

INTRODUCTION TO AFRICA YAM BEAN (*SPHENOSTYLIS STENOCARPA* (HOCHST. EX A. RICH.) HARMS)

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Received: 14 September 2021, Revised and Accepted: 10 October 2021

ABSTRACT

Food security and malnutrition are great concerns in developing and under-developed nations. Climate change, political unrest, and all sorts of crises within these nations and their neighboring nations have contributed greatly to the issue of food insecurity, malnutrition, and hunger. Many food plants that have the potential to combat the challenges of food insecurities and malnutrition in the face of climate change have been neglected, under-utilized and some of the crops are on their way to extinction. African yam bean (AYB) is one of the numerous crops with great potential in overcoming the problems associated with food and nutritional insecurities. AYB under-utilization, poor acceptance, and neglect by the farmers and consumers may be a result of poor awareness about its nutritional and health benefits, poor agronomy practices adopted by the farmers, and other production limiting factors such as low yield and long maturity period. Information that can guide the farmers and consumers for the commercial production and processing of AYB is not readily available. This review aims to summarize and made available information on AYB for the farmers and the consumers for it to be commercialized and for the researchers to see reasons and areas to make improvements on the crop.

Keywords: Africa yam bean, climate change, food-security, neglect, under-utilized.

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INTRODUCTION

War, climate change, poor governance, terrorism, bandit, poverty, and herdsmen-farmers clashes among other factors have negatively affected food production, processing, and its availability which eventually resulted in food and nutritional insecurity. Food and feed products are essential commodities for the survival of the human population and livestock. These essential commodities have been threatening by the aforementioned factors which bring about food shortage. The global human population was estimated to reach 9.4 billion by the year 2050 [1]. The rate of the food supply is far below its demand; hence, the cost of food and feed products is on the high side and is becoming not affordable for the larger part of the global population particularly in the developing and under-developed nations. If the food scarcity continues, the calamities of malnutrition and hunger will be overbearing. As the global demand for food by the human population keeps growing, the need for good, safe, and nutritious food increases. To meet the human population's food demand, the gap between food supply and its demand needs to be bridge by providing enough food and feed products [2].

According to Gbenga-Fabusiwa [3], plant food serves as a major source of key nutrients that the larger part of the global population and their livestock have access to. These plant foods are cheaper, affordable, and readily available compare to other sources of food. Unfortunately in Africa, some of the plants that would have to broaden the food base for humans and the livestock have been ignored and under-utilized to the extent that some are on their way to extinction [4]. One of the strategies to boost food production and feed availability to enhance food security is by reviving crop species that are becoming extinct due to their declining cultivation and utilization. The reasons for crops losing their popularity and utilization strength should be pointed out and proper solutions must be provided. African yam bean (AYB) is one of the crops that are on the track of extinction because it has been neglected and underutilized by farmers, consumers, and crop scientists [3]. The AYB is an annual crop that is cultivated for its nutritious edible seeds and tubers [5]. Afolabi *et al.* [6] cited Okpara and Omaliko [7] that poor

rural dwellers in Nigeria recognized AYB as a food substitute during the famine period.

Africa yam bean has the potential to combat the challenges of food and nutritional insecurity, and widen the food and feed products base for both human and livestock consumption if the crop is commercialized and is given research attention for its improvement [8,9]. According to Saxon, [10], 17 tuberous legumes are of African origin which is used for food and feed, flouring agent, medicine, and other purposes. A review of the literature indicated that the AYB is the most important and economical of the seventeen tuberous legumes that are of Africa origin [11]. This review aims to provide adequate and valuable information on AYB to the farmers, consumers, and researchers as a potential crop in combating food and nutritional insecurity so that its production and processing can be commercialized.

AFRICA YAM BEAN TAXONOMY

The botanical name of Africa yam bean is *Sphenostylis stenocarpa*. The genus name *Sphenostylis* was evolved by Harms [12] who describe some distinctive leguminous taxon previously grouped within the genus *Dolichos* and *Vigna*. The word *Sphenostylis* came from a Greek word *sphen*, meaning wedge shape [13]. The genus *Sphenostylis* consists of a group of leguminous species which are few in number [11]. Seven species are within the genus *Sphenostylis* but the AYB, *Sphenostylis stenocarpa* is the most popular and economically important among these species [14]. The AYB taxonomic profile is presented as Kingdom- Plantae; Subkingdom - Tracheobionta; Super division - Spermatophyta; Division - Magnoliophyta; Class - Magnoliopsida; Subclass - Rosidae; Order - Fabales; Family - Fabaceae; Sub family - Papilionoideae; Tribe - Phaseoleae; Sub tribe - Phaseolinae; Genus - *Sphenostylis* E. Meyer; and Species - *Sphenostylis stenocarpa* (Hochst. Ex. A. Rich.) Harms. [11,15].

GEOGRAPHICAL DISTRIBUTION OF AYB

AYB is a leguminous crop that is widely cultivated in West and Central Africa, especially in Nigeria, Ghana, Guinea, Togo, Ivory Coast, and to

some parts of central and equatorial Africa [16], though its center of origin is not documented [17,18]. The crop can perform optimally in a wide range of climatic and edaphic conditions [11]. The center of diversity of the crop lies within the latitudes 15° N to 15° S latitudes and the 15° W to 40° E longitudes of Africa [19]. Chloroplast DNA studies and linguistic data established that the domestication of African yam started in West and Central African [8]. The crop is grown at sea level to elevations of about 1800 m [20].

AFRICA YAM BEAN BOTANY AND MORPHOLOGICAL DESCRIPTION

AYB (*Sphenostylis stenocarpa*) is a climbing, annual herbaceous vine that attains a height of 1.5–3 m or more depending on the length of the staking materials and cultivar. The crop also exhibits perennial habit by regenerating from its rootstocks at the commencement of the rainy season every year [8]. The crop produces primary and secondary branches that twine on the stakes or any available plants like cassava or tree [11]. The number of branches produced by the crop depends on the cultivar. The leaves are trifoliate, depending on the cultivar, some are linear, ovate, or elliptic [8]. The leaf could either be pigmented or not with pale green, green, or dark green in color.

The flowers emerge after 90–150 days of planting [8]. The flowering duration of the plant is about 50–70 days depending on the cultivar grown, agronomy practices adopted, and the prevailing environmental factors. About six to 13 flowers are produced on a peduncle. The inflorescence is a raceme with an acro-petal mode of floral maturation [21] that bears some numbers of pedicellate bracteolate flowers. The flowers are obligate selfer and cleistogamous that opens late in the evening till early morning and closed up before noontime [22]. AYB undergoes both self and cross-pollination [21]. The pollen grains produced by the crop possessed tricolporate, fenestrate, and scabrate exine with three colpus [22]. The pollens size and fertility varies from one cultivar to the other [23]. A peduncle can bear four to eight pods depending on the cultivar grown, agronomy practices adopted, and the prevailing environmental factors. Following the flower pollination and successful fertilization, a long pod of about 30 cm long which bears the seeds are formed. According to Klu *et al.* [5], the pods mature about 30 days after successful fertilization. The pods formed can either be shattered or non-shattered, seed cavity ridges on pods may be present or absent, the seed could be round, oval, oblong, or rhomboid in shape while the seed texture could be smooth, rough, or wrinkle depending on the cultivar. Some cultivars produce tubers with brownish-orange, cream, or pink color while some do not produce tuber [21]. The pods that bear the grains mature from 140 to 210 days after planting. The crop produced tubers that resemble that of potatoes which vary in sizes and shapes depending cultivar grown [24]. The tuber matures about 210–240 days after sowing [25]. Large genetic variability among AYB traits has been reported by various researchers [5,26,27].

AGRONOMY OF AFRICA YAM BEAN

AYB is propagated by seed. Planting commences whenever the rain becomes stable [5]. The crop can withstand unfavorable climatic conditions such as prolonged drought periods, this makes it a good source of cheap plant protein in addressing the problems of climate change that persist [28]. AYB is grown as a minor crop along with some crops like cassava and yam which serve as a stake for the crop [29]. Two to three viable seeds are planted per hole. The seeds can be planted at the base of the heap or ridges of the main crop(s) or on a tilled land. The crop is also planted at the base of trees which serve as a stake for it. Sole cropping of the crop is rare because of the little importance attached to the crop by the farmers and consumers. AYB germinates 5–7 days after sowing and it exhibits hypogeal germination. Despite the thickness of the seed coat, scarification is rarely carried out among the farmers because of the little importance given to the crop [30]. Scarification is important to enhance early germination. Planting spacing for the crop varies considerably [11], no specific spacing is recommended in the literature for the crop. The spacing depends mainly on the main crop(s) that is being intercropped with. A multi-location experiment

was carried out by Adewale [21] using 30 accessions of AYB at 1 m × 1 m spacing gave a grain yield that ranges from 248–4,130.46 kg/ha.

After germination, a stake should be provided 2 weeks after planting for the vine to climb and twine on. Delay staking will result in vine spreading on the ground instead of climbing. The staking material should be about 3–4 m. The field should be free from weeds to avoid competition. Pests and diseases should be kept at a minimum. First weeding should be carried out 3 weeks after planting and every 2 months thereafter. The growing pattern of the crop can suppress weeds as it deprives the growing weeds of sunlight. AYB response to fertilizer application but it can derive about 79.0–97.6% of their nitrogen requirement from the atmosphere through nitrogen fixation [31], thereby requiring little or no nitrogen fertilizer supplement. Oganale [31] reported that the growth of inoculated AYB plants was increased by almost 1547%. According to Togun and Olatunde [32], AYB yield is at its peak at 60 kg/ha of NPK fertilizers. However, the yield and other yield-related parameters of AYB responses to further increase in NPK fertilizer beyond 60 kg/ha began to decrease. Olaposi and Adarabioyo [33] reported that the number of flowers per plant was at its peak when NPK fertilizer was applied at the rate of 60 kg/ha. This indicated that AYB production will perform maximally when NPK fertilizer is applied at the rate of 60 kg/ha.

Severe infection and infestation of AYB with diseases and pests at various phases of the crop growth and development result in crop failure. Integrated pest management approaches should be adopted in keeping pests and diseases at a minimum to avoid crop failure or reduced yield. Pod harvesting should start as soon as the matured pod is becoming dry. Overstay of the dried pods on the field leads to seeds wastage especially with the shattered cultivars. However, harvesting mature pods that are not dry leads to seeds spoilage if not well dried before processing and storage. The dry pods should be threshed, winnowed, and store at 10–12% moisture content. Threshing and winnowing should be carried out in a clean environment to achieve a high level of purity in the seed. The tuber can be harvested using hoe and cutlass. Care should be taken to avoid bruises on the tubers while harvesting to avoid spoilage during storage. The wounded or bruised tubers should be separated before storage. However, the wounded or bruised tubers can be properly cured for storage.

PESTS AND DISEASES OF AFRICA YAM BEAN

AYB was less susceptible to pests and diseases compared to some legumes such as cowpea and soybean [34]. The lectin present in the seeds could be responsible for this quality [11]. Pests attacked AYB on the field at their vegetative and reproductive phases and in the store. Ameh and Okezie [35] was able to identify *Cydia ptychora*, *Riptortus dentipes*, *Apion varium*, and *Nezara viridula* as pests that attacked AYB at its reproductive phase likewise the larvae and adults of cutworms, aphids and grasshopper also attacked AYB at its vegetative phase. These pests feed on the crop leaves thereby reducing the leaf area available for photosynthesis. Weevil is a major store pest that affects most legume grains but AYB seeds are resistant to cowpea weevil (*Callosobruchus maculatus*) due to the presence of lectin in the seeds [36,37].

The diseases affecting AYB are similar to other legumes such as cowpea, groundnut, Bambara groundnut, and soybean [38]. Diseased flower buds resulted in low seed yield and crop failure, this is one of the factors that limit its production and yield potentials. Powdery mildew, leaf spot, stem rust, wilting leaf mosaic, and root gall have been identified as the major diseases that affect AYBs [11,39]. Farmers do not take the management of pests and diseases of the crop seriously as lesser value is attached to it, unlike other legumes. These pests and diseases should be timely controlled by adopting cultural, mechanical, biological, chemical methods, or a combination of two or more of the aforementioned methods.

AFRICA YAM BEAN NUTRITIONAL AND HEALTH POTENTIALS

AYB seed is very rich in protein. The protein content ranges from 19 and 30% [40,41]. The protein in the crop seed can be compared with those

of other legumes such as chickpea, Bambara groundnut, and common bean. AYB is rich in dietary fiber [41], carbohydrate [42], and some other important minerals. The percentage of minerals such potassium (649.49 mg/100 g), phosphorus (241.21 mg/100 g), magnesium (454.16 mg/100 g), phosphorous (204.86 mg/100 g), calcium (37.44 mg/100 g), and iron (11.70 mg/100 g) present in AYB seeds is higher compare to soy and common bean [42-44]. Ajibola *et al.* [45] pointed out that albumin and globulin are the main proteins present in AYB seeds. The seed of the AYB is highly rich in essential amino acids that are essential for human and livestock body maintenance, growth, and development [46]. The amino acid profile in AYB is higher than other legumes and it can be compared with hen's egg [47]. The lysine and methionine contents in AYB have been reported by various researchers to be higher than pigeon pea, cowpea, soybean, and Bambara groundnut [48,49]. The protein content in AYB tubers is two to three more than that of Irish potatoes or sweet potatoes and is almost 10 times more than that of cassava tuber [18,50]. AYB contain high hydrophobic amino acids which serve as an anti-sickling effect on sickled hemoglobin [51].

Due to the high level of protein and other nutrients content in Africa yam bean seed and tuber, it is used for food enrichment such as composite flour with rice, cookies and snacks, and imitation yoghurt [52,53]. The seed is usually cooked with maize, rice, plantain, cocoyam, and yam. Furthermore, Ade-Omowaye *et al.* [54] and Soetan *et al.* [55] reported that AYB contains some phytochemicals and bioactive compounds such as flavonoids and phenolic acids which assist in reducing the risk of some diseases such as cardiovascular disorder and some diseases that are related to an antioxidant imbalance in the body system [54]. Hence, the inclusion of cooked AYB seeds and tubers for those at risk or suffering from some diseases like diabetic, cardiovascular disorders, and other lifestyle ailments will be of great help [28]. The high content of antioxidants and dietary fiber assists in preventing colon cancer, the fiber also improves bowel movement [56].

AFRICA YAM BEAN PRODUCTION AND USAGE LIMITATIONS

AYB exhibit some attributes that limit their production and usage. One of the challenges farmers are facing in the production of the crop is the long maturity period and the photoperiodic sensitivity [57], these make it impossible to cultivate the crop twice a year. The use of stakes and vine training is stressful and most farmers prefer to avoid the stress when they compare the crop yield with the cost of labor required to carry out these operations. The low grain yield of the crop is another factor limiting its production. The low grain yield coupled with low seed quality and long gestation period discourages the farmers to go into commercial production of the crop. Pod shattering and poor market demand for the seed is other discouraging factors. It was observed that the farmers were not encouraged to hire laborers to harvest the crop because of its poor market demand and values, these make a reasonable percentage of the dried pod shattered away due to delayed harvesting.

The use of AYB seed also has some limitations amongst the consumers. The main limitation encounter by the consumers is the hard seeds coat [58]. The hard seeds coat required a long cooking time which discourages consuming households because it leads to high energy consumption. Hence, the cooking cost is high. Although, soaking the seeds in water to soften the seed coat is a popular method adopted by consumers to reduce the time to 10–12 h [59]. The hard seed coat also brings about some levels of difficulty in its processing among consumers [60]. The seed processors find it difficult to de-hull the seeds, so they prefer other legumes that are easy to de-hull which can still perform the same role the seed wanted to be used for. The presence of anti-nutrients in the crop seed is another limiting factor [26,40]. Some non-nutritional compounds such as lectin, tannins, phytic acid, oxalate, saponins, alkaloid, trypsin inhibitors, and hydrogen cyanide were present in the crop seed [58] though most of the seeds consumers are not aware of the anti-nutrients in the seeds. Moreover, a poor level of awareness about the nutritional value of the crop is also a reason for its poor marketability.

POTENTIAL OF AFRICA YAM BEAN TOWARD FOOD SECURITY AND SUSTAINABILITY

AYB is an under-utilized leguminous crop with the potential to widen the food and feed products for human and livestock consumption. The leaves, seeds, and tubers produced by the crop are edible to both humans and livestock. The leaves are cooked as a vegetable for humans [16] and serve as fodder for livestock. The protein contained in the tubers produced is more than Irish and sweet potatoes, and cassava. The crop produces a seed yield of about 2000 kg/hac [61]. The crop tubers can be roasted, fried, or cooked and eaten such as yam and potato. The tuber flavor is like that of potatoes [62]. The tubers from Africa yam bean can be store for a longer period without any form of spoilage due to microbial action as a result of its low moisture content of about 10.3% [44]. Various researchers have reported the nutritional potential of the crop to supplement most food that lacks essential nutrients that were consumed by the poor in underdeveloped and developing nations. This crop is very rich in both protein and starch [63]. The nutritional components and the multiple food products (leaves, seeds, and tubers) produce by the crop gave it commercial importance.

AYB AND SUSTAINABLE CROP PRODUCTION

AYB is highly adapted to a wide range of soils. It can grow and performed reasonably on acid and leached sandy soil [14]. According to Obiagwu [64], the use of AYB does not only increase the soil nitrogen content in the soil by fixing atmospheric nitrogen in the soil but also increases the soil organic matter. Different research findings have reported the contributions of AYB nodulation to soil and crop productivity. Okpara and Omaliko [57] intercrop AYB with yellow yam (*Dioscorea cayensis*) while Obiagwu [64] also intercrop it with maize, yam, and cassava. The yield obtained in all the crops intercrop with AYB by the researchers was significantly increased in all the cases. The increase in yield was attributed to AYB capability of forming a nitrogen-fixing symbiosis with *Rhizobium*.

FUTURE RESEARCH IN AFRICA YAM BEAN

The level of attention given to AYB by researchers, farmers, and consumers compare to some other legumes such as cowpea, groundnut, or soybean shows the level of its neglect and underutilization [5]. The challenges that both the farmers and consumers encounter in respect to crop production and processing were the key areas researchers have been looking into though with a little attention. Plant breeders have made efforts using genetic and breeding principles to improve the crops for it to be widely accepted. The research interest and level of success recorded in improving this crop in far below expectation [65,66]. Conventional breeding methods such as hybridization and other breeding techniques have been adopted by few researchers in improving the crop though meaningful results have not been recorded. Little understanding of the crop floral biology and high rate of hand pollination failure are limiting factors in genetic improvement in the crop [37,67]. The reproductive barriers limiting AYB improvement by plant breeders could be overcome by employing tissue culture and micropropagation as it can produce fertile haploid crops. Morphological evaluation of desired agronomic characters of AYB could also be of great importance for breeding purposes. Moreover, the identified constraints in AYB could be overcome by whole genome sequencing and gene editing tools [37, 68-70]. The danger of losing the crop germplasm is a challenge. Researchers have launched a massive exploration to identify, collect, and conserve a huge number of the crop genetic resources of the crop which is fundamental to a good breeding program for improvement. This has not only lead to the conservation of the crop's genetic resources but also save the crop the genetic resources.

Moreover, the researcher's attention should be shifted to the crop to proffer timely solutions to some of the challenges that make the plants received less attention such as the long maturity period and the photoperiodic sensitivity of the crop. Breeding for improved varieties with a growing pattern that needs no staking materials will

encourage the farmers as the cost and stress of acquiring stakes have been eliminated. Breeding for early maturity variety is another key research area to look into, a long maturity period of about 7–8 months may give some other legumes time comparative advantage over the crop. However, the longer the crop stays on the field, the higher the cost inquired by the farmers because he/she will have to continue weeding or managing pests and diseases. A longer period of cooking time and poor texture of some cultivar that gave the crop lesser market values should be worked on. The low grain yield of the crop has made it remain a minor crop. Sole cropping of the crop like some legume is not profitable due to its low yield. Therefore, plant breeders should breed for the varieties that produce higher yields. Shattering of the pods leads to wastage if it is harvested to time, a non-shattered variety should be bred for.

CONCLUSION

The place of AYB, an underexploited crop in Africa in ensuring food security by providing food and feeds products, enrichment of other foods that are deficient in key nutrients with beneficial phytochemicals and bioactive compounds that reduce the risk of some lifestyle diseases and its capability of increasing the yield of other crops that are intercrop with it as well as its soil improvement potential cannot be ruled out. However, the crop is still underutilized due to little information relating to its agronomy, processing, and usefulness that is available to the farmers and consumers. At present, improved cultivars are not available in AYB unlike other legumes such as soybean, cowpea, and groundnut; this has made these crops over-shadow the AYB. These other crops have been seriously improved with respect to yield, growth habit, produce quality, pests and disease resistance, shorter maturity period, anti-nutrient, etc. The use of seeds retained from the previous harvest or sourced from the local market made the problems limiting the production and usage of Africa yam bean by the farmers and consumers persist. Improvement of the crop through conventional breeding and biotechnology will break the production and usage constraints such as low yield, shorter maturity period, longer cooking period, shattering ability, and hard seed coat for the crop to be commercialized. Conventional breeding should be intensified in regions where their economy cannot sustain the adoption of biotechnological techniques in improving the crop. Morpho-genetical evaluation and investigation on the physiological activities controlling tuber formation in AYB should be carried out *in vivo* and *in vitro*.

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