African Yam Bean the Choice for Climate Change Resilience: Need for Conservation and Policy

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C. V. Nnamani, D. B. Adewale, H. O. Oselebe, and C. J. Atkinson

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C. V. Nnamani (✉)
Plant Systematics and Conservation Biology Research Unit, Department of Applied Biology, Faculty of Science, Ebonyi State University, Abakaliki, Nigeria
e-mail: nnamanicatherine@ebsu.edu.ng

D. B. Adewale
Department of Crop Science and Horticulture, Federal University Oye-Ekiti, Ikole-Ekiti, Nigeria

H. O. Oselebe
Department of Crop Production and Landscape Management, Ebonyi State University, Abakaliki, Nigeria

C. J. Atkinson
Natural Resources Institute, University of Greenwich, London, UK

Department of Agriculture, Health and Environment, Natural Resources Institute, University of Greenwich, Chatham, UK
e-mail: c.j.atkinson@gre.ac.uk; c.j.atkinson@greenwich.ac.uk

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Abstract

Global warming has emerged as a major challenge to development and human wellbeing in Sub-Saharan Africa in general and Nigeria in particular. Periodic incidents show that this challenge will continue and increase in impact on all aspects of natural resources – agriculture, ecosystems services, biodiversity depletion, environmental degradation and human health. Recognizing the enormous potential of underutilized plant genetic resources (PGRs) is crucial as sources of solutions to a number of these threatening challenges emanating from climate change (food and nutrition insecurity, genetic erosion, loss of agro-biodiversity, green job growth and income generation) cannot be overemphasized. *Sphenostylis stenocarpa* (Hochst. *ex*. A. Rich) Harms., commonly known as African yam bean (AYB) belonging to the leguminous Fabaceae, is an underutilized PGR with rich portfolio which could serve as vital source of robust adaption and resilient germplasm for vulnerable local communities in Nigeria. Its substantial nutritional, environmental, cultural, social, medicinal, industrial and soil restorative potentials underpins its position as climate – smart species. Enhancing the potentials of African yam bean via robust innovative approaches for wider utilization through accelerated research, farmer seed exchanges, in-situ and ex-situ conservations, farmers selection, and policy programs such as seed sovereignty will accentuate its adaptation and used as resilient climate –smart species for the vulnerable groups in Nigeria to cushion impact of climate change.

Keywords

African yam bean · Climate smart species · Adaptation climate change · Resilience · Conservation · Nigeria

Introduction

The Intergovernmental Panel on Climate Change (IPCC) reported that global warming of 1.5 °C and greater upsurge of 2 °C is projected for 2046–2065 and that these will have consequential impacts on food and water security, health, and other components of sustainable development, limiting strategies for adaptation, losses and damages to biodiversity and ecosystem services (IPCC 2018). All players are potential culprits to these increase, and accordingly need to undertake considerable behavioral changes to counteract this life threatening global warming, particularly in Sub-Saharan Africa. However, the above scenario is dependent on the level of anthropogenic activities on future greenhouse gas emissions (Pachauri and Meyer 2014).

Resilience is required within any systems to deal with climate stresses and disturbances and this include the willingness to change, skills to learn and capacity to adapt to such changes. It is therefore the zeal of managing changes and adaptations that can stand the test of current and future climate risks.

Population Increase and Challenges of Food Security

There has been a geometric increase in global population over the last 200 years and it is projected to continue to rise. United Nations forecast stated that due to exponential growth, that population will rise from the current 7 billion to reach 9.7 billion by 2050 and subsequently 10.9 billion by 2100 (Fig. 1). This brings with it a number of life threatening challenges, especially in the absence of adequate food production technology, integrated programs which simultaneously address those community needs for food and reproductive health and impact of climate variability and change (World Bank 2014). The consequential effects of this population increase will be greater in Sub-Saharan Africa due to many factors such as, higher fertility rate, demographically younger population entering childbearing life phase, joblessness and a more volatile employment market.

Rapid national population growth has induced and intensified major environmental changes in response to climate change and variability which have led to the emergence of novel pests and diseases, loss of crop genetic diversity and a decline in resources such as water (Dobermann and Nelson 2013). Despite these, current global food production rates being at there highest level, they still fail to match population demand. Given the predicted population increase, food production will need to increase to meet demand by between 59% and 98% by 2050 (Elferink and Schierhorn 2016). United Nations Food and Agriculture Organization (FAO 2010) estimated that about 795

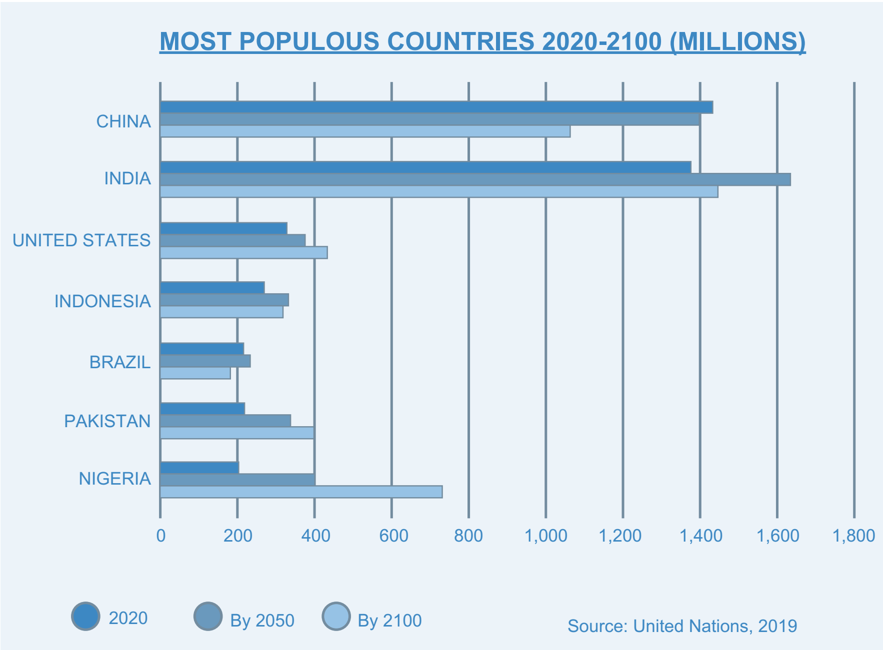

Fig. 1 Predicted population growth for 2020–2100

million people, of the current 7.3 billion population, suffered chronic malnourishment between 2014 and 2018 and majority of these people lived in developing countries. The Global Hunger Index (Grebmer et al. 2019) shows that multiple countries have higher hunger levels now than in 2010, and approximately 45 countries in current reality will not be able to achieve lower levels of hunger by 2030.

Poor monotonous diets, low in calorific quantity and quality with respect to nutritional level, variety and diversity are the primary cause for poor human health in many developing countries. Coincidentally, while the number of mouths to feed is increasing more rapidly than those farmers who are able to produce food. Hunger, malnutrition and famines and many endemic diseases, desertification, and floods continue to pose high risks in developing countries with low resilience which will be further exacerbated by climate change and climate variability aboard (Dobermann and Nelson 2013).

Nigeria ranks 93rd out of 117 qualifying countries with a score of 27.9, showing that its population is malnourished with high number of hungry people. This is an indication that out of the 162.5 million people, 1 in every 7 go to bed hungry (Grebmer et al. 2019). Mary Robinson, an Adjunct Professor of Climate Justice, Trinity College Dublin and former UN High Commissioner for Human Rights stated that “it is a terrible global indictment that after decades of sustained progress in reducing global hunger, climate change and conflict are now undermining food security in the world’s most vulnerable regions.” She concluded that with the number of hungry people rising from 785 million in 2015 to 822 million in 2018, “we can no longer afford to regard the 2030 Agenda and the Paris Climate Agreement as voluntary. This could be inferred from the level of changes over time in West Africa (Fig. 2). The above scenario needs vital actions and collective change of

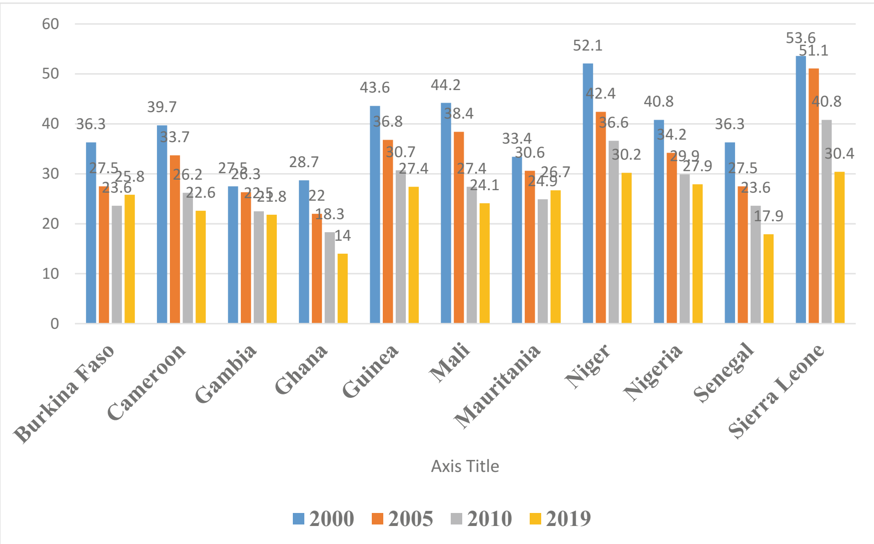

Fig. 2 West Africa Global Hunger Index scores, and changes over time. (Source: Grebmer et al. 2019)

attitude at both global and local levels in order to secure a habitable world for our forthcoming generations" (Grebmer et al. 2019).

Proffering Solution with Neglected and Underutilized Plant Genetic Resources

Plant genetic resources (PGR) are those varieties of heritable materials confined in traditional selections and modern domesticated cultivars together with their wild relatives and other wild plant species locally used as food, feed for domestic animals, fibre, clothing, medicine, shelter, wood, timber, energy and for recreational activities.

Neglected and underutilized plant genetic resources are domesticated and wild plants species which have been used for centuries as sources of food, fibre, fodder, oil, or have medicinal properties (stimulants, narcotics, aromatics), but their importance has remained unharnessed, abandoned, replaced with exotic foods or only very slowly now being considered for use. They are known by various names, including orphan, abandoned, lost, forgotten, neglected, underutilized, local, minor, poor man's food, traditional, alternative, niche, or underdeveloped plants (Padulosi 2017). Their underutilized potentials can be significantly exploited to combat climate change, as a future "smart crop" to improve food and nutrient insecurity. Here we adopt a progressive and positive approach to their potential exploitation as a source of "smart food," with an emphasis on their exploitation and/or development into viable future crops which are climate resilient. The Global Facilitation Unit for Underutilized Species (Bhat and Taiwo 2015) defines these species, as those with a potential not fully exploited; with respect to contributing to food security and poverty alleviation, combined with their strong links to local community cultural heritage. Their limited or poor documentation by research are evidenced by their adaptation to specific agro-ecological niches, a weak or non-existent seed supply systems, fully in the domains of traditional users only. They are produced with little, or no external inputs.

Our ancestors used over 7000 plant genetic resources (PGRs) as food, from which farmers produced about 70% of the global food supply (Bhat and Taiwo 2015). Currently, very few of these PGRs are still exploited in sustaining humans. Making food and nutrient security dependent on a handful of crops with 65% requirements for protein, calories and minerals met by wheat, rice, yam and cassava (FAO 2017). This shrinking portfolio of PGRs, shifts in life style, and the preference for fast foods are currently contributing factors involved in food and nutrient insecurity. These are reducing the capacity of farmers to adapt to changing markets, to innovate, to develop supply chains, and our ability to cope with climate change variability and its extremities (IPGRI 2003). Recognizing the considerable potentials which underutilized PGR can provide is crucial in finding solutions to the impacts of climate change on food and nutritional insecurity, genetic erosion, conservation of agro-biodiversity, green growth jobs and income generation (Padulosi et al. 2013; Nnamani 2015).

Nigeria as a nation holds a rich variety of PGRs linked to food, and other treasured traits. However, most of these species have received little, or no attention with respect to support for basic research, breeding improvement, commercial exploitation of germplasm selections, or consideration by policy itineraries to support enhanced utilization, thereby leaving them neglected. In order to meet food security challenges for a growing population under changing climate, it is necessary to identify and valorize these neglected and underutilized species (NUS) to develop greater resilience within local communities and the adaptation potential to increasing climate unpredictability and change.

African Yam Bean an Underutilized Plant Genetic Resources

Sphenostylis stenocarpa (Hochst. ex. A. Rich) Harms, customarily called African yam bean (AYB), is a legume of the subfamily Faboideae and family Fabaceae. *Sphenostylis* as a genus is represented by only 7 species (Potter and Doyle 1992). African yam bean is an orphan crop cultivated and utilized by local communities. It is a climbing annual, prostrate, or erect and approximately 1–3 m tall. The leaves are trifoliate, about 2.7–13 cm long and 0.2–5.5 cm broad. The inflorescence could be a raceme which shows an acropetal variety of flowering with pink colour intermingled with purple, twisted backward characteristics of the Fabaceae family (Fig. 3).

African Yam Bean is synonymous with African continent only, its geographical distribution is tolerated mainly within the soil, climate, and vegetation of Africa especially within the range of latitudes 15° North to 15° South and longitudes 15° West to 40° East (Adewale et al. 2008). The above geographical range could be referred to as the center of diversity of AYB (Fig. 3) since there is no record of the origin of the crop in any other continent beyond Africa (Potter and Doyle 1992). It is a crop of African origin, made for Africans and utilized as such in Africa, hence this

Fig. 3 Growth habit, floral and fruits features of African yam bean. (Photo © Adewale, B. D. and Nnamani, C. V.)

confirming the common claim that the crop is a tropical African legume. The rich hot spots of *S. stenocarpa* is found in Chad and Ethiopia in northeast tropical Africa, Kenya, Tanzania and Uganda for east tropical Africa, and in Burundi, Central African Republic and Zaire for west-central tropical Africa. It is also found in West Africa in places like Cote d'Ivoire, Ghana, Guinea, Mali, Niger, Nigeria and Togo while in south tropical Africa it is cultivated in Angola, Malawi, Zambia and Zimbabwe (USDA Agricultural Research Service 2015) (Fig. 4).

In South-east, Nigeria, the plant is diverse in distribution and geographical range thriving more in the derived savanna vegetation zone (Fig. 5).

Nutritional Potentials of African Yam Bean for Climate Change Adaptation

The seeds and tubers of AYB are highly rich in protein, minerals, and vitamin (Fig. 5). It is a promising source of plant protein for resource poor rural and semi-rural communities. The amino acid (lysine and methionine) has been reported to be higher than those of pigeon pea, cowpea, and bambara groundnut (Uguru and Madukaife 2001). Omeire (2012), noted that the amino acid (g 100^{-1} g) profile of AYB comprised of lysine (6.1), histidine (3.1), arginine (6.5), aspartic acid (9.1), glycine (3.9), alanine (4.1), valine (5.0), and phenylalanine (5.1) (Fig. 5). Its lysipne and methionine contents were similar or better than those of soybean protein (Yetunde et al. 2009) and comparable with whole chicken eggs (Ekpo 2006). The protein profile of the tubers compares favourably with that of other African root crops such as yams and sweet potatoes and has almost two and half times the protein value of cassava tubers (National Research Council 1979; Amoatey et al. 2000; Adewale and Aremu 2013) (Fig. 6).

African yam bean is cultivated for its edible seeds and tubers (Fig. 7), which have sustained indigenous community's livelihoods. A report of its medicinal value was reported in a traditional Igbo settings at Enugu State, Nigeria. The seed is an important ingredient utilized in the topical treatment of stroke, insomnia, diabetics, measles and stress. Extract of mashed AYB, after cooking, is used to induce lactation in mothers after child birth, while the fried seed coat is ground and used in the treatment of stroke (Nnamani et al. 2017). Culturally, it is used traditionally to entertain guests during traditional marriage ceremonies and serves as a famine food when every other crops have failed. Industrially, African yam bean flour is used to fortify conventional wheat flour which is frequently lower in protein content (Nnamani et al. 2017).

Nomenclatural Etymology of African Yam Bean to Climate Change

Sphenostylis stenocarpa is botanically synonyms in numerous literatures with *Sphenostylis ornata* A. Chev., *Sphenostylis congensis* A. Chev., *Dolichos stenocarpus* Hochst. ex. A. Rich., *Sphenostylis katangensis* (De Wild.) Harms, *Vigna katangensis* De Wild., and *Vigna ornata* Welw. ex. Baker. However, the

Fig. 4 Center of diversity of African Yam Bean in Africa. (Source: USDA Agricultural Research Service 2015)

current acceptable nomenclature is *Sphenostylis stenocarpa* (Hochst. ex. A. Rich) Harms (Adewale et al. 2012). Keay (1989) reported the followings common names as "Diegemtenguere" (Mali), "Girigiri" (Hausa, West Africa), "Norouko" and/or "Roya" (Sudan). Adewale and Odoh (2013) reported on some of the tribal synonyms of the crop in Nigeria: it is known as "Azama" (Ebonyi, State), "Akidi" or "Azima" or "Okpududu" (Ohafia, Abia State) and "Uzaaku" or "Ijiriji" (Nsukka, Enugu State)

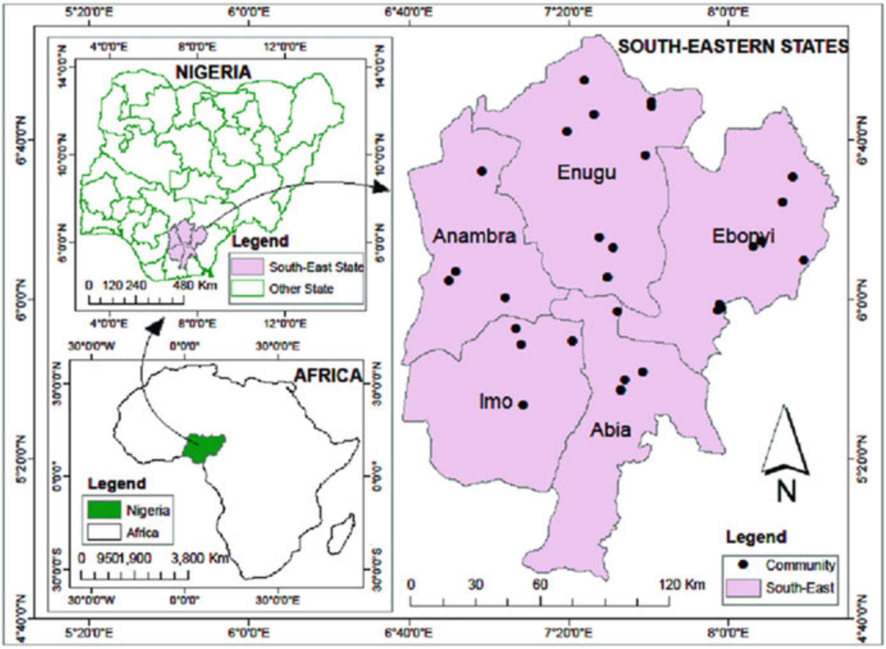

Fig. 5 Geographical distribution of African yam bean in south-east Nigeria. (Source: Nnamani et al. 2017)

in Igbo land; it is "Ewe" (Ijesha, Osun State), "Otiili" (Ekiti, Ekiti State),"Ekulu" (Ipe-Akoko, Ondo State), "Orogodo" (Owo, Ondo State), "Peu" (Ijebu, Ogun State) and "Sunmunu" (Iseyin, Oke-Ogun, Oyo State), Yoruba land. Some other tribal names for AYB in Nigeria are "Ihiehie" (Ishan, Edo State), "Iye" (Estako, LGA, Edo State),"Ahuma" (Tiv, Benue State), "Nsama" (Efik-Ibibio, Akwa Ibom) and Cross River State) (Adewale and Odoh 2013).

Al Azharia (2006) noted that throughout human history, folk nomenclature has been the underpinning factor for plant selection, improvement and conservation. It was and still is customarily for the local custodians to recognized species which have accomplished high serviceable and cultural values by custodians of such plants worldwide. When folk names given to species it often carries etymological meaning such as healing effects, morphological features, mythical connotations, adaptive strength, mitigating capability and allegorical values (Nnamani et al. 2019). Etymological data showed the AYB had sustained the lives of the local communities for ages. Indigenous lingual synonyms for AYB in Nigeria have etymological significances relating to how this crop had interfaced with the livelihood and environmental conditions of the local communities in different scenarios in the past (Table 1). These names often convey relationships to specific plant therapeutic effects, nutritional capacity, morphological features, mythological connotations, and ecological conditions playing out at a particular point in time in their environs (Leyew 2011; Rankoana 2012).

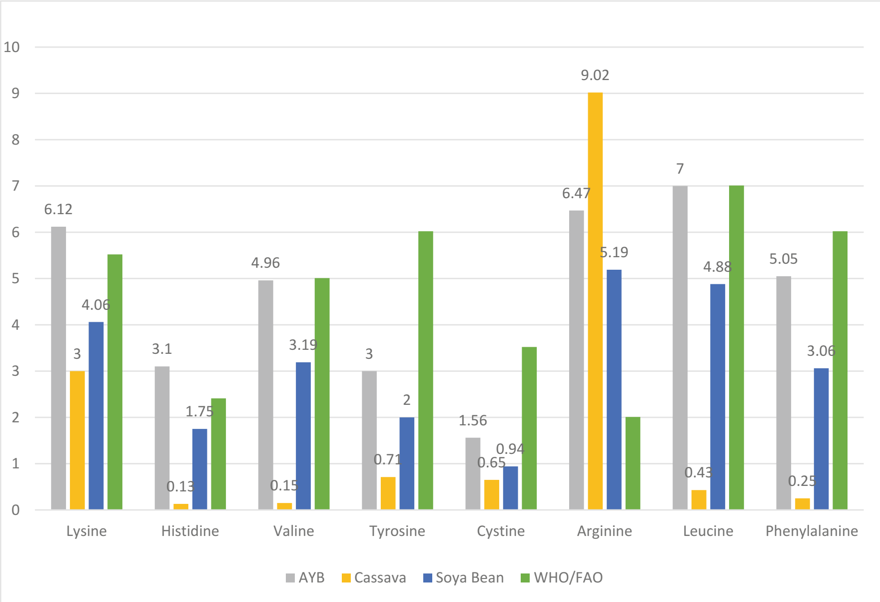

Fig. 6 Amino acid profile of African yam bean compared with other crops and WHO/FAO bench marks. (Source: Omeire 2012)

Fig. 7 Seeds and tuber of African yam bean. (Photo © Nnamani, C. V. and Adewale, B. D.)

African Yam Bean, the Choice for Climate Change Resilience

"Neglected and Underutilized species (NUS)" are plant species which are sidelined, ignored or completely underexploited, by researchers, breeders and policy makers. They have great prospects to improve people's livelihoods, guaranteeing food security and self-sufficiency to the users. Their environmental restoration ability are not yet fully appreciated due to their limited competitiveness with fundamental

Table 1 Etymology of African yam bean in South-east, Nigerian

S/ no.	Ethnic group	Name	Meaning	Etymological facts
1	Izzi	Azama	Feeder of people in hard times (mitigating food)	They believed that God had answered their prayer by giving them this crop to feed them when other crops have failed in the land
2	Ezza	Azama	Healing food for the people (medicine)	In the past when kwashiorkor (malnutrition/hidden hunger was the major problem facing the people of Ezza, boiling the crop, eating AYB and the use of water from the cooked seeds to bath provides healing
3	Ikwo	Azaaki	Multiple seed-food provider (resilient seed)	They named AYB Azaaki because of the multiple food types it provides, which help poor farmers when they cultivate the crop. They believe that cultivating AYB is a way of avoiding hunger
4	Ngbo	Azaakuru	Plant small and harvest plenty (dominating and climate–smart crop)	Aza-akuru because, it is a passive crop but when planted, it will dominate the whole farm and yield lots of food types both seed and the tuberous root. A dominating crop that God gave to help poor farmers during famine
5	Ntezi and okpoto	Etiti	"Subduer of hunger" (the central hungry killer)	They believed that God has given them the crop to feed them during a time of famine. AYB is the only crop that can feed people even when the quantity is small
6	Afikpo	Azuma	Food server God and medicine	They name this crop Azuma because of its great feeding capacity and its ability to stop some illness, e.g., stomach disorder. They believed that God answered their prayer in times past
7	Ohozara	Aza-ama	Dominating food crop God and medicine	Prayer answered by God for the crop provides food even when other crops have failed. It yields great food for the poor. When the poor cannot cultivate other crops as a result of environmental changes

(continued)

Table 1 (continued)

S/ no.	Ethnic group	Name	Meaning	Etymological facts
8	Nkalagu	Azaku	Food helper of the poor	They called it "Azaku" because of the role it played during famine in times past. They believed that God provided it to help the poor through its simplicity in cultivation and survival
9	Ohafia-Agba	Azama	Feeder of people Adaptation to climate change	They believed that the God of harvest has provided this crop to sustain his people when other crops do not perform very well on the farm. AYB can compete in and adapt to many difficult environments
10	Agba, Nkalegu and Igboasa	Eriwa	Minor crop that feeds many people Gender	It's a women's crop that helps to sustain the women's little income when the major crops (the men's crops like yam, rice and cassava) are finished in the bans, particularly after planting. AYB is usually intercropped with other crops by women hence it is termed women's crop
11	Ezza and Ikwo	Onyiaoduru	Sustainer and friend of the farmer Sustainer	Respondents believe that after eating AYB, the consumer keeps drinking water through the day and it gives sufficient energy to work without getting exhausted
12	Ngbo and Izzi	Mgbadumue	Saving seed Seed	When labourers are hired to work on farms. They eat the food in the morning and it will keep them active until evening

Source: Nnamani et al. (2019)

crops in conventional use. Although their potential may not be fully realized at national or international levels, they are of significant importance locally, because of their high adaptation capacity to marginal, complex, and difficult environments contributing significantly to diversification and resilience of agroecosystems (Padulosi et al. 2011).

Shyam et al. (2014) stated that climate modeling is the commonest approach used today for predicting the responses of species to climate change. Species which have resilience biotic characteristics are often informative when used in climate modelling and underutilized plants frequently have an array of stress resistance traits. They are of significant importance locally, highly adaptable to marginal soil, complex and changing environments and agriculturally degraded land. They are hubs contributing meaningfully to diversification and resilience to community agro ecosystems, this is because of their long-standing use with little, or no, conventional breeding improvement. As orphan crops, notwithstanding their intrinsic low-yield potential, they still have the capacity of resisting climate stresses, having been selected and exploited in local climate stress adaptation within the local communities for generations. In this regard, underutilized PGR could contribute to further building of community resilience over the long-term in response to impending climate change adaptation after effective valorization of a PGR's potential (Mabhaudhi et al. 2019).

African yam bean usefulness as a climate smart species for communities to achieve resilience to climate stresses is based on its ability to survive and even thrive (reliable yield annularly) in marginal soils and environments where other crops fail in the absence of often unavailable resources, such as nitrogen fertilization and adequate irrigation. AYB, as a legume, improves soil quality and function through its beneficial effects on soil biological, chemical and physical attributes. Such benefits include enabling improvements in crop N-supply, increasing soil organic matter reserves, stimulating soil microbial diversity and activity, and improvements in soil structure, reducing soil erosion while increasing soil aeration and enhanced soil water-holding capacity. AYB is suitable for wide climatic conditions (Anochili 1984; Betsche et al. 2005) and nitrogen fixation (Oganale 2009; Tettey 2014). Ojuederie and Balogun (2019) obtained better tuber production from genotypes in a year with lower rainfall and sunshine hours. This is a display of smart features.

Policy and Conservation African Yam Bean

Intergovernmental Panel on Climate Change (IPCC 2018) reported the likely consequences of rapid global climatic change on species and their habitats. Such changes could cause a shift in the conservation status of so many species, pushing some towards the red line list of International Union for Conservation of Nature (IUCN). African yam bean has not received much conservation attention to date. Currently, much of its germplasm is in the hands of the local custodians as landraces (Nnamani et al. 2018), while the Genetic Resources Centre at the International Institute of Tropical Agriculture (IITA), Ibadan, Nigeria also hold some quantity of AYB germplasm. The disadvantages of poor conservation technology include the limited access to germplasm by researchers, breeders and farmers, the vulnerability of AYB to natural disasters, genetic erosion and loss of crop diversity are there.

Enhancing the potentials of African yam bean by policy via robust innovative approaches for wider utilization through accelerated research, farmer seed exchanges, in-situ and ex-situ conservations, farmers selection, and policy programs such as seed sovereignty will accentuate its adaptation and used as resilient climate – smart species for the vulnerable groups in Nigeria to cushion the impact of climate change.

These species may be conserved in-situ or ex-situ for future generations. On-farm (in-situ) techniques have several advantages compared with ex situ conservation, as the former allows for evolution of traits through continued natural and human-driven selections, which will contribute to greater crop adaptation and resilience to abiotic climate stress (Padulosi 2017).

Through the recognition of its promising nutritional potentials, policy could be synchronized in the conservation, promotion, marketing network and utilization of AYB by mainstreaming it into various dietary menus and products to include a range of food products appropriate for a broad range of consumption opportunities. This should include a rebranding of its nomenclature from "poor man's food" to a more widely acceptable range of producers, retailers and consumers. Decision makers could equally support the development of value chains, scale up development collaborations and information sharing of AYB among researchers, conservationists, breeders, extension workers, farmers, farmer organizations, vendors and NGOs.

Finally, there is need for policy to intensify efforts to support research on the conservation of *S. stenocarpa* through participatory engagement between the species custodians of the species for both in situ and ex situ conservation approaches. Globally the exploitation and development of legumes, which are climate resilient, will provide a significant opportunity for improving human health through integration into food-systems as a replacement, or partial replacement, of current animal sourced proteins. A programmed germplasm conservation approach is needed to collect, characterize, develop and exploit existing diversity in the provision of food, feed, nutritional security and environmental resilience.

Conclusions

Convincingly, recognizing the potential of AYB as an excellent climate smart species through active food governance policy would initiate novel business opportunities by changing the narrative via:

(i) Scaling up programs on the use of African yam bean in its various dietary forms and consumptions routes. This could rebrand the nomenclature of the species from "poor man's food" to an added value nomenclature (high protein source).
(ii) Organizing regular retailer food fairs to showcase various dietary menus accruing from AYB will encourage its selection and consumption by the publics.
(iii) Support the development of value chains and market networks for small agribusinesses for priority crops such as AYB.
(iv) Provide credit facilities and farmer/user-friendly technologies to the crop custodians to accelerate production.
(v) Promote the use of AYB through directed awareness campaigns on the nutritional benefits of the crop.
(vi) Exploit the offsetting potential AYB consumption of added value of this nutritious crop against the probable reduction in government health budget associated with alleviating malnutrition and it related conditions.

(vii) Including policy programs that enhance the selection of quality AYB seed available to farmers, with respect to climate resilience.
(viii) AYB will require more attention firstly, research-based, then technological germplasm development and subsequently supporting exploitation policy and markets. This will direct and facilitate appropriate solutions to major constraints for greater AYB cultivation and utilization.
(ix) Scaling up development via policy programs has the prospect of empowering resource poor communities who are predominantly women and the unemployed.
(x) Promote direct and appropriate consumer lead engagement and communication between knowledge acquirers and exploiters to drive AYB germplasm conservation.
(xi) Innovative biotechnological tools should be used to catalyze transformative change in AYB to promote its selection as a major staple food through a broad food product base.

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