CHANGING ASPECTS OF BAMBARA GROUNDNUT EXPLOITATION: 1. LIMITATIONS AND ALLEYWAYS FOR FUTURE EXPANSION

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Abstract. Bambara groundnut is an under-exploited legume that has the potential to contribute enormously to food security. It can be used to increase the fertility of the soil leading to high yields of other crops during mixed cropping. It was deduced from the literature reviewed that Bambara groundnut will play a major part in dealing with climate change. Bambara groundnut is the third most important legume after groundnut and cowpea in Africa, and its cultivation has extended to Asia and the Americas. It requires very little inputs (fertilizers and agrochemicals) to produce. Bambara groundnut contains crude protein (18.8 g), crude fat (6.2. g), total ash (2.4 g), crude fibre (4.8 g), carbohydrate (61.3 g), moisture (10.3 g), and energy (367 Kcal) which makes it a complete food. Bambara groundnut seeds have a higher content of amino acids (80%) (i.e.; arginine, leucine, valine, methionine, and lysine), compared to cowpea, soybean, and groundnut (circa 64%, 74%, and 65% respectively). The gross energy value of Bambara groundnut is greater than that of cowpea, lentil, and pigeonpea. Bambara groundnut is very rich in mineral nutrients: potassium, calcium, iron, magnesium, and zinc. Efforts to increase its yield are hindered by cultural heritage, inadequate knowledge, adaptation to particular agroecological zones, lack of genetic improvement, inadequate processing, lack of functional value chains, gender stigmatization, poor land tenure systems, pests, and diseases, This review (1 of 3) was carried out to document these challenges and the efforts being made so far to overcome them.

Keywords: climate change, complete food, production constraint, soil fertility, uses, yield

INTRODUCTION

Azam-ali et al. (2001) bemoaned that initiatives adopted to develop and commercialize the exploitation of Bambara groundnut (*Vigna subterranea* (L.) Verdc.) are yet to yield the expected results. This could be tied to over-generalisation, assumptions, inadequate attention to the reality about the production and utilization of Bambara groundnut. Often even indigenes of Sub-Saharan Africa do not know much about this crop. Though Bambara groundnut is an indigenous underutilized legume it has a significant capability to contribute to the attainment of food security since it tolerates drought stress and yield well on unproductive soils (Muhammad et al., 2020).

Sanusi et al. (2018) affirmed that Bambara groundnut can be used to increase the fertility of the soil (via N fixation) and bring about high yields of nonlegumenous crops intercropped with it. Bambara groundnut cultivation is highly adapted to subsistent farming in the tropics (Pillay, 2003). Nweke and Emeh (2013) argued that adopting underutilized legume crops can enable humans to attain food security economically.

Bamishaiye et al (2011) reported that Bambara groundnut seeds are richer than groundnut (*Arachis* species) in essential amino acids (such as isoleucine, leucine, lysine, methionine, phenylalanine, threonine, and valine). Bambara groundnut seeds have a higher content of amino acids (80%) (that is; arginine, leucine, valine, methionine, and lysine), compared to cowpea (*Vigna* species), soybeans (*Glycine* species), and groundnut (circa 64%, 74%, and 65% respectively) (Mazahib et al., 2013). Nowadays, this is very important for the wholesome-food-wise individuals who desire to revert to several vegan life styles.

Moreover, Celine (2010), Schaafsma (2012), and Oyeyinka et al. (2018) elucidated that the high carbohydrate (65%), moderate protein (18%), and ample quantities of fats (6.5%) make Bambara groundnut a complete food. Bambara groundnut is richly endowed with these food ingredients which make it an excellent foodstuff for weaning infants.

The gross energy value of Bambara groundnut seed is greater than that of other legumes such as cowpea, lentil (*Lens esculenta*), and pigeonpea (*Cajanus cajan*) (FAO, 1982). The three most important food legumenous crops in Africa in order of descending importance are groundnut, cowpea, and Bambara groundnut (Howell et al., 1994; Azman-Halimi et al., 2019). Thus, breeding Bambara groundnut for high yield is highly required.

Bambara groundnut has several traditional therapeutic uses. For instance, its leaves are applied as a dressing for infected wounds, its leaf sap is applied to the eyes as a treatment for cataracts, and its milled seeds are used to treat epilepsy, while its roots can be ingested as an aphrodisiac. Bambara groundnut seeds are high in fibre thus their ingestion may reduce the incidence of heart disease and cancer of the colon.

To crown it all, the gross energy value of Bambara groundnut seeds is greater than that of some popular food legumes (such as cowpea (*Vigna unguiculata*), lentil (*Lens esculenta*), and pigeonpea (*Cajanus cajan*)) (FAO, 1982). Certainly a holistic approach is required to change long established trends. Three reviews were initiated to achieve this change. Up till now, there is a huge dearth of information on many aspects of the production and exploitation of these crops, which necessitated this review to document and highlight these gaps in our know-how concerning the exploitation of Bambara groundnut.

COMPOSITION AND UTILIZATION OF BAMBARA GROUNDNUT SEEDS.

Bambara groundnut is a complete food

Bambara groundnut can help mankind in realizing food security since it has the potential to fulfil the four dimensions of food security (viz.; food availability, food accessibility, food utilization, and food stability) Burchi and Fanzo (2011). Food security can best be achieved by developing processing solutions to improve the quality of local food produce and increasing the shelf life of crops like Bambara groundnut. However, current research in this area has not considered the needs of resource-poor communities (Padulosi et al., 2013). Moreso, Bambara groundnut currently suffers from the ‘hard-to-cook’ phenomenon though it is a great foodstuff.

First and foremost, the fact that Bambara groundnut is a complete food is good news for the resource-poor rural dwellers and vegans. Thus, Atiku et al. (2004) pointed out that nowadays, Bambara groundnut is grown across the continent from Senegal to Kenya and from the Sahara to the Kalahari.

Presently, food-processing methods for legumes used in sub-Saharan countries include chemical treatments (i.e.; *cooking aids*), biological treatments (viz; sprouting/*germination and fermentation),* and physical treatments (*like milling, roasting, baking, and canning*) (Mubaiwa et al., 2017). Boiling is the preferred food-processing method for Bambara groundnut, thus easy cooking time has become a major trait sought after by end users of the crop (Berchi et al., 2010).

Onimawo et al. (1998) estimated that Bambara groundnut has great potential for incorporation into different human foods because it possesses crude protein (17.5-21.1%), crude fat (7.3-8.5%), total ash (4-5%), crude fibre (1.8-2.0%), carbohydrate (53.0-60.8%), moisture (7.5-12.3%), and energy (367 Kcal).

However, like other legumes, Bambara groundnut lacks sulphur-containing proteins which have to be supplemented with cereals (Massawe et al., 2005). Khan et al. (2020) reported that Bambara groundnut has a high content of iron and protein with a significant level of lysine (10.3%).

Dansi et al. (2012) reported that the content of essential amino acids in Bambara groundnut seeds (i.e. per 100 g) is tryptophane (192 mg), lysine (114 mg), methionine (312 mg), phenylalanine (991 mg), theonine (617 mg), valine (937 mg), leucine (1385 mg), and isoleucine (776 mg). Damfami and Namo (2020) added that Bambara groundnut contains β-carotene (10 µg), thiamin (0.47 mg), riboflavin (0.14 mg), niacin (1.8 mg), and traces of ascorbic acid.

Bambara groundnut is a rich source of essential minerals

Mubaiwa et al. (2017) reported that Bambara groundnut is very rich in micronutrients (such as potassium, calcium, and iron). Besides Tan et al. (2020) agreed that essential mineral elements (like magnesium, iron, zinc, and potassium) in Bambara groundnut are especially suitable for those living in arid and semi-arid regions of the tropics.

Bambara groundnut seeds contain Ca (95.5–99.0 mg/100g), K (5.1–9.0 mg), Na (2.9–10.6 mg), and Zn (20.9 mg), which can have a significant impact on preventing prostate cancer in men (Angeot et al., 2014). Damfami and Namo (2020) also pointed out that its micro-minerals include Cu, Fe, and Zn.

Muimba-Kankolongo and Muimba-Kankolongo (2018) reported that the mineral composition of Bambara groundnut varies based on the variety. For example, its red varieties contain twice as much iron as the cream variety. Moreover, Asante et al. (2004) reported that Bambara groundnut has lower tannin content than cowpeas and pigeonpeas. Fortunately, Ajilogba et al. (2020) observed that low levels of tannin have a beneficial effect on human and animal nutrition.

Utilization of Bambara groundnut

- For human consumption

Bambara groundnut is produced mainly for home consumption. Bambara groundnut is cultivated mainly for its seed or flour which can be used as a thickener in soups and stews or baked as bread. The seeds can be processed into milk and fermented products. Mahazib et al. (2013) and **Igbabul** et al. (2013) said that immature Bambara groundnut seeds are boiled, grilled or roasted, and eaten as a snack. The matured dry seeds are often milled into flour and used for the preparation of various dishes or as a substitute for coffee. Akpalu et al. (2013) pointed out that different types of porridge can be made using Bambara groundnut flour.

Brough et al. (1993), Masindeni (2006) and Khan et al. (2020) agreed that Bambara groundnut seeds are used for making bread and soup while roasted seeds are eaten as snack. Chewing and swallowing raw Bambara groundnut seeds or its green leaves prevents nausea and its hay is used to feed livestock (Uvere et al., 1999; Khan et al., 2020). Damfami and Namo (2020) reported that the commercial canning of Bambara groundnut was previously practised in Ghana and Zimbabwe.

- Therapeutic uses of Bambara groundnut

According to Akpalu et al. (2013) if the white-seeded variety of Bambara groundnut is mixed with guinea fowl meat it can be used to treat diarrhoea, while if the black-seeded variety is mixed with water, it can heal sick children. Bambara groundnut pulverized seeds are used to treat skin rashes or its seeds are chewed to assuage swollen jaw diseases. Adamu et al. (2015) reported that legumes like Bambara groundnut have the potential to reduce the sugar level in the human body.

- Other uses of Bambara groundnut

Damfami and Namo (2020) reported that Bambara groundnut is drought tolerant. Currently, research to prove this point is inadequate. More research has to be carried out on the mechanisms of drought tolerance in this crop.

BAMBARA GROUNDNUT PRODUCING AREAS

Bambara groundnut is widely cultivated in sub-Saharan Africa (especially in Central and West African regions), and to a lesser extent in the tropical parts of the Americas, Asia, and Australia (Mabhaudhi, 2009). Thus, the top six Bambara groundnut-producing countries in the world as of in 2018 include Mali, Burkina Faso, the Cameroons, Niger, the Democratic Republic of Congo, and Togo in descending order of magnitude (Majola et al., 2021; FAO, 2021). Nigeria and Ghana produce a lot of Bambara groundnut but yield statistics are lacking.

Based on simulations and careful study, Azam-Ali et al. (2001) reported that there is a potential for cultivating Bambara groundnut in many countries with a Mediterranean climate (viz; Lebanon, Israel, Italy, Portugal, Spain, and Greece).

Bambara groundnut is cultivated in tropical environments by small-scale farmers under traditional rainfed cropping systems. Karwani et al. (n.d.) indicated that about 93.3% of the farmers involved in Bambara groundnut production are female and children. Temegne et al. (2020) agreed with this opinion and stated that in the Cameroons, Bambara groundnut is mainly produced by women (74%), the elderly, or poor peasants.

World production of Bambara groundnut

Africa-wide production of Bambara groundnut was estimated to be over 330,000 tonnes annually (based on pooled data from various sources) (Hillocks et al., 2011). Myers (2003) reported that based on the world production of leguminous food crops, domesticated legumes can be ranked in descending order of magnitude as follows: soybean, groundnut, cowpea, pigeon pea, and Bambara groundnut. The yield of shelled Bambara groundnut in Africa varies from 0.6−1.0 metric tonnes ha^{-1} depending on the variety and the environment (Majola et al., 2021).

Low yield of Bambara groundnut

Fatimah et al. (2018) reported that Bambara groundnut seed yields (0.5–3.0 tonnes ha^{-1}) vary in Africa based on the location and the landrace. On average, a yield of 0.85 metric tonnes ha^{-1} is achievable for Bambara groundnut (Mayes et al., 2019). However, Bambara groundnut has a genetic potential to produce up to 4.0 metric tonnes ha^{-1} (Fatimah et al., 2018).

Research on factors influencing the yield of Bambara groundnut is highly needed. Collinson et al. (2000) observed that pod yield declined from >3 000 kg ha^{-1} to zero when the sowing date was delayed by 60 days during a field experiment in Tanzania. In Côte d'Ivoire, the highest yields were obtained with high-density planting (250 000 plants ha^{-1}) in flat beds using a semi-bunch type of Bambara groundnut (Kouassi and Zoro, 2010).

Bambara groundnut 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 (Thottappilly and Rossel, 1997). In Ghana, Bambara groundnut is sometimes planted on yam mounds thus protecting the mound from erosion (Doku and Karikari, 1971).

Heller et al. (1995) in Burkina Faso reported that varying planting dates resulted in a low level of Bambara groundnut seed production (0.02-0.4 tonnes ha^{-1}) of 20 varieties and a decrease in the severity of the disease when the crop was planted early. They reported that planting dates from 24th June to 9th July revealed seven varieties with yields from 0.6-1.0 tonnes ha^{-1}.

PRODUCTION CONSTRAINTS RELATED TO BAMBARA GROUNDNUT

Agricultural organizations and policymakers have recognized the role of neglected and under-utilized crops (like Bambara groundnut) for food security, generating income, and adapting to climate change. However, little effort is being put into research and development activities that can enable society to tap into this potential (Padulosi et al., 2013; Ani et al., 2013).

Temegne et al. (2020) reported that in the Cameroons, weeds, lack of improved varieties, low yields, diseases, and pests (insects and rodents) were the main production constraints identified. Heller et al. (1995) declared that the area under Bambara groundnut cultivation increased during the previous two decades in southern Guinea savannah and forest zones of Nigeria, but it decreased in the arid northern parts of the country due to drought. Presently, research on the effect of drought on Bambara groundnut is not sufficient.

Tan et al. (2020) concurred that rapid population growth, climate change, intensive monoculture, and resource depletion are among the challenges that threaten the increasingly vulnerable global food system. Thus, due to resource limitations, knowledge gaps, social stigma, and lack of policy incentives, Bambara groundnut has not attained its production potential.

Tadele et al. (2012) enumerated constraints related to Bambara groundnut production as follows: cultural heritage, inadequate knowledge, localized adaptation to particular agroecological zones, and lack of research on its genetic improvement.

Moreover, Enwere et al. (1996) emphasized that this crop produces seeds which exhibit hard-to-cook characteristics, the crop suffers from inadequate processing and dehulling the seedcoat is extremely difficult to achieve. They hinted that the lack of a functional value chain is among the constraints faced in attempting to improve and produce this crop.

Karwani et al. (n.d.) reported that the yield of Bambara groundnut is usually low (150-400 kg ha-1) due to lack of improved seeds (89.2%), pests and diseases (35%), gender related stigmatization, and unfavourable land tenure system. It was noted that the price of Bambara groundnut (USD 1.6-2.0 kg-1) compared favourably with that of beans (USD 0.8-8.0 kg-1). Yet, Bambara groundnut is stigmatised as a 'poor man's crop' (see Kew Species Profiles).

Consequences of unproductive soil on the production of Bambara groundnut

Taffouo et al. (2010) and Temegne et al. (2018) reported that soil variation and ecological factors (soil moisture stress, temperature, and day length variation) affect vegetative development, phenology, and the yield of Bambara groundnut. Musa et al. (2016) revealed that Bambara groundnut landrace Ex-Sokoto produced higher yield and N fixation. The grain yield (703.0-2,256 kg ha-1) and N fixation (32-81 kg ha-1) were recorded which suggests that Bambara groundnut could be integrated into a cereal-based cropping system.

Ncube and Twomlow (2007) agreed that Bambara groundnut is useful in crop rotation because it contributes nitrogen to the soil at a level similar to that of other legumes (20–100 kg ha-1). Mkandawire (2007) elucidated that Bambara groundnut grows well on the acidic laterite soils of Africa, but less so on the calcareous soils.

Ajilogba et al. (2020) reported that the soil rhizosphere of legumes (like Bambara groundnut) can enhance plant growth, and control plant pests and diseases. This is due to the presence of plant growth-promoting rhizobacteria (including the species of *Bacillus*, *Actinomycetes*, *Pseudomonas*, *Burkholderia,* and *Rhizobium).*

Puozaa and Dakora (2017) reported that the legume secrets flavonoids and the seedcoat pigmentation (of its landraces) play a major role in attracting compatible rhizobia. Even when Bambara groundnut landraces were planted together in one hole, nodulating bradyrhizobia clustered differently based on the landrace concerned.

LAND PREPARATION FOR THE PRODUCTION OF BAMBARA GROUNDNUT

Department of Agriculture, Forestry and Fisheries (2016) reported that Bambara groundnut produces its best yields on a deeply ploughed field with a fine tilt. For compacted soil and weed-infested areas, ploughing, followed by about two times of harrowing, is recommended to ensure good germination and establishment of stand. A level seedbed is best; however, it can be planted on ridges when very wet conditions prevail.

Mkandawire (2007) lamented that mechanized harvesting of Bambara groundnut is difficult because it grows at ground level and the nuts are produced underground. Bambara groundnut is a typical short-day plant thus flowering and pod development may be delayed or prevented by long-day conditions (Mkandawire, 2007). There is a close association between yield and planting date, which becomes more prominent further from the equator. This may relate both to the effect of longer days and intolerance to very wet conditions.

EFFECT OF CLIMATIC FACTORS (ESPECIALLY RAINFALL, RELATIVE HUMIDITY, AND TEMPERATURE) ON THE PRODUCTION OF THE CROP

Berchi et al. (2012) reported that Bambara groundnut var. Burkina was the most drought and heat-tolerant variety among the five landraces they evaluated. However, they pointed out that this crop is negatively affected by high temperatures greater than 38°C coupled with low relative humidity.

Ouedraogo et al. (2008) reported that in the southern part of Ghana, (where the rainfall pattern is bimodal), Bambara groundnut can be cultivated twice a year. However, we note that sowing time affects the yield of Bambara groundnut which is a short-day plant. The life cycle of Bambara groundnut varies from 3-5 months so it can be grown under varying conditions of the rainy season and irrigation (Abejide et al., 2018).

Department of Agriculture, Forestry, and Fisheries (2016) clarified that Bambara groundnut requires warm temperatures (30-35°C) and does not tolerate freezing temperatures during the growing season. An average daytime temperature that is ideal for the development of the crop is from 20-28°C. Concerning drought tolerance, extreme temperatures cause the dying of the leaves resulting in a decrease in biomass yield. They further clarified that Bambara groundnut requires moderate rainfall (500-1200 mm) from sowing until flowering. The plant tolerates heavy rainfall, but too much rainfall at harvest time may result in yield loss.

EFFECT OF INPUTS (i.e. FERTILIZERS AND AGROCHEMICALS) ON THE PRODUCTION OF THE CROP

It has been continuously peddled that Bambara groundnut can do well in poor non-fertile soils. This point has been misinterpreted by implying that Bambara groundnut should be grown on poor soils. This is the tragedy of Bambara groundnut production. It is because of its under-rated status that this crop has been relegated to the poorer soils in rural farmlands. This crop performs exceedingly well when its nutrient requirements have been adequately met.

For instance, Hillocks et al. (2012) put that the crop yields (500–800 kg ha^{-1}) are reasonably well on poor soils in areas of low rainfall and can be grown without fertilizers and agrochemicals. This may sound like an advantage to the crop, but in reality, it is not. The crop is deprived of inputs and then in the end it is hailed for daring to survive the ill-treatment it went through.

This is the point of contention in this review and to do justice to this subtheme, the effects of soil fertility are handled elsewhere. A longer review is in the press about this view. Bambara groundnut can significantly benefit from fertilizer application as will be briefly illustrated herein.

For instance, Nweke and Emeh (2013) emphatically said that in the field, Bambara groundnut responded significantly ($P \leq 0.05$) well to all the levels of Phosphorus applied. Pod yield increased with the increasing rate of phosphate fertilizer application. Likewise, the number of nodules, length of the root, number of leaves per plant, number of branches, number of flowers, and plant height increased significantly throughout.

Secondly, Dakora and Muofhe (1997) earlier reported that inoculating Bambara groundnut using selected strains of *Bradyrhizobium* species markedly increased yields. They reiterated that efforts aimed at increasing Bambara groundnut production should consider cultivar selection for effective symbiosis with mainly native bradyrhizobial strains.

CONCLUSIONS

Bambara groundnut is an underutilized legume that has the potential to contribute enormously to food security. Among the legumes, this crop withstands drought, pests and diseases better. The production of this crop has not been adequately studied, which necessitated this review to highlight these gaps in our know-how. Numerous factors contribute to the crop being under-utilized amongst which are weeds, poor production techniques, lack of improved varieties, low yields, diseases, and pests (insects and rodents). Bambara groundnut can compete favourably with most of the popular legumes if given enough attention by researchers and policymakers. This is coupled with the low input requirements of the crop which means that all and sundry can participate in the production of this nutrient-rich crop.

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