MEDWIN PUBLISHERS
Committed to create value for Researchers

Journal of Ecology & Natural Resources
ISSN: 2578-4994

Origin and Ecology of Bambara Groundnut (*Vigna Subterranea* (L.) Verdc: A Review

Temegne NC[1]*, Gouertoumbo WF[1], Wakem GA[1], Nkou FTD[1], Youmbi E[1,2] and Ntsomboh-Ntsefong G[1,3]

[1]Department of Plant Biology, Faculty of Science, University of Yaounde I, Cameroon

[2]African Centre for Research on Banana and Plantain (CARBAP), Cameroon

[3]Institute of Agricultural Research for Development (IRAD), CEREPAH La Dibamba, Cameroon

Review Article

Volume 2 Issue 4

Received Date: June 26, 2018

Published Date: July 31, 2018

DOI: 10.23880/jenr-16000140

***Corresponding author:** Carine Nono Temegne, Department of Plant Biology, Faculty of Science, University of Yaounde I, P. O. Box 812 Yaounde, Cameroon, Tel: +237 651323456; Email: nonocarine2003@yahoo.fr

Abstract

Bambara groundnut (*Vigna subterranea* (L.) Verdc.) is an underutilized legume used as food, medicine and animal feed. Despite of the many useful properties of this pulse, it remains a neglected crop in sub-Saharan Africa. The objective of this paper is to record the ecology of Bambara groundnut on the basis of data from the literature in order to raise awareness on its importance. The following aspects are discussed: the origin and current distribution of Bambara groundnut, its classical and vernacular nomenclature, appropriate climatic conditions for its growth, soil requirements and the adaptability of the crop to climate change in relation to its ecology, origin, distribution and intrinsic properties. It is hoped that this review will enhance Bambara groundnut production given its high potential as a future crop that could be well adapted to various agro-ecological conditions.

Keywords: Bambara Groundnut; Ecology; Fabaceae; Menorrhagia; Intraspecific

Introduction

Bambara groundnut (*Vigna subterranea* (L.) Verdc.) is a neglected African plant of the family *Fabaceae*. It is recognized for its high nutritional value, its tolerance to poor soils, drought, salt stress and its ability to produce in conditions where peanuts completely fail [1-7]. However, it remains unfortunately less cultivated and poorly known in tropical Africa. In fact, seed legumes, especially Bambara groundnut, have an important socio-economic role in tropical Africa, where they are part of tradition in culinary habits [8,9]. Bambara groundnut is native to northeastern Nigeria and northern Cameroon [10]. Its seeds are used as feed for pigs and poultry. Their leafy stalks are also used as livestock feed [9]. The seeds contain on average 63% of carbohydrates, 19% of

proteins and 6.5% of fats; these values are considered sufficient to make this legume a complete food [11]. It is also rich in calcium, potassium, iron and nitrogen [12].

The highly nutritious content of Bambara groundnut and its high content of essential amino acids (methionine, leucine, isoleucine, lysine, phenylalanine, threonine, valine and tryptophan) make it an important crop to consider for food security [12,13]. Bambara groundnut also contains vitamin E (3.18±0.15 mg/100 g), vitamin C (1.17±0.20 mg/100 g) and vitamin A (26.05±0.14 mg/100 g). It is a medicinal plant used to treat diarrhea, anemia, abscesses, internal injuries, ulcers, infected wounds, epilepsy, cataracts, menorrhagia during pregnancy, nausea in pregnant women, kwashiorkor and venereal diseases. It also helps to prevent heart disease, eye disease and colon cancer [3,9]. It contains kaempferol, an antioxidant polyphenol, which reduces the risk of many chronic diseases such as cancer [3,13]. Its cultivated area decreases over time while that of other legumes increases. The aim of this review is to record the ecology of Bambara groundnut on the basis of data from the literature in order to popularize it and open up more perspectives for its conservation, cultivation and further exploitation.

Origin and Distribution

The known distribution of Bambara groundnut extends from West to southern Africa via Central Africa (Figure 1). Investigations into the origin of Bambara groundnut all concluded that the crop originated from the African continent [10,14-17]. The common name (Bambara groundnut) actually seems to be derived from a tribe named Bambara, whose members live today mainly in Mali. Its exact area of origin in Africa has however been a subject of debate. No spontaneous or wild form of the crop has been found in Mali, although Guillemin et al. reported the probable occurrence of wild forms near Senegal. Bambara groundnut was actually found by Dalziel in his wild state in 1901 in the northern province of Nigeria (Yola) [14,18]. He reported that Ledermann also found the wild plant the same year near Garoua in northern Cameroon. Dalziel's conclusion was confirmed by Hepper in 1957 [19].

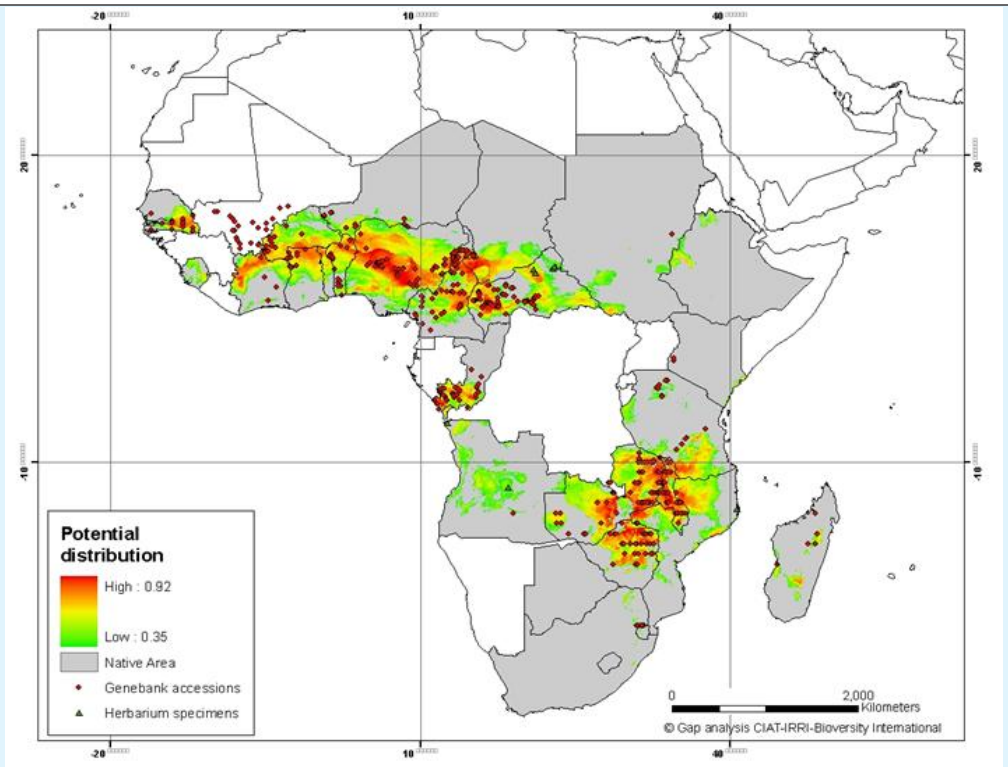

Figure 1: Distribution of Bambara groundnut (Vigna subterranea (L.) Verdc.) in Africa (CIAT-IRRI-Biodiversity international).

The distribution of wild Bambara groundnut is now known to extend from the Jos and Yola plateau in Nigeria, to Garoua in Cameroon, and probably beyond. In addition, Begemann carried out detailed analysis of seed diversity for the IITA's (International Institute of Tropical Agriculture) large collection of Bambara groundnut [10]. He found that samples collected within 200 km of the original putative center, between Yola and Garoua, showed greater seed diversity [10]. Diversity indices for most parameters studied (number of days to maturity, pod length, number of shoots per plant, etc.) were relatively higher for accessions from Nigeria and Cameroon [10]. His conclusion confirmed the hypothesis that the center of origin of the Bambara groundnut is in the northeastern region of Nigeria and northern Cameroon. Recent work of Olukolu et al. on 124 accessions from 25 African countries, maintained at IITA (Nigeria) using DArT markers also revealed greater genetic diversity for the Cameroon / Nigeria region compared to other regions [20]. This is consistent with the hypothesis that this region (Northeast Nigeria and Northern Cameroon) is the center of origin of Bambara groundnut. Rungnoi et al. concluded on the basis of the analysis of 363 local varieties that West Africa (including the Cameroon / Nigeria region) is the center of diversity/domestication of Bambara groundnut [21]. Bambara groundnut may have reached Southeast Asia (Thailand) from West Africa via East Africa [21]. But, Somta et al. reported higher genetic diversity in Burkina Faso accessions than in Cameroon / Nigeria. Various studies show that the accessions from West-Central Africa and those from South-East Africa are still grouped separately during of molecular analysis [21-24]. Thus, they hypothesize that the southern African region is a center for the domestication or diversity of Bambara groundnut.

Several studies have also been carried out using molecular tools such as RAPD, AFLP, Microsatellite, DArT Array markers [25]. Ho, et al. constructed two individual intraspecific linking cards composed of DArTseq markers. Chai et al. determined quantitative trait loci (QTL) implied in agronomic and drought-related traits [26,27].

Bambara groundnut is now widely cultivated throughout tropical Africa, Indonesia, Malaysia, India, Sri Lanka, Philippines, South Pacific, parts of northern Australia, Papua New Guinea, Central and South America [28].

In 1995, the proceedings of the International Plant Genetic Resources Institute (IPGRI) revealed that, of the 2,008 accessions listed in Africa (Table 1), Cameroon had 207 [19]. IITA possibly have 1,815 accessions in its collection in Nigeria and IRD (Institute of Research for Development) 1,000 accessions in its collection in France [22,29]. To date, several studies have been realized on the genetic diversity of Bambara groundnut across Africa [20,25,30,31].

N°	Country	N° of accessions	N°	Country	N° of accessions
1	South Africa	1	13	Malawi	59
2	Benin	27	14	Mali	28
3	Botswana	5	15	Niger	33
4	Burkina Faso	97	16	Nigeria	310
5	Cameroon	207	17	Central African Republic	103
6	Congo	42	18	Senegal	36
7	Côte d'Ivoire	4	19	Sudan	7
8	Ethiopia	1	20	Swaziland	11
9	Gambia	11	21	Tanzania	28
10	Ghana	120	22	Chad	70
11	Kenya	2	23	Togo	139
12	Madagascar	49	24	Zambia	284
Total					2008

Table 1: The origin of IITA (International Institute of Tropical Agriculture) Bambara groundnut accessions [19].

Nomenclature

The current scientific name of Bambara groundnut is *Vigna subterranean.* It has also been called *Glycine subterranea* L., *Voandzeia subterranea* (L.) Thouars ex DC. In French, it is still called voandzou, "pois Bambara" or "pois de terre" or "pois arachide". In English, it is called Bambara groundnut, Bambara pea, Bambara nut,

Bambara-bean, Congo goober, earth pea, ground-bean, or hog-peanut [32,33]. In Cameroon, there are several vernacular names depending on languages: *Matop/Wondenkana* (Bassa'a), *Matob* (Douala), *Moto/Mɔto/Matoba*(Fe'efe'e), *ngalaa-ji* (Fulfulde), *Motobo* (Bafia), *Debbi* (Foulbe), *Mogran* (Toupouri), *Souonchié* (Moundang), *Atob/Metop* (Ewondo), *Deppi, Jwə/Djué* or *matobɔ* (Ghomala), *ndzu/Ndən* (Mankon), *Kezo Ke Zon* (Nugunu), *mendzo wah'a sah* (Bagam), etc [4,5].

In 1763, Linnaeus described it in Species Plantarum, and named it *Glycine subterranea*, according to his system of nomenclature [34]. In 1806, Du Petit-Thouars found the culture in Madagascar, under the vernacular name "voanjo", later written as "voandzou" in French. He then proposed the name *Voandzeia subterranea* (L.) Thouars, which has been widely used by researchers for more than a century [35]. Detailed botanical studies conducted by Maréchal et al. revealed great similarities between peas and the genus *Vigna* [36]. This corroborated that of Verdcourt, who in 1980 proposed the current name *Vigna subterranea* (L.) Verdc [37].

Bambara groundnut is a Dicotyledonous angiosperm. Its APG IV classification is as follows [38]:

- Kingdom: *Plantae* ;
- Sub Kingdom: *Tracheobionta*;
- Class : *Magnoliopsida* (Dicotyledon) ;
- Sub Class : *Rosidae*
- Order : *Fabales* ;
- Family : *Fabaceae*
- Sub Family : *Fabaceae Papilionoideae*
- Tribe : *Phaseoleae*
- Sub Tribe : *Phaseolinae*
- Genus : *Vigna*
- Species : *Vigna subterranea* (L.) Verdc.

Climate

With regards to rainfall, Bambara groundnut is very resistant to drought [2,39,40]. The required minimum annual rainfall for optimal performance is about 300 mm and optimum annual rainfall is between 750 and 1,400 mm and should not exceed 3,000 mm [41]. According to South Africa Department of Agriculture, Forestry and Fisheries, an annual rainfall ranging from 500 to 1,200 mm is required during the growing season [42]. Bambara groundnut can tolerate heavy rainfall, but too much rainfall at harvest may result in yield losses [42].

Production is most suitable in tropical humid and dry (Aw) and subtropical dry (Cs) tropical climates; between 20°C and 30°C latitude [41]. The optimum temperature is between 19°C and 30°C. Temperatures below 16 °C and above 38°C are not suitable for Bambara groundnut production [41]. Depending on temperature, the rate of leaf formation ranges from 0.19 to 0.63 leaves/day [43]. In 2015, Nordin and Singh found that highest seedling emergence was recorded at 30°C [44].

Soil Requirements

Sandy soils are the best for the production of Bambara groundnut [41]. However, it can grow on sandy to sandy loam and well-drained soil, which make it easier to harvest [42]. These soils prevent clogging. Light textured soils are recommended. The optimal depth of the soil is between 50 and 100 cm [41]. Soil pH is better adapted between 5 and 6.5 and should not be less than 4.3 or greater than 7 [41,42,45]. Bambara groundnut generally performs better on poor soils than groundnuts (*Arachis hypogaea* L.) [42,46]. It is the least demanding for mineral elements and its yields on low–fertility soils are generally higher than those of *A. hypogaea* L. grown on similar soil.

Although, it has been reported that soil fertility should be low for its production; the richness of the soil in mineral elements (P especially) influences its growth, development and yield [5,41,47-49]. Tweneboah advise to apply 250 $kg.ha^{-1}$ of single super phosphate before Bambara groundnut planting. Toungos et al. found that 60 $kg.ha^{-1}$ of simple superphosphate significantly increased the Bambara groundnut yield on poor soils in Yola, Nigeria [50,51]. In addition, the work of Nweke & Emeh has shown that 165 $kg.ha^{-1}$ of simple superphosphate is needed for optimum yield of the Bambara groundnut in Igbariam in south-eastern Nigeria [52]. The work of Temegne showed that 150 $kg.ha^{-1}$ simple superphosphate is needed for the production of Bambara groundnut on the poorer Ferralsols in the Centre Region of Cameroon [5]. Other studies in Nigeria have also shown that phosphate fertilization improves the growth and yield of Bambara groundnut [53-55]. The soluble P input improved its growth in the greenhouse; while biological fertilization with arbuscular mycorrhizal fungi significantly boosted its growth, development and yield in Cameroon [4,5,47-49].

Nitrogen requirement is provided by natural N_2 fixation with nitrogen–fixing bacteria belonging to the genus *Rhizobium* [56]. Bambara groundnut fixes 32-81 kg N ha^{-1} [57]. High nitrogen level mostly leads to few pods production and seeds [50,58]. But, in some cases, for various reasons, nitrogen assimilation is poor and

nitrogen fertilizer application improves Bambara groundnut growth, particularly in the early period. The dose varies from 30 to 50 kg of nitrogen per hectare [46]. Later application of nitrogen could inhibit nodulation. According to Mkandawire, a yield of 1000 kg of seed and 925 kg of leaves removes 55.7 kg of nitrogen, 26.2 kg of K, 25.1 kg of C, 7.8 kg of P and 6.6 kg of Mg [59].

Bambara Groundnut and Climate Change

Legumes, including Bambara groundnut, have the potential to contribute to climate change mitigation by reducing the use of fossil fuels or by providing raw materials to emerging bio based economies [60,61]. They can biologically fix 33 to 46 Tg N each year [60]. They are adaptive and resilient; have low water demand and can therefore tolerate drought, rising temperature and reduced precipitation [6,7,39,40,61]. They have a range of ecosystem services, the ability to reduce greenhouse gas emissions, reduce the use of fossil fuels, accelerate carbon sequestration rates and provide a valuable source of raw materials for bio refineries [61].

Importance of Bambara groundnut

Nutritional Importance

Bambara groundnut (Figure 2) play an important role in the diet and culture of populations. The leaves, rich in P, are used for livestock feed [62]. Seeds are given to pigs and poultry while leafy stems are used as livestock fodder [9]. Largely grown for its underground seeds such as peanuts, it can be eaten fresh, dry or after cooking.

Figure 2: Bambara groundnut plants.

Dry, ripe seeds are boiled and eaten as a dry vegetable or mixed with corn or plantain [9]. The seeds are also ground into flour, sometimes after roasting, to make a porridge. In Cameroon, this flour is added to cereals by the IRAD (Institute of Agricultural Research for Development) for the manufacture of “baby lion” porridge [5]. Bambara groundnut seeds are eaten raw, boiled, roasted; they are used for making cakes (*koki*, dough, pounded/crushed, etc.), stews, couscous, soups, and porridge, as a snack [5]. They are also added to corn flour toenrich traditional foods. Its immature pods can be picked green and used as a green vegetable. Bambara groundnut contains little fat (6%) [63]. It is highly caloric (387 kcal / 100 g), rich in vitamins and mineral elements and very balanced in protein. It also contains 63% carbohydrate, 18% oil and fatty acids [11,64]. These values are considered sufficient to make this legume a complete food [11].

Bambara groundnut are a rich source of protein that, along with other local sources of protein, can help alleviate the nutritional problem in poor tropical countries [8]. Its seeds are used to produce vegetable milk comparable to soy milk. The test of protein functionality in crushed seeds shows that it can replace other conventional flours in the range of processed products. Its seeds constitute a complete food because they contain sufficient amounts of protein, carbohydrate and fat [8,62]. These seeds are also a balanced diet, as compared to

other legume species, since they are rich in iron and the protein contains more lysine and methionine.

Agronomic Importance

This legume is used in crop rotations to improve soil productivity through its ability to fix atmospheric nitrogen and provide it to the soil [65]. It is mainly grown by farmers because it has several agronomic benefits including high nutritional value, drought tolerance and the ability to produce in poor soils compared with preferred species such as common bean, peanut, and groundnuts [66,67]. Bambara groundnut tolerate acidic and poor soils. It has good resistance to water stress and is characterized by a strong link between good symbiotic nitrogen fixation capacity and high seed yield [62]. The potential of this plant could explain its presence in the arid regions of the African continent [68].

Medicinal Importance

The seeds and leaves of Bambara groundnut are used in traditional medicine. Leaf preparations are used in Senegal to treat abscesses and infected wounds [9]. The juice extracted from the leaf is applied to the eyes to treat epilepsy and the roots are sometimes used as an aphrodisiac [9]. Crushed seeds, mixed with water, are administered to treat cataracts. The Ibo of Nigeria use the plant to treat venereal diseases [9]. In Cameroon, Bambara groundnut are used to fight amoebic dysentery, sore throat, headaches, stomach pain, joint pain and bone decalcification [5]. It helps in digestion through its laxative properties. It stimulates milk production in breastfeeding women and is given to women who have just given birth to heal their wounds [5]. Bambara groundnut seeds also contain kaempferol, an antioxidant polyphenol, which reduces the risk of many chronic diseases such as cancer [3,13].

Economic Importance

Bambara groundnut is the third most widely grown legume in the plains of tropical Africa after groundnuts and cowpeas [69]. It is after peanut, soybean and cowpea, the fourth important legume in Cameroon [70]. In 2016, Cameroon was the second world's largest producer, behind Burkina Faso, and ahead of Niger, Mali and the Democratic Republic of Congo (Table 2). Bambara groundnut production in Cameroon increased from 6,800 tons in 1996 to 42,041 tons in 2016 [71]. World production was estimated by FAO at 164,589 tons in 2016 for a yield of 7,195 hg/ha on 228,764 ha [71]. Bambara groundnut production is essentially from Africa.

	Countries					World
	Burkina Faso	Cameroon	Niger	Mali	RDC	
Production (t)	53,141	42,041	32,625	25,963	10,819	164,589

Table 2: Main Bambara groundnut producers in the World [71].

Conclusion

Bambara groundnut (*Vigna subterranea* (L.) Verdc.) is an African indigenous crop used for human and animal nutrition and as medicinal plant. The seeds contain on average 63% of carbohydrates, 19% of proteins and 6.5% of fats; they also contain calcium, potassium, iron, nitrogen, vitamins E, C and A, making it an important crop to consider for food security. Bambara groundnut is originated from the African continent, more specifically from the north-eastern region of Nigeria and northern Cameroon (West Africa) according to most of studies. However, the real centre of diversity or origin of Bambara groundnut remains controversial. The South-East Africa region could be a secondary centre of domestication for Bambara groundnut. It is widely cultivated throughout tropical Africa, Indonesia, Malaysia, India, Sri Lanka, Philippines, South Pacific, parts of northern Australia, Papua New Guinea, Central and South America. Due to its ecology, distribution, nutritional and medicinal properties, it could be a potential future crop to be exploited for food security, climate change mitigation and poverty alleviation, given that it is well adapted to various agro-ecological conditions and climate change.

References

1. Taffouo VD, Wamba OF, Youmbi E, Nono GV, Akoa A (2010) Growth, yield, water status and ionic distribution response of three Bambara groundnut (Vigna subterranean (L.) verdc.) landraces grown under saline conditions. Int J Bot 6(1): 53-58.

2. Temegne NC (2011) Analysis of early indicators involved in water stress tolerance of four leguminous species. Master thesis, Fac. Sci., Univ. Yaounde I.

3. Jideani VA, Diedericks CF (2014) Nutritional, therapeutic, and prophylactic properties of Vigna subterranea and Moringa oleifera. In: Oguntibeju O

(Ed), Antioxidant-antidiabetic agents and human health. Intech Publishers, pp: 22.

4. Temegne NC, Mbogne TJ, Nbendah P, Youmbi E, Taffouo VD. et al (2015) Effect of phosphate deficiency on growth and phosphorus content of three Voandzou (Vigna subterranea (L.) Verdc.) varieties. IOSR JAVS 8(9): 52-59.

5. Temegne NC (2018) Improvement in the performances of Voandzou (Vigna subterranea (L.) Verdc.) in response to phosphate deficiency through chemical and biological fertilization. Ph.D Thesis, Fac Sci Univ Yaounde I.

6. Tsoata E, Temegne NC, Youmbi E (2017) Analysis of early biochemical criterion to screen four Fabaceae plants for their tolerance to drought stress. IJCR 9(1): 44568-44575.

7. Tsoata E, Temegne NC, Youmbi E (2017) Analysis of early growth criterion to screen four Fabaceae plants for their tolerance to drought stress. RJLBPCS 2(5): 94-109.

8. Massawe FJ, Mwale SS, Azam-Ali SN, Roberts JA (2005) Breeding in Bambara groundnut (Vigna subterranea (L.) Verdc.): strategic considerations. Afr J Biotechnol 4(6): 463-471.

9. Brink M, Grubben GJH, Belay G, Agrooh (2006) Ressources végétales de l'Afrique tropicale 1: Céréales et légumes secs. (Edn.), Brink M, pp: 328.

10. Begemann F (1988) Ecogeographic differentiation of Bambara groundnut (Vigna subterranea) in the collection of the International Institute of Tropical Agriculture (IITA). Wissenschaftlicher Fachverlag Dr Fleck, Niederkleen, pp: 153.

11. Bamishaiye OM, Adegbola JA, Bamishaiye EI (2011) Bambara groundnut: an under-utilized nut in Africa. Adv Agric Biotechnol 1: 60-72.

12. De Kock C (2013) Bambara groundnut.

13. Yao DN, Kouassi KN, Erba D, Scazzina F, Pellegrini N, et al. (2015) Nutritive evaluation of the bambara groundnut Ci12 landrace [Vigna subterranea (L.) Verdc. (Fabaceae)] produced in Côte d'Ivoire. Int J Mol Sci 16(9): 21428-21441.

14. Dalziel JM (1937) Voandzeia Thou. The Useful Plants of West Tropical Africa. Crown Agents, London, pp: 269-271.

15. Jacques-Félix H (1946) Remarques sur l'origine et la geocarpie du Voandzeia subterranea Thou. Bull Soc Bot France 93(9): 260-362.

16. Rassel A (1960) Voandzou, Voandzeia subterranea Thouars, and its cultivation in Kwango. Bull Agric Congo belge 51: 1-26.

17. Hepper FN (1963) The Bambara groundnut (Voandzeia subterranea) and Kersting's groundnut (Kerstingiella geocarpa) wild in West Africa. Kew Bull 16: 395-407.

18. Guillemin JA, Perrottet GS, Richard A (1832) Florae Senegambiae Tentamen. Paris.

19. Heller J, Begemann F, Mushonga J (1997) Bambara groundnut (Vigna subterranea (L.) Verdc.). Promoting the conservation and use of underutilized and neglected crops. Proceedings of the workshop on Conservation and Improvement of Bambara groundnut (Vigna subterranea (L.) Verdc.), 14–16 November 1995, Harare (Zimbabwe), Institute of Plant Genetics and Crop Plant Research, Gatersleben/Department of Research & Specialist Services, Rome (Italy).

20. Olukolu BA, Mayes S, Stadler F, Ng NQ, Fawole I, et al. (2017) Genetic diversity in Bambara groundnut (Vigna subterranea (L.) Verdc.) as revealed by phenotypic descriptors and DArT marker analysis. Genet Resour Crop Evol 59(3): 347-358.

21. Rungnoi O, Suwanprasert J, Somta P, Srinives P (2012) Molecular genetic diversity of Bambara groundnut (Vigna subterranea L. Verdc.) revealed by RAPD and ISSR marker analysis. SABRAO J Breed Genet 44: 87-101.

22. Somta P, Chankaew S, Rungnoi O, Srinives P (2011) Genetic diversity of the Bambara groundnut (Vigna subterranea (L.) Verdc.) as assessed by SSR markers. Genome 54(11): 898-910.

23. Stadler F (2009) Analysis of differential gene expression under water-deficit stress and genetic diversity in Bambara groundnut [Vigna subterranea (L.) Verdc.] using novel high-throughput technologies. PhD Thesis, Technische Universität München.

24. Molosiwa OO, Aliyu S, Stadler F, Mayes K, Massawe F, et al. (2015) SSR marker development, genetic diversity and population structure analysis of Bambara groundnut [Vigna subterranea (L.) Verdc.] landraces. Genet Resour Crop Evol 62(8): 1225-1243.

25. Aliyu S, Massawe F, Mayes S (2016) Genetic diversity and population structure of Bambara groundnut (Vigna subterranea (L.) Verdc.): synopsis of the past two decades of analysis and implications for crop improvement programmes. Genet Resour Crop Evol 63(3): 925-943.

26. Ho WK, Chai HH, Kendabie P, Ahmad NS, Jani J, et al. (2017) Integrating genetic maps in Bambara groundnut [Vigna subterranea (L) Verdc.] and their syntenic relationships among closely related legumes. BMC Genomics 18: 192-201.

27. Chai HH, Ho WK, Graham N, May S, Massawe F, et al. (2017) A cross-species gene expression marker-based genetic map and QTL Analysis in Bambara groundnut. Genes (Basel) 8(2): 84.

28. Duke JA (1981) *Voandzeia subterranea* (L). Thouars, *In:* Handbook of legumes of world economic importance. Plenum Press, New York, pp: 307-310.

29. Goli AE (1995) Characterization and evaluation of IITA's Bambara groundnut collection. *In:* Begemann, JH, Mushonga J (Eds.), Proceedings of the workshop on conservation and improvement of Bambara groundnut (Vigna subtarranea (L.) Verdc.). Zimbabwe: Internatinal Plant Genetic Resources Institute (IPGRI).

30. Ndiang Z, Bell JM, Missoup AD, Fokam PE, Amougou A (2012) Étude de la variabilité morphologique de quelques variétés de voandzou [Vigna subterranea (L.) Verdc] au Cameroun. J Appl Biosci 60: 4410-4420.

31. Ouoba A, Zida SF, Ouédraogo M, Nandkangre H, Ouédraogo HM et al (2017) Assessment of genetic diversity in Bambara groundnut (Vigna subterranea (L.) Verdcourt) landraces in Burkina Faso using microsatellite markers (SSR). Agric Sci Res J 7(3): 96-102.

32. FAO (1994) Definition and classification of commodities (draft): 4. Pulses and derived products. Food and Agriculture Organization. Retrieved 13 December 2017.

33. USDA (2017) Taxon : Vigna subterranea (L.) Verdc.

34. Linnaeus C (1763) Species Plantarum. 2nd (Edn.), Impensis Laurentii Salvii, Stockholm 2: 785-1684.

35. Du Petit-Thouars LMA (1806) Bambara groundnut (Vigna subterranea (L.) Verdc). *In:* Heller J, Begemann F, Mushonga J (Eds.), Conservation and Improvement of Bambara Groundnut. Proceeding of Workshop, Harare, pp: 1-4.

36. Maréchal R, Mascherpa JM, Stainier F (1978) Etude taxonomique d'un groupe complexe d'espèces des genres Phaseolus et Vigna (Papilionaceae) sur la base de données morphologique et pollinique, traitées par l'analyse informatique. Boissiera 28: 177-178.

37. Verdcourt B (1980) The correct name for the Bambara groundnut. Kew Bull 35(3): 474.

38. APG IV (2016) Angiosperm Phylogeny Group. "An update of the Angiosperm Phylogeny Group classification for the orders and families of flowering plants: APG IV" (PDF). Bot J Linn Soc 181(1): 1-20.

39. Tsoata E, Njock SR, Youmbi E, Nwaga D (2015) Early effects of water stress on some biochemical and mineral parameters of mycorrhizal Vigna subterranea (L.) Verdc. (Fabaceae) cultivated in Cameroon. IJAAR 7(2): 21-35.

40. Tsoata E, Temegne NC, Youmbi E (2016) Analysis of early physiological criteria to screen four Fabaceae plants for their tolerance to water stress. Int J Recent Sci Res 7(11): 14334-14338.

41. FAO (2007) Data sheet Vigna subterranea. Ecocrop. FAO.

42. Anonymous (2016) Bambara groundnuts. Department of Agriculture, Forestry and Fisheries, Pretoria, 20.

43. Massawe FJ, Azam-Ali SN, Roberts JA (2003) The impact of temperature on leaf appearance in Bambara groundnut landraces. Crop Sci 43(4): 1375-1379.

44. Nordin N, Singh A (2015) Seedling emergence of Bambara groundnut (Vigna subterranea (L.) Verdc.) landraces at various temperature conditions. Proc Environ Sci 29: 201-202.

45. Messiaen CM (1992) The vegetable garden. Macmillan Press Limited. pp: 318.

46. Borget M (1992) Food legumes (Tropical Agriculturalist). In: Wibberley EJ, Tindall HD (Eds.), Macmillan Education, pp: 120.

47. Temegne NC, Nkou Foh TD, Taffouo VD, Wakem G-A, Youmbi E (2018) Effect of mycorrhization and soluble phosphate on growth and phosphorus supply of Voandzou (Vigna subterranea (L.) Verdc.). Legume Research An International Journal, pp: 1-6.

48. Temegne NC, Wakem GA, Taffouo VD, Mbogne TJ, Onguene AN, et al. (2017) Effect of phosphorus fertilization on arbuscular mycorrhizal fungi in the Bambara groundnut rhizosphere. Afr J Microbiol Res 11(37): 1399-1410.

49. Temegne NC, Nkou Foh TD, Taffouo VD, Ntsomboh-Ntsefong G, Youmbi E (2017) Influence of mycorrhization and phosphate fertilizer on growth of Voandzou (Vigna subterranea (L.) Verdc.). IJBCS 11(6): 2587-2593.

50. Tweneboah CK (2000) Modern agriculture in the tropics, food crops. Co-wood Publishers.

51. Toungos DT, Sajo AA, Gungula DT (2010) Effect of P_2O_5 on the yield components of Bambara groundnut (Vigna subterranea (L) verd.) in Yola Adamawa State, Nigeria. WJFPB 1(1): 1-7.

52. Nweke IA, Emeh HO (2013) The response of Bambara groundnut (Vigna subterranean (L.) Verdc.) to phosphate fertilizer levels in Igbariam South East Nigeria. IOSR-JAVS 2(1): 28-34.

53. Ellah MM, Singh A (2008) Bambara groundnut (Vigna subterranea (L.) Verdc.) yield as influenced by phosphorus and cultivars in the semi-arid savanna of Nigeria. J Plant Sci 3(2): 176-181.

54. Effa EB, Nwagwu FA, Osai EO, Shiyam JO (2016) Growth and yield response of Bambara groundnut (Vigna subterranea (L.) Verdc) to varying densities and Phosphate fertilizer rates in Calabar, South Eastern Nigeria. J Biol Agric Healthcare 6(16): 14-20.

55. Ikenganyia EE, Anikwe MAN, Ngwu OE (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. Int J Plant Soil Sci 17(4): 1-17.

56. Baudoin JP, Mergeai G (2001) Grain legumes in crop production in tropical Africa, pp: 313–317.

57. Musa M, Massawe F, Mayes S, Alshareef I, Singh A (2016) Nitrogen fixation and N-balance studies on Bambara groundnut (Vigna subterranea L. Verdc) landraces grown on tropical acidic soils of Malaysia. Comm Soil Sci Plant Anal 47(4): 533-542.

58. Anonymous (2011) Production guidelines for Bambara groundnuts. Department of Agriculture, Forestry and Fisheries, Pretoria, pp: 10.

59. Mkandawire CH (2007) Review of Bambara groundnut (Vigna subterranea (L.) Verdc.) Production in Sub-Sahara Africa. Agric J 2(4): 464-470.

60. Jensen ES, Peoples MS, Boddey RM, Gresshoff P, Hauggaard-Nielsen H, et al. (2011) Legumes for mitigation of climate change and the provision of feedstock for biofuels and biorefineries. A review. Agron Sustain Dev 32(2): 329-364.

61. Sambo BE (2014) Endangered, neglected, indigenous resilient crops: a potential against climate change impact for sustainable crop productivity and food security. IOSR JAVS 7(2): 34-41.

62. Yao Djè, Béket BS, Zoro Bi IA (2005) Observations préliminaires de la variabilité entre quelques morphotypes de voandzou (Vigna subterranea (L.) Verdc., Fabaceae) de Côte d'Ivoire. Biotechnol Agron Soc Environ 9(4): 249-258.

63. Westphal E, Ferwerda JD, Van Gils-Meeus HAE, Mutsaers HJW, Westphal-Stevels JMC (1985) Cultures vivrières tropicales avec référence spéciale au Cameroun, pp: 260-320.

64. Minka DR, Bruneteau M (2000) Partial chemical composition of Bambara pea (Vigna subterranea L. Verdc.). Food Chem 68(3): 273-276.

65. Anikwe MAN, Atuma J (2003) Characterizing the suitability of selected indigenous soil improving legumes in a humid tropical environment using shoot and root attributes. Tropicultura 21(4): 179-185.

66. Anchirinah VM, Yiridoe EK, Bennett-Lartey SO (2001) Enhancing sustainable production and genetic resource conservation of Bambarra groundnut: a survey of indigenous agricultural knowledge systems. Outlook Agric 30(4): 281-288.

67. Azam-Ali SN, Sesay A, Karikari KS, Massawe FJ, Aguilar-Manjarrez J, et al. (2001) Assessing the potential of an underutilized crop - a case study using bambarra groundnut. Exp Agric 37(4): 433-472.

68. Collinson ST, Clawson EJ, Azam-Ali SN, Black CR (1997) Effects of soil moisture deficits on the water relations of Bambara groundnut (Vigna subterranea (L.). J Exp Bot 48(4): 877-884.

69. Yaya T, Koné M, Silué S, Yatty J (2013) Prospection, collecte et caractérisation agromorphologique des morphotypes de voandzou de la zone savanicole en Côte d'Ivoire. ESJ 9(24): 308-325.

70. IRAD/FAO (2008) Rapport national sur l'état des ressources phytogénétiques pour l'alimentation et l'agriculture. IRAD/FAO, Yaoundé, pp: 83.

71. FAO (2018) Statistic of production (FAOSTAT). Food and Agriculture Organization of the United Nations.