe pods are yellowish-white, while mature pods may be yellowish-brown or purple. After fertilization the flower stem elongates and penetrates soil where the fruits develop. The colour of testae varies according to ripeness from light yellow to black, purple and other shades. Seeds are round up to 1.5 cm diameter, smooth and hard when dried. Seeds may be black, creamy, brown, red or mottled, with or without hilum colouration.

Genetic resources: The germplasm for bambara groundnut is abundant in Sub-Sahara Africa, as it is grown in every tropical region of the continent. The crop is believed to have originated from northeastern Nigeria and northern Cameroon where its wild relatives have been found. Electrophoretic studies done by Howell (1990) revealed that there was no significant difference between the cultivated genotypes and the wild forms and it was concluded that the wild plant might just be an escape from the cultivated form. Successful intraspecific hybridization has not yet been reported in the crop, which limits the full exploitation of the available diversity.

The major germplasm collection is held by IITA and has been characterized and evaluated. The large collection of IITA has been gathered from countries across Sub-Sahara Africa and the provenance of the various accessions is indicated in Table 2.

Bambara groundnut seeds are orthodox and can be stored at temperatures below 0°C. IITA collections are maintained at -20°C, while the collection for distribution is kept in another cold room at 5°C and 30% RH. Most national programmes maintain their collections for medium-term conservation at temperatures above 0°C and deep freezers are used for conservation of base collections in a number of countries (Goli, 1995).

Table 2: Countries of origin of bambara groundnut accessions held at IITA

Country	No. of accessions
Benin	27
Botswana	5
Burkina Faso	97
Cameroon	207
Central African Republic	103
Chad	70
Congo	42
Cote d'voire	4
Ethiopia	1
Gambia	11
Ghana	120
Kenya	2
Madagascar	49
Malawi	59
Mali	28
Niger	33
Nigeria	310
Senegal	36
South Africa	1
Sudan	7
Swaziland	11
Tanzania	28
Togo	139
Zimbabwe	245
Zambia	284
Unidentified	101
Total	2008

After Goli (1995)

However, the collections of bambara groundnut available in most national programmes may not reflect all the diversity existing in the respective countries. The crop germplasm is often collected in an opportunistic manner. Germplasm collectors use a collecting mission for a major crop to include sampling of bambara groundnut. Collecting missions primarily devoted to bambara groundnut need to be organized in many countries producing the crop. It has been suggested that where no research programme on the crop exists, an expedition can be organized by the International Bambara Groundnut Network to save those ecotypes that are in the process of extinction.

CLIMATE, CULTIVATION AND DEVELOPMENT

Bambara groundnuts can be cultivated up to 1 600 m above sea level. The average temperature ideal for the crop is 20 to 28 °C and the crop does well in weather conditions suitable for groundnuts. The crop has a growth period of 110 to 150 days with widespread rain of 600-700 mm. Too much rain at harvest time, however, can be detrimental as it may damage the crop.

Bambara groundnuts do well in deep, well-drained soils with a light friable seedbed (Johnson, 1968). Many farmers grow the crop on flat seedbeds, but some grow it on mounds or ridges. Planting density is usually low farmer's fields, especially when the crop is not grown in rows. The recommended has been established to range from 6 to 29 plants m^{-2} (Rassel, 1960). Chemical fertilizers are not normally applied to the crop as the nitrogen requirement is by the natural N_2 fixation as evidenced by several nodulation studies (Doku, 1969a; Somasegaran *et al.*, 1990).

Bambara groundnut seeds take about 7-15 days to germinate depending on landrace. Seed stored for about 12 months germinate well, but longer storage results in loss in viability. Flowering starts 30 to 35 days after sowing and may continue until the end of the plant's life. Bambara groundnuts are typically short-day plants and the following variations were observed;

- Day neutral but fruit formation is delayed by long days
- Day neutral but fruit setting is prevented by long days
- Delayed flowering and no fruit setting under long days
- No flowering under long-day conditions

The optimum conditions for the germination rate of bambara groundnut were stipulated by The International Seed Testing Association (ISTA) that the germination test should include i) duration germination and ii) percent of normal seedlings, hard seeds and dead seeds. If the result for any of these is found to be nil, then it is entered as '0'. Sowing seeds that do not have capacity to produce an abundant crop of the required cultivar is one of the greatest hazards in crop production. Large Bambara groundnut seeds reportedly produce more vigorous seedlings (Karikari,1969).

Assessing the germination of different genotypes under controlled environments and seedling emergence in the field has been found to be a useful rapid screening technique, which can facilitate the selection of germplasm with good early vigour for moisture stressed soil conditions (Perry, 1981). Seeds of high germination and vigour are highly desirable in the establishment of most crops.

The effect of the duration of storage on germination is also an important determinant of the physiological quality of a seed lot. Prolonged storage for 18 months reportedly reduced germinability of Bambara groundnut, delayed germination, reduced root and epicotyl growth and increased the number of stunted seedlings (Sreeramula, 1983).

Table 3: Macro-elements of Bambara groundnuts (% dry matter)

	K	Mg	Ca	P	N
Roots	1.5	0.6	0.9	0.2	2.7
Leaves	1.1	0.5	2.6	0.2	1.8
Seed	1.6	0.2	0.	0.6	3.9

Table 4: Quantities of elements from the soil

Element	Quantity removed (kg)
K	26.2
Mg	6.6
C	25.1
P	7.8
N	55.7

Vegetative growth takes place in spring and early summer and pods form in late summer. Pod and seed development take place approximately 30 to 40 days after fertilization (Swanevelder, 1998).

Currently cultivation of this crop is not very intensive and at a small scale by subsistence farmers. The crop is mainly grown as a casual crop intercropped with major crops like maize. When Bambara groundnut is grown in rotation it improves the nitrogen status of the soil. The crop thrives better in deep, well-drained soils with a light, friable seedbed (Johnson, 1968). Planting density is usually low in farmer's fields especially when crops are not in rows. The recommended plant density as found in experimental plots ranged from six to 29 plants per m^2 (Rassel, 1960). Fertilizers are not usually applied to this crop. Nitrogen requirement is met by the presence of node on the roots of these plants.

Harvesting of Bambara groundnut is by pulling the plant out of the soil. For the bunched type, most pods remain attached to the root crown after pulling. Detached pods left in the ground are picked manually by hand. Harvested pods are air dried for several days before shelling. The seeds are the product that are consumed or sold in markets. Preserving planting material is mainly in pod-form, which are more resistant to attacks by insects.

Bambara groundnut grows on any well-drained soil, but light, sandy loams with pH 5.0 to 6.5 are most suitable. The crop does well on poor soils, which has low nutrient content. The crop however grows poorly in calcareous soils.

The chemical composition of Bambara groundnut is made up of elements given in Table 3.

Roots are not normally removed and the leaf: seed ratio is approximately 75:81, i.e., 1 000 kg seed and 925 kg leaves remove the following quantities of elements from the soil (Table 4).

NITROGEN FIXATIO IN BAMBARA GROUNDNUT

Bambara groundnut is typically a tropical legume that nodulate with cowpea-type bradyrhizobia. Studies done by Doku (1969b) demonstrated the ability of Bambara groundnut to cross-nodulate with isolates from different tropical legumes, which indicate that the species is less selective in its bacterial requirements. But because Bambara groundnut grows over a wide range of soil factors, such as low fertility, low moisture, or low temperature, its symbiosis with root-nodule bacteria is bound to differ from one locality to another within Africa. Bradyrhizobia strains nodulating Bambara groundnut will not only differ between dry and well-moistured soils, but also between low and high NO_3 soils and low temperature conditions.

Cowpea studies by Ahmad *et al.* (1981) have shown that bradyrhizobia nodulating this plant in much drier, hotter and infertile soils of Niger are serologically and morphologically different from those occurring in wetter, humid and more fertile soils of Ibadan. This wet/dry colony characteristic could possibly account for the ability of bradyrhizobia nodulating African legumes such as bambara groundnut, Kersting's bean and cowpea to survive in soils with highly differing moisture, temperature and pH levels.

It is not known whether these features affect bacterial strain survival and persistence in soil. However, the marked variation in yields (600-3000 kg ha^{-1}) of bambara groundnut in Africa (Rachie and Silvestre, 1977) and the fact that high-yielding cultivars from one country can perform poorly in another country (NAS, 1979) suggest considerable differences in the symbiotic efficacy of native bradyrhizobia which nodulate this species.

Increasing bambara groundnut production in Africa, therefore, targets symbiotic effectiveness as a way to improve yields.

Johnson (1968) suggested that bambara groundnut does not require inoculation, but growing evidence indicates the need for inoculation with effective Bradyrhizobium, especially where newly cultivated fields are involved (Stanton *et al.*, 1966). It has been demonstrated in Togo that inoculating bambara groundnut with suitable strains of Bradyrhizobium can significantly increase yields (Dadson *et al.*, 1988). The increase in symbiotic performance and grain yields was higher when cultivars were inoculated with indigenous bradyrhizobia, rather than with exotic strains.

Research has shown that application of nitrogen and phosphorous fertilizers had no influence on yield.

DISEASES AND PESTS OF BAMBARA GROUNDNUTS

Diseases: Bambara groundnut is one indigenous African crop currently receiving interest from researchers, owing to its high yield and resistance to diseases (Hepper, 1970) as well as its adaptability to poor soils and low rainfall.

Diseases which have been recorded on Bambara groundnut include leaf spot (*Cerscospora canescens*), powdery mildew (*Erysiphe* sp.), leaf spot (*Phyllosticta voandzeia*), wilt (*Fusarium* sp.), leaf blotch (*Phomopsis* sp.) and *Scleorotium rolfsii*. Leaf spot symptoms include isolated brown spots on leaflets and severe attack can cause defoliation. Pod size can be reduced significantly in infestation occurs before flowering. Wilting and yellowing of Bambara groundnut caused by Fusarium sp., results in stunted growth with vascular discolouring appearing after 50 days of sowing. Symptomatic yellowing, necrosis and wilting will occur and the affected plant eventually dies.

Powdery mildew is characterized by a whitish powder on both sides of leaflets, but is more frequent on the abaxial side. Infected leaves dry and die prematurely. Powdery mildew is a widespread disease in Madagascar and has been named *Sphaerotheca voandzeia* (Bouriquet, 1946).

Phyllosticta voandzeia is identified by the characteristically ill-defined, irregular, circular, brownish purple spots o the leaves.

Bambara groundnut stem rot caused by *Sclerotium rolfsii* is a disease whose initial symptoms are rot at the base of stem, followed by production of black sclerotia on infected tissue. The rot, which begins below soil level, spreads into the crown of the plant and in severe cases, to the pods and downwards to the roots. Sclerotia can survive in soil between crops.

Pests: Pests which have been recorded on Bambara groundnut include aphids (*Aphis* sp.), bruchids (*Callosobruchus* sp.), leaf hoppers (*Hilda patruelis*) and termites. In the field pests feed on leaves and sap, thereby disrupting the photosynthetic process and causing low yields. Other pests feed on seed, reducing its viability and quality.

Aphids represent 65% of the insect pests on the crop. The aphid problem is exacerbated by late planting and by periods of heavy rainfall followed by sunshine (Mabika and Mafongoya, 1997). Ants and termites constitute another 15% of Bambara groundnut pests and the remaining 20% are accounted for by cutworms, nematodes and weeds.

Pests and diseases of Bambara ground are, however, not considered very serious problems on the crop.

Viruses: Bambara groundnut is susceptible to rosette; a viral disease which is spread by aphids. The two main strains of rosette are chlorotic rosette and green rosette. The symptoms of chlorotic rosette are a mosaic patter of dark green banding on light green leaflets, or the leaves may be completely necrotic. The symptoms of green rosette are a dark green foliage mottle on a light green background and a marked reduction in leaflet size.

Nematodes: The root-knot nematode (Meloidogyne javanica) has been found to seriously infect bambara groundnut (Martin, 1959). Meloidogyne larvae invade roots and feed in the vascular system of the host, causing formation of giant cells. In severe cases the roots of infested plants are completely covered with swellings caused by hypertrophy of the cortical cells. Damage to roots impairs the normal growth of bambara groundnut, resulting in s tunted growth, yellowing and wilting. Root-knot nematode infestation has also been observed to reduce dry matter accumulation and flower abortion.

CHARACTERIZATION AND EVALUATION OF IITA'S BAMBARA GROUNDNUT COLLECTION

Bambara groundnut is an important food legume in Africa, which has a long tradition of cultivation. However, no significant research has been undertaken to improve the crop. The availability of germplasm materials is important to crop breeding. The International Institute of Tropical Agriculture (IITA) made a collection and gathered about 2000 accessions of the crop from most countries in Sub-Sahara Africa. Quantitative characters were described and were used to make basic statistics.

Other features that were used to characterize Bambara groundnuts were eye pattern, which corresponds to pattern of hilums. Eight eye patterns were identified as no eye, eye as thin circle around hilum, eye as 2 thin circles on both sides of hilum, eye as two thick lines on both sides of hilum, eye almost triangular, large eye shapeless becoming frayed, eye like a butterfly and mottled eye. Testa patterns were also used to characterize Bambara groundnuts and these included no pattern, entire line, striped, marbled, dotted, little rhomboid spotting only on one side of hilum, rhomboid on both sides of hilum and much rhomboid.

Modelling: Models are used to simulate rate of progress to flowering and podding. The models are based on the PARCH model (Predicting Arable Resource Capture in Hostile environments) which incorporates a soil profile divided into layers, coupled with a crop growth model. The model has been developed primarily for harsh environments where water availability is scarce. On each day, light and water are intercepted and converted into dry matter.

If water is non-limiting then growth is equal to the amount of radiation intercepted multiplied by the conversion coefficient for intercepted radiation. If water is limiting, growth equals the amount of water transpired multiplied by the transpiration equivalent (g dry matter produced per kg water transpired). An index of crop stress is derived from the ratio of light-limited growth, depending on the availability of these resources and the crop's ability to intercept them. Partitioning of dry matter between plant organs depends on the developmental stage and the level of stress; increased stress results in increased partitioning to roots and reduced partitioning to pods. Initially most assimilates are partitioned to the leaves, increasing the leaf area and enabling more light to be intercepted. When podding occurs there is gradual decline in partitioning to leaves and stems as assimilates are preferentially partitioned to pods.

REFERENCES

Ahmad, M.H., A.R.J. eaglesham, S. Hassouna, B. Seaman, A. Ayanaba, K. Mulongoy and E.L. Pulver, 1981. Examining the potential for inoculant use with cowpea in West African soils. Trop. Agric., 58: 325-335.

Brough, S.H. and S.N. Azam-Ali, 1992. The effect of soil moisture on the proximate composition of Bambara groundnut (*Vigna subterranea* L. Verdc). J. Sci. Food Agric., 60: 197-203.

Brough, S.H., S.N. Azam-Ali and A.J. Taylor, 1993. The potential of Bambara in milk production and basic functionality systems. Food Chem., 47: 277-283.

Bouriquet, G., 1946. The diseases of cultivated plants in Madagascar. Diseases of *V. subterranea*. Encycl. Mycol., 12: 352-359.

Coudert, M.J., 1982. Niebe et voandzou: une perspective pour developpement du commerce regional en Afrique de l'ouest (Cowpea and bambara groundnut: Prospects for regional trade development in West Africa). FAO microfiche XF 83322635. International Trade Centre UNCTAD/GATT, Geneva, Switzerland, pp: 125.

Dadson, R.B., C.B. Brooks and J.G. Wutoh, 1988. Evaluation of selected rhizoidal strains grown in association with bambara groundnut (*Voandzeia subterranean* (L.) Thouars). Trop. Agric., 65: 254-256.

Doku, E. V. and S .K. Karikari, 1971a. Bambara groundnuts. Econ. Bot., 25: 357-362.

Doku, E.V., 1969a. Growth habit and production of bambara groundnut (*Voandzeia subterranean*), Ghana J. Agric. Sci., 2: 91-95.

Doku, E.V., 1969b. Host specificity among five species in the cowpea cross-inoculation group. Plant and Soil 30: 126-128.

FAO, 1982. Legumes in human nutrition. FAO Food and Nutrition Paper No.20. FAO, Rome.

Goli, A.E., F. Begemann and N.Q. Ng, 1991. Germplasm diversity in Bambara groundnuts and prospects for crop improvement. Crop Genetic Resources of Africa.

Hepper, F.N. 1970. Bambara groundnut (*Voandzeia subterranea*). Review article. Field Crop Abstr., 23: 1-6.

Howell, J., 1990. Variation and evolution of bambara groundnut (*Vigna subterrranea* (L.) Verdc.; Fabaceae). Ph.D Dissertation, Miami University, Oxford, Ohio, pp: 237.

Johnson, D.T., 1968. The bambara groundnut: A Review. Rhodesia Agric. J., 65: 1-4.

Karikari, S.K., 1969. Flowering, Pollination and Pod Formation in Bambara groundnut (*Voandzeia subterranea* Thou.) in Ghana. MSc Thesis, University of Ghana, Legon.

Linnemann, A.R., 1987. Bambara groundnut (*Vigna subterranea* (L.) Verdc.): A Review. Abstr. Trop. Agric., 12: 7.

Linnemann, A.R., 1990. Cultivation of Bambara groundnut (*Vigna subterranean* (L.) Verdc.) in Western Province, Zambia. Report of a field study. Trop. Crops Comm., pp: 15.

Mabika, V. and P. Mafongoya, 1997. Zimbabwe. In Bambara groundnut (Vigna subterranean (L.) Verdc.). Promoting the Conservation and Use of Underutilized and Neglected Crops. 9. Proceedings of the Workshop on Conservation and Improvement of Bambara groundnut. (Eds. J. Heller, F. Begemann and J. Mushonga). Rome. IPGRI., pp: 68-71.

Martin, C.G., 1959. Plants attacked by root-knot nematodes in the Federation of Rhodesia and Nyasaland. Rhod. Agric. J., 56: 162-157.

National Academy of Sciences (NAS), 1979. Tropical legumes: Resources for the future. Natl. Acad. Press, Washington DC.

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

Perry, D.A., 1981. Methodology and Application of Vigour Tests. In Handbook of Vigour Test Methods (D.A. Perry, Ed.). International Seed Testing Association, Zurich, pp: 8-10.

Rachie, K.O. and P. Silvestre, 1977. Grain legumes. In Food Crops of the Lowland Tropics. (C.L. Leaky and B.J. Wills, Eds.), Oxford University Press, London.

Rassel, A., 1960. Le voandzou Voandzeia subterranea Thou. Et sa culture au Kwango. Bull. Agric. Du Congo Belge et du Ruanda-Urundi, pp: 51.

Sellschop, J.P.E., 1962. Cowpeas, *Vigna unguiculata* (L.) Walp. Field Crop Abstr., 15: 259-266.

Somasegaran, P., R.C. Abaida and F. Kumaga, 1990. Host-*Bradyrhizobium* relationships and nitrogen fixation in the bambara groundnut (*Voandzeia subterranean* (L.) Thou.). Trop. Agric., 67: 137-142.

Sreeramula, N., 1983. Germination and food reserves in bambara nut seeds (*Voandzeia subterranean* (L.) Thou.) after different periods of storage. Ann. Bot. 34: 27-33.

Stanton, W.R., J. Doughty, R. Orraca-Tetteh and W. Steele, 1966. *Voandzeia subterranean* (Thou.). In: Grain Legumes in Africa. FAO, Rome, pp: 128-133.

Swanevelder, C.J., 1998. Bambara-food for Africa. National Department of Agriculture, ARC-Grain Crops Institute, Pretoria.

Verdcourt, B., 1980. The correct name for the bambara roundnut. Kew Bull. 35: 474.