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Sustainable food production in Nigeria: a case study for Bambara Groundnut (*Vigna subterranea* (L.) Verdc. Fabaceae)

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Abstract
Access to sufficient food for an active and healthy life defines food security, which is a critical factor for economic growth and development. Food insecurity ranks among developmental challenges. Sustainability is the ability of a process or activity to meet present needs without much alteration of the natural resources involved in order for future generations to benefit. It involves the development and proper management of resources without wastage and threat to the environment. Agriculture is strategic to the Nigerian economy especially in light of dwindling fortunes from crude oil, hence a real and potential contributor to wealth creation and poverty alleviation. Humans depend on less than thirty crops for food production from a sufficiently diverse pool of plant genetic resources. With increasing world population, we need to look beyond the limited crop list on which we depend. Bambara groundnut is an indigenous orphan, underutilised, under-researched crop, cultivated throughout sub-Saharan Africa, with high potentials. It is drought resistant and highly nutritional. *Vigna subterranea* can be grown without fertilisers, which are costly and often difficult to access. The seed makes a complete food, as it contains sufficient quantities of essential nutrients and minerals and it may be consumed in diverse ways. The crop has a reputation for resisting pests and diseases. Bambara groundnut is a promising commodity, which needs publicity. However, to ensure its wider adoption, the crop may need some improvement. Sustainable management and modern processing methods would also ensure distribution to non-producing areas.

Keywords
Bambara groundnut (*Vigna subterranea*), Food security, Food production, Sustainability, Plant resources

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Contents

1. Introduction

Food security is the access by all and at all times to enough food for an active and healthy life [1]. Food security exists when physical and economic access to sufficient, safe and nutritious food is available to meet the dietary needs and preference for promoting active and healthy lifestyles [2]. The concept of food problem is complex and goes beyond the simplistic idea of a country's inability to feed its population [1]. Food insecurity is a global challenge and may lead to a catastrophe if it is not possible to increase food supply at a rate faster than that at which the world population increases [3]. Four global threats that has significant implications for the food security of any nation include; population explosions, global warming, loss of biodiversity and the threat of poverty and globalisation of injustice [4]. It is in view of the foregoing that the attainment of food security is imperative and all developed and developing countries are making considerable efforts to increase their food production capacity. This review paper seeks to highlights the need for sustainable food production using a vastly available resource in Bambara groundnut (*Vigna subterranea* (L.) *Verdc.*,

Fabaceae).

Food security is a critical factor for the economic growth and development of a nation and in recent times, many resources are now been channeled towards programmes aimed at eradicating food insecurity and poverty by various international organizations and government especially in developing nations [5; 6]. To address how V. subterranean can contribute to attaining food security, economic growth and development in sub-Saharan Africa, this review uses Nigeria as a case study by focusing on its location and geography, population, available plant resources, and food insecurity challenges, which is typical of the region. Subsequent sections will address the roles of sustainable agriculture and food production systems to stimulate economic growth through efficient supply systems, making raw materials available and promoting foreign exchange earnings. The section will also highlight factors militating agricultural sector while the next section will focus on the impact of sustainable production of *V. subterranea* to the economy and agriculture.

2. Nigeria and Food Insecurity

Nigeria lies roughly between longitudes 3^o and 14^o East of the Greenwich meridian and latitudes 4^o and 14^o North of the Equator, sharing a common boundary with the Republic of Benin to the West, Chad and Cameroun to the East and the Niger Republic to the North. The Atlantic Ocean with a 960 Km coastline borders the south. It covers a land mass of approximately 923,768 Km^2 representing about 14% of land area in West Africa. The Federal Ministry of Environment of Nigeria [7] estimate of irrigated land is 9,570 Km^2 and arable land about 35%; 15% pasture; 10% forest reserve; 10% for settlements and the remaining 30% considered uncultivable for one reason or the other. The mean annual rainfall range from about 450 mm in the north-east to about 3500 mm in the coastal Southeast, with rainfalls within 90 to 290 days [4]. Floristically, Nigeria is rich with vegetation that supplies food, fodder, timber, fuelwood, medicines, essential oils spices, gum and exudates. These resources are suitable and capable to meet the food needs. However, Nigeria population is growing at an alarming rate. In 1963, the population was 55,671,000 in 2005 it was put at over 140 million. Nigeria's population was 164 million in 2011 representing 20% of the entire African population (Fig. 1) but is currently over 180 million and remains the most populous African nation with an estimated growth rate of about 3.2% per year [7]. The associated growth and development continues to exert competing demands on land for schools, house, roads hospitals, industries, offices and agriculture.

Nigeria is physically and climatically diverse with substantial natural resources endowments. It encompasses three major ecological regions, a humid forest region, a

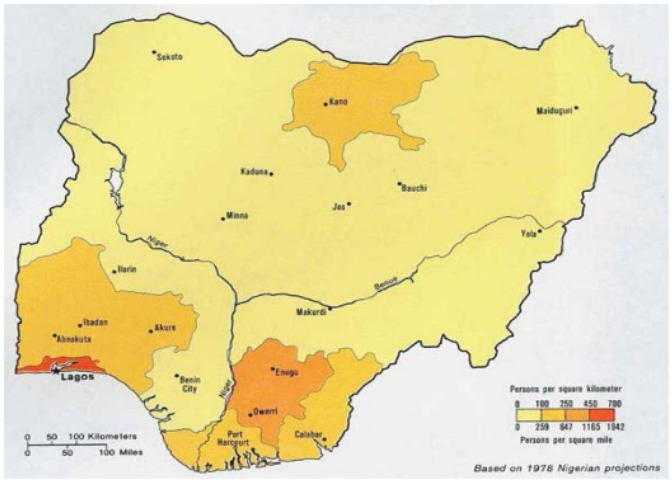

Figure 1. Map of Nigeria showing population density (Source: FAO [8])

sub-humid region with Highland, and a semi-arid region, with annual rainfall ranging from about 250 mm in the Sahelian north to over 3,000 mm in the southern coastal areas. The natural vegetation varies from rain forest to savanna. There are nine distinct ecological zones which, due to similarity of characteristics, can be streamlined into five, namely (i) Sahel/Sudan savanna, (ii) Guinea savanna, (iii) Derived savanna, (iv) Lowland rainforest/montane forest and (v) Freshwater swamp forest/mangrove forest and coastal vegetation (Fig. 2) [9]. The inherent diversity and endowments support the growth of a wide variety of crops. The Southern coastline is indented by lagoons, and by the Niger-Delta wetland. The River Niger with its tributary, the Benue, form a large 'y' across Nigeria providing a potential source of irrigation. The geological characteristics of the country comprise a large number of base rocks of diverse origins, from plinths to sedimentary rocks. The landscape associated with these "older" granites is mainly narrow and deep valleys and pediments (surfaces made smooth by erosion) from the middle of which rose rounded hills with sheer rock faces. There are also numerous volcanoes and vast basaltic plateaus from lava flow, due to volcanic activity of the past in the south, a typical mangrove type sedimentation has superimposed itself on the Niger Delta giving it its swampy outlook [9].

In Nigeria, food insecurity ranks topmost among development problems and it continues to rise steadily since the 1980s. It rose from about 18% in 1986 to about 41% in 2004 [10]. Maziya-Dixton et al. [11] reported that over 40% of households across all agro-ecological zones in Nigeria face problems associated with severe food insecurity. Similarly, Idachaba [12] reported that many households and individuals in Nigeria merely eat for survival. This implies that there is little to no consideration given to the nutritional component of meals regardless of high agricultural potential and income status. Nigeria has about

Figure 2. Map of Nigerians Ecological Zones. (Source: NACGRAB [9])

79 million hectares of arable land, of which 32 million hectares are cultivated [13]. A significant proportion of agricultural production is rain-fed while poorly set up irrigation systems and individual generated borehole water supply system account for the smallholders, mostly subsistence farm holdings. Extension department only exists in books and buildings with no reasonable contribution resulting in low crop and livestock production. Inadequate access to and low uptake of high-quality seeds, low fertiliser use and inefficient production systems lead to this shortfalls.

Despite a seven percent growth rate in agricultural production (2006 – 2008), Nigeria's food import bill has risen [14]. The trend persists despite population growth and change in government systems. Nigeria's demographic history reveals that from a population of 30 million persons in 1952/53, the country's population rose to 88,992,200 in 1991, more than twice the 1952/53 within 39 years. In 2006, Nigeria recorded a total population figure 140,003,542 comprising of 71,704,869 males and 68,295,683 females. These translate in an annual growth rate of 3.2% over 1991 census figure. Base on this growth rate the population will double itself in 22 years [15]. This dramatic growth in human population has caused much concern especially about the strains it places on the resources of the environment and the quality of the lives resulting in a growing dependence on imported food staples, including rice, wheat and fish. The fight, however, is not just about food insecurity but more on sustainable food security [12].

3. Status of Agriculture and Sustainable Food Production in Nigeria

Sustainability is the ability of a process (in this case food production) or human activity to meet present needs, but also maintain natural resources and leave the environment in good order for future generations [16]. It involves the development and management of available natural resources to support the ever-increasing population without immediate or future wastage and threat to the environment. This implies that for there to be food security, the food supply must meet the people's need now and in future [17]. The application of the sustainable concept is capable of bringing about meaning development to where it is applied. Presently, food production in Nigeria is not sustainable both in quantity and quality; hence, the need to grow more food to meet the demand of the growing population and this can be achieved through improved agricultural practices, diversification of staples and development indigenous crops of which Bambara groundnut stands as an exceptional example.

Agriculture is strategic to the Nigerian economy and plays the key roles of supplying food for the population, raw materials for industries, earning high foreign exchange, which is next only to that from crude oil, providing market for the industrial sector and a key contributor to wealth creation and poverty alleviation [9]. It was one of the most successful sectors of the economy producing and accounted for more than 50% of GDP and more than 75% of export earnings in the 1960s [8]. The 1970s was characterised by the 'oil boom'. This resulted in the neglect of further agricultural development. The consequences were importation of food (especially grains), low domestic farm products and food aids. The productivity of the Nigerian agricultural sector is low in spite of enormous possibilities for growth and improvement and currently, Nigerian agriculture is still mainly smallholder farming which is characterized by agricultural systems like shifting cultivation, mono-cropping and mixed culture, where crude implements like cutlass, hoe and axe are used for pre and post planting activities. However, more than 70% of the population derives their living from agriculture and agro-allied activities, with the sector contributing about 41% of the Gross Domestic Product (GDP) and accounts for 5% of total export. It provides 88% of non–oil earnings. Crops contribute 85% of the agricultural GDP, livestock 10%, fisheries 4% and forestry 1%. About 94% of the agricultural output is accounted for by small-scale, subsistent farmers cropping less than two ha [9]. Labour is self with less than 20% hired and Large-scale, specialised, commercial agricultural enterprises are not only few but in the embryonic stages. The use of agricultural technologies and external inputs to enhance productivity is dramatically sub-optimal in Nigeria.

Fertiliser consumption is about 7 Kg/ha, the lowest in sub-Saharan Africa. Local production of major staple food items like maize, cowpea, rice, cassava, tomato, meats, eggs, oil, etc., is grossly inadequate to meet demand despite that the majority of the population lives

below $1 per day and about 40% of family income is spent on food. Nigerian food situation is vulnerable to global trends because the country depends heavily on importation of food items including as rice, wheat, milk, among others, Table 2 shows production indices for Agriculture from 1995–2004. Estimates of production output for principal staple crops in 2003 were maize (5.2 million tonnes), sorghum (8.0 million tonnes), millet (6.1 million tonnes) and rice (4.9 million tonnes). Others include cassava (33.5 million tonnes), yams (27.0 million tonnes), potatoes (6.0 million tonnes) and vegetables (9.1 million tonnes) (FAO, 2009). From the above, food production in Nigeria is not sustainable in both quantity and quality (Table 1) and this is further compounded by the paucity of private agricultural institution. Farmers also have limited access to credit and the existing extension services are grossly inadequate with the ratio of one extension worker to 25,000 farming families [9].

Table 1. Trend of daily nutrient per capita intake in Nigeria from 1970 – 2001

Year	Carbohydrate (daily carb per capita)	Protein (Daily grams per capita)	Fat (daily grams per capita)
1970-80	2038.3	46.9	54.9
1981-85	2000.4	47.4	53.4
1986-89	2183.6	51.6	54
1990-94	2656.1	58.4	60.8
1995	2801.8	63	63.4
1996	2781	62.5	67.4
1997	2791.3	63.2	68
1998	2837.4	4	68
1999	2833.4	64.5	70.1
2000	2850.1	65.2	68.5
2001	3062.2	58.4	72.1
Average	2621.4	53.2	63.7

Sources: Adapted from Ibrahim et al. [1].

Table 2. Production statistics of some major stable foods (in million tonnes)

Staples	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004
Maize	6931	5667	5254	5127	5476	4107	4620	4934	5150	5150
Millet	5563	5881	5902	5956	5960	6105	5530	6100	6100	6100
Sorghum	6997	7084	7297	7516	7520	7711	7081	7704	8100	8100
Rice	2920	3122	3266	3275	3277	3298	2752	3192	4952	4952
Wheat	44	47	66	98	101	73	51	77	73	73
Cassava	31404	31418	32050	32695	32697	32010	32586	34476	33379	33379
Yam	22818	23201	23972	24768	25873	26201	26374	26849	27000	27000
Cocoyam	1182	1195	1832	3823	3835	3886	3910	3929	3500	35000
Sweet potato	1168	1478	1493	1560	2451	2468	2473	2503	2150	2150
Potato	95	99	103	107	573	599	599	629	600	600
Plantain	1632	1687	1744	1803	1902	1969	1999	2058	2110	2110
Groundnut	1579	2278	2531	2534	2894	2901	2683	2699	2700	2700
Soya beans	287	322	361	403	410	429	436	437	484	484
Melon	287	317	330	330	338	345	348	347	347	347
Tomato	569	569100	650	810	879	879	879	889	889	889
Chilli pepper	612	633	745	709	715	715	715	720	720	720
Onions	500	550	567	580	596	600	600	600	615	615
Pineapple	800	800	830	857	881	881	881	889	889	889
Mango	631	656	689	731	729	730	730	730	730	730
Papaya	648	662	675	751	748	748	748	755	755	755
Okra	630	650	612	638	719	719	719	730	730	730
Carrot	198	203	210	225	231	231	231	235	235	235
Coconut	149	151	152	152	158	160	161	161	161	161
Kolanut	95	85	82	82	82	82	82	85	85	85
Cashew nut	95	110	125	152	176	184	185	186	186	186
Tobacco leaves	9200	9200	9200	9200	9200	9200	9200	9200	9200	9200

Source: Adapted from FAO [8]

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 fertilisers 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 [18]. Furthermore, because many of these crops are grown for subsistence, little effort has been made to genetically or agronomically improve them or assesses 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.

Other factors affecting the agricultural sector of Nigeria economy in climate change which is affected by two opposing air masses- Tropical Continental air mass, which blows from the Northeast originating from the Eurasia-Arabia high-pressure belt. Significant climate changes have been observed globally and Nigeria is particularly affected resulting in flooding in the Southeast and desertification in the northern regions. Climatic changes already have varying, mostly adverse effects on agriculture and, therefore, food security. Higher temperatures result in decreased agricultural productivity and production, high evaporation rates and reduced soil moisture, lowering of the groundwater table and shrinking of surface water. Heat stress reduces human labour use on farms, lowers labour productivity and leads to rapid deterioration and wastage of farm produce [8].

Nigeria within the last decade has been experiencing a random alteration in rainfall pattern. Changes in the amount of rain increased rainfall intensity and changes in rainfall patterns leading to decreased resource productivity and production. Changing and erratic rainfall patterns make it difficult for farmers to plan their operations, may reduce the cropping season and can lead to low germination, reduced yield and crop failure. Erratic weather interferes with processing of produce (such as sun-

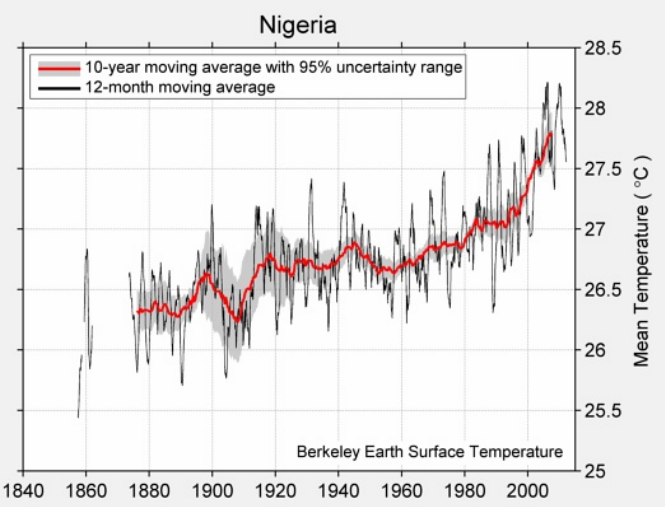

Figure 3. Change in Nigeria. (Source: Berkeley earth [20])

drying of crops and smoking fish). Increased frequency of major storms causes damage to farmland, crops and livestock. Major storms can also cause road wash-outs, which make it difficult to access farms and to market products. Evidence from literature and past studies has revealed that the recent global warming has influenced agricultural productivity leading to declining food production [21]. In order to meet the increasing food and non-food needs due to population increase, the human is rapidly depleting fertile soils, fossil groundwater, biodiversity, and numerous other non-renewable resources to meet his needs. Findings from their study indicate that agricultural impacts of climate change in Nigeria are uncertain (Table 3). It was shown that climate change will have an overall positive impact on Nigeria's agriculture both quantitatively and qualitatively by zone and season resulting in farmers abandoning mono-cropping for mixed and mixed crop-livestock systems [21].

Table 3. Frequency Distribution of Average Amount of Rainfall, Population and Food Production (of Grains in Million Tonnes) 1971-2000.

Zone	North Central	North East	North West	South East	South West	South South
		1971 - 1980				
Average amount of rainfall (mm)	1074.85	783.68	952.03	-	1696.41	3034.15
Population	7,346,380	5,427,094	11,649,891	-	897,8946	12,175,889
Food production (of grains in million tonnes)	23.74	17.54	37.65	-	29.02	37.34
		1981 – 1990				
Average amount of rainfall (mm)	1173.43	762.52	762.50	2194.50	1226.20	2376.10
Population	12,657,202	9,350,432	20,071,793	9,188,059	15,469,976	11,786,539
Food production (of grains in million tonnes)	34.59	25.55	54.85	25.11	42.28	32.21
		1991 - 2000				
Average amount of rainfall (mm)	1087.43	701.06	840.15	2011.70	1543.90	2435.59
Population	16,454,363	12,155,561	26,093,331	11,944,476	20,110,969	15,322,500
Food production (of grains in million tonnes)	11.56	11.16	12.48	11.13	11.91	11.46

Source: Adapted from Apata [21]

4. Bambara Groundnut and Potential for Sustainable Food Production

Vigna subterranea is an indigenous orphan, underutilised, and until lately, under-researched crop, cultivated throughout sub-Saharan Africa. The crop has a high potential to contribute to the attainment of food security and poverty alleviation through income security in Africa, as it shows considerable drought resistance and potentially, high nutritional qualities. Bambara groundnut belongs to the family Fabaceae, subfamily Papilionoideae, although further refinement of its taxonomy has been a subject of controversy [22]. The crop was first mentioned in the 17th-century literature, where it is referred to as 'mandubi d'Angola'. In 1763, Linnaeus described it in Species Plantarum, and named it *Glycine subterranea*, in accordance with his system of nomenclature. Du Petit-Thouars (1806) found the crop in Madagascar, under the vernacular name 'voanjo', subsequently written as 'voandzou' in French. He then proposed the name *Voandzeia subterranea* (L.) Thouars, which was widely used by subsequent researchers for over a century. Recently, detailed botanical studies were undertaken by Maréchal et al. [23], who found great similarities between Bambara groundnut and plant species of the genus Vigna. This confirmed studies done by Verdcourt, who seized the opportunity in 1980 to propose the current name *Vigna subterranea* (L.) Verdc. [22]. The common name appears to have been derived from a tribe, called Bambara, which resides in Mali although no spontaneous or wild forms of the crop have been found in Mali [22]. Other common names which it has been known for include Congo Groundnut, Congo goober, Madagascar ground¬nut, Earth pea, Baffin pea, Jugo bean, Njugo bean, Sepedi dialogue, Tshivenda Phonda voandzou, Nzama, Malawi Indhlubu and Underground bean. In Nigeria, its vernacular names include; Juijiya (Hausa), Okpa Otuanya (Ibo), Epi-roni or epi-roro (Yoruba), Ere-oto or Ere-Okuta (Edo).

4.1 Origin and Geographic Distribution

Bambara groundnut, *Vigna subterranea* (L.) Verdc. originated in West Africa but has become widely distributed throughout the semi-arid zone of sub-Saharan Africa [24]. Although occasionally grown in Asia and elsewhere, its cultivation is rare outside the African continent. The distribution of wild Bambara groundnut is known to extend from Jos Plateau and Yola in Nigeria to Garoua in Cameroon [25]. The exact area of origin of the crop in Africa has been a matter of debate, however, Heller [22] propose that the centre of origin should be in the region of northeastern Nigeria and northern Cameroon based on reported wild forms. Also it is in West Africa that most of the world's Bambara groundnut is grown and where the crop is most prominent in the traditions of rural communities, for instance, its significant role in the traditional food and culture of peoples in the Western and Northern parts of Côte d'Ivoire have been reported by Yao et al. [26]. It constitutes the third most important pulse crop in the continent after groundnut and cowpea. In Nigeria, however, it ranks fourth in importance after groundnut, cowpea and soybean [17]. According to Mkandawire [25], the cultivation of Bambara groundnut seems to have flourished in Nigeria before the introduction of groundnut (Arachis hypogea, Fabaceae). Nevertheless, it has become less important in many parts of Africa because of the expansion of groundnut production. In recent years, there has been renewed interest for cultivation in the arid savannah zones. It is resistant to drought and has the ability to produce a reasonable crop when grown on poor soils.

4.2 Botany

Bambara groundnut is a herbaceous, intermediate, annual plant, with creeping stems at ground level (Fig. 6a). Heller et al. [22] have identified seven types of Bambara groundnut varieties including (1) Black: Early maturing, usually small to medium-sized kernels. Mainly one-seeded (2) Red: Late maturing. Kernels are large. A good yielder, however, it is prone to rotting onsite (3) Cream/black eye: A large kernel and a good yielder (4) Cream/brown eye: A moderate kernel and a good yielder (5) Cream/no eye: Very small pods and kernels. It mainly produces one seed and yields are lower. (6) Speckled/flecked/spotted: Purple colour predominates. Kernels are small and pods are mainly one-seeded. (7) Brown: Continuous variation between light and dark brown. Kernels are of medium to large size.

Bambara groundnuts take about three to six months to mature, depending on weather conditions and the cultivar with a well-developed taproot with many profuse geotropic short lateral roots 20 cm long. The roots form nodules for nitrogen fixation, in association with appropriate rhizobia. It has lateral stems, which develop from the root. The leaves are trifoliate (± 5 cm long) and are attached to the stem by the petiole. The petioles are about 15 cm long, stiff and grooved, and the base is green or purple in colour. Leaves and flower buds arise alternately at each node. Leaves are pinnately trifoliate, glabrous with erect petiole and thickened at the base. Two stipels are subtended to the terminal leaflet, while only one is assigned to each of the two lateral leaflets. The oval leaflets are attached to the rachis with marked pulvini. The terminal leaflet is larger than the lateral leaflets, with an average length of 6 cm and an average width of 3cm.

Flowering starts 30 to 35 days after sowing and may continue until the end of the plant's life. (Fig. 6b). After fertilisation the flower stem elongates. The sepal enlarges and the fruit develops above or just below the soil surface. The unripe pod is yellowish green, with up to six pods while the mature pods may be yellowish green

or purple. The pod is small, about 1–5 cm long, round or slightly oval shaped and wrinkled with mostly one or sometimes two seeds. The seeds are round, up to 1.5 cm in diameter, smooth and very hard when dried. They are cream, brown, red, mottled, with or without haulm colouration. The essential parts are the flowers and pods [22].

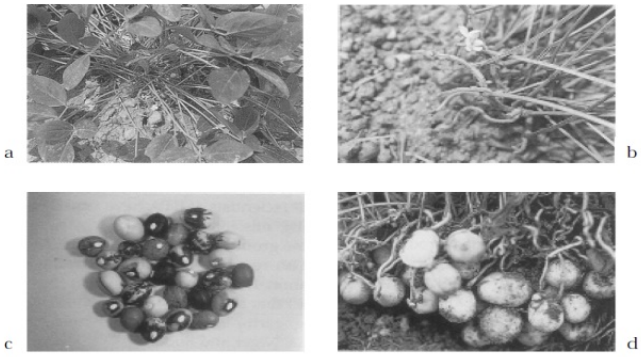

Figure 4. Bambara groundnut – growth habit; b. Bambara groundnut flowers and stems; c. Bambara groundnut pods; d. Bambara groundnut – various seed colours and testa patterns. Source: Heller et al. [22]

4.3 Cultivation

Bambara Groundnut yields reasonably well on poor soils in areas of low rainfall (500 – 800 kg ha-1) and can be grown without fertilisers and chemicals, which are costly and often difficult to access in more remote areas. It grows well on acidic laterite soils, which are common in Africa, but less well on calcareous soils [25]. It grows close to the ground and the nuts are produced underground [24]. Bambara groundnut is cultivated predominantly on the flat soil but sometimes, on mounds or ridges and does not tolerate water-logging. Bambara groundnut is typically a short-day plant and flowering and nut development may be delayed or prevented by long-day conditions [25]. The crop is widely grown in Nigeria, particularly in the Southern Guinea Savanna belt, where it is mostly grown as a mixed crop with cowpea, maize, sorghum and groundnut [24]. The crop is usually grown by women and so, it is often given a lower priority within the villages, in the allocation of land [24], However it has a great potential to enhance soil productivity because it contributes nitrogen to the soil at a level similar to other legumes (20 – 100 kg ha-1) [27]. Traditionally, Bambara groundnut has being seen as a snack or food supplement, but not a lucrative cash crop. Harvesting is recommended before full foliage drying. Harvested pods are air-dried for several days before threshing. The raw product is sold at markets, as pods or seeds. In dry areas, materials for planting the following season are usually kept by farmers as pods. This reduces or eliminates attacks by insects.

4.4 Uses

Bambara groundnut is essentially grown for human consumption. The seed makes a complete food, as it contains sufficient quantities of protein, carbohydrate and fat and can be consumed in many ways. They can be eaten fresh, or grilled while still immature. At maturity, they become very hard and therefore require boiling before any specific preparation. In many West African countries, the fresh pods are boiled with salt and pepper and eaten as a snack. Bread made from Bambara groundnut flour has been reported and in Nigeria, the dried seeds are made into a paste, which is then used in the preparation of various fried or steamed products, such as 'akara' and 'moin-moin'. Seeds are often crushed into flour, to prepare the following dishes: 'alele', 'alelen ganye', 'danwake', 'gauda', 'kosai', 'kunu', 'tuwo' and 'waina' [17]. Nutritious flour made from roasted groundnut seeds can also be incorporated into soups and other dishes for example boiled Bambara beans (beans soaked overnight then boiled) can be served with rice and yam. Another favourite Nigerian dish is 'okpa', which is a doughy paste that is wrapped in banana leaves and boiled. Recently, a trial of Bambara groundnut milk was carried out which compared its flavour and composition with those of kinds of milk prepared from cowpea, pigeon pea and soybean [28]. Bambara groundnut was ranked first, and while all kinds of milk were found to be acceptable, the lighter colour of the Bambara groundnut milk was preferred. Bambara groundnut has long been used as an animal feed, and the seeds have been successfully used to feed chicks and the leaves were reported to be rich in nitrogen and phosphorus, and therefore suitable for animal grazing

4.5 Nutrient Value

The seeds have an excellent nutritive value, with 18 – 26% protein content, which is very rich in lysine, a scarce amino acid in plant protein and relatively low oil content (Table 4) [29]. In addition it contains 4 – 9% fat, 50 – 65% carbohydrate, 3- 5% fibre and 6.5% oil. This makes the seed an exceptionally balanced food for human consumption [17]. The gross energy value of Bambara groundnut seed is greater than that of other common pulses such as cowpea, lentil (*Lens esculenta*) and pigeon pea (*Cajanus cajan*) (Table 4). Bambara groundnut is a good source of fibre, calcium, iron and potassium. The red seeds could be useful in areas where iron deficiency is a problem, as they contain almost twice as much iron as the cream seeds [24]. It is believed to be suitable for consumption by people with diabetes [17], capable of reducing nutritional deficiencies and a probable raw material source for the canning industry. Boateng et al. [29] reported that Bambara groundnut has great potential for incorporation into various human foods where it could provide useful plant proteins. Such properties as high water and oil absorption capacities of Bambara groundnut isolates is an indication that they will do very well in

terms of physicochemical properties in the development of vegetable milk.

According to Boateng et al. [29] apart from soybeans, Bambara is rated high in protein compared to other legumes and staples. It also contains methionine, which makes its protein more complete than any other bean. It also has the highest concentration of soluble fibre than any bean, which research has shown to reduce the incidence of heart disease and certain types of cancer [30]. In addition to the good nutritional properties, Bambara groundnut also contains rich quantities of polyunsaturated fatty acids, with linoleic acid being the predominant fatty acid. Although Bambara groundnut dishes are nutritious, its preparation, processing and consumption are constrained by the hard to- cook characteristics, dehulling difficulty, antinutritional inhibitors, strong beany flavour and bitter aftertaste. As an edible legume with good nutritional attributes the potential to develop many food products could be unprecedented [29].

Table 4. Nutrient composition of *V. subterranea* compared with other common legumes

	Bambara groundnut (*V. subterranean*)	Soybean (*Glycine max* [L.] Merr.)	Phaseolus beans (*Phaseolus vulgaris* L.)	Cowpea (*Vigna unguiculata* [L.] Walp)	Faba bean (*Vicia faba* L.)	Chickpea (*Cicer arietinum* L..)
Calories	390	416	343	333	341	364
Protein (%)	21.8	36.5	23.8	23.6	26.1	19.3
Carbohydrate (%)	61.9	30.2	59.6	60	58.3	60.6
Fat (%)	6.6	19.9	2.1	0.8	5.7	6

Source: Adapted from Hillock [24]

4.6 Production

About 45 – 50% of world production comes from Africa where it is the main secondary legume in some parts, however, there is a poor record of its production and trade as most of the production ends in local consumption [31]. The majority of Bambara groundnut is produced for home consumption although a small amount is grown as a cash crop [29]. It is difficult to obtain accurate production and yield figures for the Bambara groundnut crop in Nigeria. However, Heller et al. [22] estimated that the country produces about 100 000 t of the crop annually. The area under Bambara groundnut cultivation in the Sahel and Sudan savanna zones of Nigeria has declined over the past two decades. Farmers in these areas estimated that the present area is about 5 – 20% of that of 20 years ago. They attributed this decline to drought. On the other hand, the area under Bambara groundnut cultivation has increased during the same period in the southern Guinea and forest zones of Nigeria. The increase in the amount of the crop produced in these areas is thought to be due to the fact that the crop commands a high market price, with demand far outweighing supply in many areas [18]. Although it is reported that Nigeria produces one-third of total annual world production which is around 300,000 metric tonnes [17], it is grossly inadequate to meet with world demand put at over 800,000 metric tonnes, hence the higher prospect for farmers in the region and indeed Nigeria to increase their production.

4.7 Potential of Bambara Groundnut

The crop has high potential in meeting the need of poor resource farmers for increased food output in that it is reported to tolerate or even prefer poor soils hence, yield better than most pulses on poorer soils with little rainfall as well as produce substantial yields under better agronomic conditions [32; 33]. In fact, it is reported that nitrogen-rich soils are to be avoided as they stimulate the plant to produce too much leaf at the expenses of pods and seeds [17], this alone means the crop can be grown better by most farmers. The crop also has a reputation for resisting pests and disease [34] and unconfirmed observations indicate that the crop can suppress Striga species, a parasitic weed found in sandy soils [22]. Bambara groundnut is a promising commodity, which needs more publicity, both as a crop and as a food. Even in tropical Africa, few people in the forest zones are aware of its existence. It should be emphasised that, *V. subterranea* is a low-cost and dependable crop, which can grow in harsh environments where many other crops fail. Its high nutritive value should be made known to the public, and, in particular, to the rural poor. However, to ensure the wider adoption of Bambara groundnut, the general mode of consumption of the crop needs improving. Modern processing methods would enable distribution of Bambara groundnut to non-producing areas.

Another important attribute of Bambara is the availability of varieties with a varying maturity period ranging from 3 -6 months, which makes it suitable for production and harvest all year round while minimizing yield losses [35]. They also help to smother weeds and protect soil surface for other agricultural purposes, from the impact of heavy rain, wind and sunlight. Harvesting is simple with simple with simple farm tool. Shortfalls in food gaps and nutrient requirement of the populace may be addressed with the high yielding potentials and phytochemical composition of the crop. Significantly, the effect of diseases on growth and yield is minimal. Adequate storage of crops provides food throughout the year and alleviation the hungry gap between harvest as sophisticated storage facilities are not required. Due to the hard seed coat, the Seed can be stored for six months up to next harvesting period without significant loss of food composition. Farmers recognise the ease of storage without seed destruction and loss of viability as a significant advantage over groundnut and cowpea.

4.8 Challenges Associated with Bambara Groundnut Utilization

Despite its high and balanced protein content, Bambara remains under-utilized because it takes a long time to cook, contains anti-nutritional factors and does not deshell easily. Challenges enumerated by Ogwu [36] and Osawaru and Ogwu [37] associated with the utilization and conservation of plant germplasm plague V. subterranea especially pollution, diseases, habitat fragmentation and utilization pattern or mode. Existing Bambara products are not promoted in the local or international markets and new products are needed that highlight its inherent nutritional and culinary advantages. A number of projects on Bambara, involving several countries in sub-Saharan Africa since the 1980s, have failed to stimulate a sustainable increase in the production of the crop. The absence of functioning value chains has been a factor in this failure, as accessible market outlets might provide the required incentive for smallholder households to obtain improved seed and invest more of their land and labour in the crop [24]. Bambara groundnut has a reputation for resisting pests and compares favourably with other legumes such as groundnut or cowpea in this regard. In humid environments, however, fungal diseases such as Cercospora leaf spot, Fusarium wilt and Sclerotium rot are common. In such circumstances, spraying with the fungicide benlate (1 Kg/ha) has proved beneficial. Viral diseases like cowpea mottle virus and cowpea aphid-borne mosaic virus are widespread in most environments, especially in areas where other grain legumes such as cowpea are grown. Removal of infected parts, as well as proper clearing and burning for cultivation, would be helpful [22].

4.9 Recommendations and Conclusion

Bambara Groundnut is a crop with great potentials, which needs improved management and attention. Presently, no major industrial use of the crop has been reported in spite of the growing interest in cultivation for subsistence and small-scale agriculture. To harness and maximise the potentials of this crop in achieving food security in Nigeria, the following should be addressed:

1. Bambara groundnut germplasm should be collected from all over Nigeria and Africa where landraces are available and integrated breeding work carried out to determine yield and the feasibility of commercial production, selection; especially for superior cultivars that can tolerate semiarid areas where groundnut yield poorly because of drought and are resistant to disease and pest.

2. Currently, it is only cultivated on small plots, but it has high potential as a field crop thus efforts should be made to improve the management of the crop in the field and this involves investigation in areas of mechanised cultivation, harvesting, shelling and processing. Therefore, Bambara groundnut should be introduced into mixed cropping systems.

3. The potentials as a cash crop, processed foods and world trade should be harnessed.

4. Research into Bambara groundnut's nutritional effectiveness should be carried out as there are indications that the protein digestibility is inhibited by anti-nutritive factors in the seeds is encouraged.

In conclusion, food security implies meeting the needs of the populace in terms of their food requirements in both quantity and quality. Bambara groundnut is high in protein, which has been reported to be of high quality. More so, it is indigenous to the northeast region of Nigeria, hence is highly adapted and if proper attention is given to the crop in terms of breeding and agronomic practices, the crop can serve as one of the pulses for the growing population. The management should include classification into ecotype, morphotypes as well as focus on promoting public awareness of the nutritional importance and increasing the digestibility through food processing.

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