HARNESSING THE POTENTIAL OF PLANT BREEDING TOWARDS SUSTAINABLE DEVELOPMENT GOALS IN NIGERIA

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Abstract

Research in conventional plant breeding and other emerging areas such as biotechnology develop new improved varieties that can deliver higher on-farm yields. Climate change and food security are a subject of global concern. Food security challenges can best be addressed through a new form of international collaboration and a coherent policy framework that stimulates innovation and puts the right technology in the hands of end-users (growers, processors and consumers). The Sustainable Development Goals (SDGs), among other frameworks, call at different levels, national, regional and global, for agricultural action that systematically address poverty (SDG 1), and translate to a sustainable reduction of hunger and malnutrition (SDG 2), good health and wellbeing (SDG 3), professional training of plant breeders (SDG 4), gender equality and empower women farmers (SDG 5), affordable renewable energy through bio-fuel varieties (SDG 7), decent work and economic growth (SDG 8), promote sustainable agro-based industrialization and foster innovation (SDG 9), reduce inequality within and among countries through agriculture (SDG 10), make cities and human settlements inclusive, safe, resilient and sustainable through food self-sufficiency (SDG 11), responsible consumption and production (halve per capita global food waste at the retail and consumer levels and reduce food losses along production and supply chains, including post-harvest losses) (SDG 12), development of climate resilient varieties (SDG 13), life below water to protect marine and coastal plants ecosystems, strengthen their resilience, and take action for their restoration in order to achieve healthy and productive oceans through plant breeding (SDG 14), Life on land to promote fair and equitable sharing of the benefits arising from the utilization of plant genetic resources (SDG 15), through partnerships (SDG 17), resulting in peace, justice and strong institutions (SDG 16). Attainment of SDGs requires a regional or sub-regional intervention strategy, hence involvement of Forum for Agricultural Research for Africa (FARA), International Fund for Agricultural Development (IFAD), Economic Community of West African States (ECOWAS), and West and Central Africa Council for Agricultural Research and Development (CORAF), for example. Development of new crop varieties is necessary for attainment of food security. Agriculture has been closely linked to economic development of Nigeria and many African countries. Plants are grown for many reasons including food and industrial applications such as biofuel production. The National Agricultural Research System (NARS) plant scientists have developed and released different crop varieties suitable for production in the different agro-ecological zones of Nigeria. Advances of plant breeding have delivered up to 90% of increase in crop yields. Increased crop yield leads to significant reduction in number of people below the poverty line. The improved varieties have major impact on poverty reduction through direct effects on producer incomes, indirect effects on consumer welfare through increase in quality food availability, accessibility and affordability, and employment and wage effects throughout the economy. The crop varieties developed include early and medium maturing, drought tolerant to mitigate the effects of global warming and tolerant to abiotic and biotic stresses such as Striga, the obnoxious witch weed, which have devastating effects on cereals and legumes. Plant breeding output should be climate smart, gender and nutritive sensitive with good environmental adaptation ready for adoption by producers and end users. Quality protein maize, pro-vitamin A cassava and maize, nutrient dense sorghum, etc., contribute significantly to nutrition security and improved health. Substantial and sustainable reduction in malnutrition will remain a significant challenge without effective engagement of plant breeding. There is therefore need to improve plant breeding research budget in the NARS to accelerate the attainment of the SDGs. Harnessing Plant breeding potential has a unique role to play in attaining the SDGs because it is the source of food, it also affects the

income of the majority of people. For rapid attainment of SDGs to take place, local inputs such as technology generated on a continuous basis through plant breeding activities, among others, must be ensured and be made to serve as catalysts. Research on genetically engineered crops can produce a wide range of drugs, vaccines, and other pharmaceutical proteins at cheaper rates. Nigeria is endowed with abundant human and natural resources. If properly harnessed, and judiciously utilized in a spirit of multidisciplinary teamwork, these resources will enable Nigeria to attain some of the SDG targets.

Introduction

Food security challenges can only be addressed through a new form of transnational collaboration and a coherent policy framework that stimulates invention and puts the right technology in the hands of farmers worldwide (Anon., 2009). Agricultural research technologies' impact on Nigeria has been profound and no way more so than today. The success of Sasakawa Global 2000 is a typical illustration because it was absolutely based on the extension of our technologies. The ability of plant breeding to contribute to food security, wealth generation, and economic development makes it a national priority (Ado, 2009b). One critical constraint in sustainable food production is the availability of improved seeds and seedlings. Without good quality seed, any investment in crop production will not reap the required dividend (Ado, 2009b).

Food and nutrition security is one of the biggest burning challenges for sustainable social and economic development in Nigeria. Meeting this need is an important opportunity for the Sustainable Development Goals (SDGs). Improved diets among families contribute to improved health and productivity of farmers and consumers. In Africa, besides CORAF, there is a consortium of actors who have been mobilized to implement the SDGs across the continent. This includes the Forum for Agricultural Research in Africa (FARA), the African Forum for Agricultural Advisory Services (AFAAS), the Association for Strengthening Agricultural Research in Eastern and Central Africa (ASARECA), and the Centre for Coordination of Agricultural Research and Development Eastern and Southern Africa (CCARDESA). West and Central African countries face numerous common and shared problems that the SDGs cannot be effectively attained by any individual country alone and thus require regional solutions (Binswanger-Mkhize and McCalla, 2009). It is time for WCA to feed itself. However, the challenge is that WCA countries have been unfit to feed their growing population owing to low agricultural productivity and the effects of agricultural disruptors, such as climate change, insecurity, and the COVID-19 pandemic. Attainment of SDGs requires a regional intervention strategy, hence, the West and Central Africa (WCA) Council for Agricultural Research and Development (CORAF) was established in 1987 to "improve livelihoods in West and Central Africa through sustainable increases in agricultural production and productivity, as well as to promote competitiveness and access to markets". CORAF's main objective is to work towards solving the critical problems of food and nutrition insecurity, chronic poverty, and youth unemployment, which are parts of the SDGs. The CORAF's Agricultural Innovations and Technologies Market (MITA) mechanism, within the framework of the implementation of the West Africa Agricultural Productivity Programme (WAPP) over the 2007 – 2019 period, has enabled more than a hundred technologies to cross the borders of WCA countries (http://mita.corsf.org/). CORAF leads Component 2: Sustainability and adaptive capacity of the food systems productive base of the Food System Resilience Programme (FSRP) which is a flagship regional intervention programme aimed at building food system resilience in WCA through a strategic regional approach. CORAF has therefore been promoting agricultural research innovation systems and food systems transformation approaches to promote sub-regional food and nutrition security, wealth creation, and natural resource management (CORAF, 2019). More than 50% of foods consumed in households, including agricultural households, are procured. With Nigeria's population increasing at an intimidating rate of 3.2% per annum, food availability, accessibility, and utilization must constantly be increased to prevent food insecurity

(SDG 2) (Global Foods Security Index, 2014). Small-scale seed enterprises are now emerging and providing quality seeds (products of plant breeding) to farmers across Nigeria and other countries of West and Central Africa. Nigeria accounts for 60 percent of the total seeds retailed in West Africa. If a researcher develops a new variety in any ecological zone, this variety if released in one Member State, can be multiplied and sold in another one. So, there is a mechanism that brings all the advantages of working together in the same community.

Increasing agricultural productivity requires strong scientific intervention (Agyeman and Mbuya, 2022). Science and research have delivered ground-breaking innovations in agriculture, but to face the challenges ahead, science must make sense to all by better connecting global science with the SDGs dockets. Fundamental research in plant breeding, biotechnology, biosafety and other emerging areas will help to develop the technologies that can deliver higher on-farm yields (Pan Africa Chemistry Network, 2012). Increasing agricultural productivity requires investment in multidisciplinary research, including the infrastructure to support this research. Success in agriculture will, therefore, depend on building scientific capacity at the national agricultural research institutes (NARIs). The generation of new technology is better done on a regional or sub-regional basis because WCA has so many small and poor countries, which need to be supported to provide transformative agricultural research solutions within their respective countries (Agyeman and Mbuya, 2022). In addition, about 70 percent of the population in the region depends on agriculture, primarily smallholder agriculture, for their livelihoods. The population is also predominantly young, with more than 64 percent under the age of 24 representing a potentially tremendous resource for the region if supported by the right investments (UNFPA, 2018). It is anticipated that by 2025, WCA will not only have the largest number of young people globally but will also be the only sub-region of the world where the population of young people will continue to grow (IFAD, 2019). Youth unemployment in WCA is among the loftiest in sub-Saharan Africa (SSA) and the world. Only about one-third of females and two-thirds of males aged between 15 and 24 in WCA are employed. Millions in the sub-region remain trapped in child labour, working primarily as farmhands, hawkers, bonded domestic servants, and slaves (lzugbara *et al.*, 2017). The incidence of poverty is approximately 75 percent in rural areas, widespread and concentrated among women and young people. Across the WCA sub-region, more than 58 million people were facing severe food insecurity. More than 70 percent of the population in the region lives in cities, a number that is expected to continue to rise in the coming decades.

Agriculture is important to the West and Central African economy, furnishing income and livelihoods for 70-80 percent of the population (Toulmin and Gueye, 2003). Most farms in the WCA sub-region are small, typically 1 to 5 hectares. Although the small size of farms reflects a scarcity of land in heavily populated areas, as in parts of Nigeria, it is also a result of the limited technology available to rural households (Stock, 2012). Agriculture accounts for 65 percent of employment and 35 percent of the gross domestic product (GDP) of WCA. The incidence of poverty is approximately 75 percent in rural areas, out of a total impoverished population of about 120 million persons (IFAD, 2001). In 2021, flooding affected over 1.2 million people in 13 countries of the WCA region. Heavy rains and floods take a heavy toll on mortal life, property, land, and livestock (Agyeman and Mbuya, 2022). Addressing the concerns of the people of Regional Economic Organizations (REO) such as the Economic Community of West African States (ECOWAS) in the West Africa Sub-region is necessary for sustainable food security in Nigeria. Ensuring sustainable livelihoods of neighboring countries which face food instability requires a comprehensive approach. This must include a judicious mix of adequate policies and institutions enabling the greater involvement of civil society and the development of a dynamic private sector (Ado *et al*., 2009). With a strong regional convening advantage, the development and implementation of high quality agricultural research solutions, starting with plant breeding, and cutting edge technologies from university laboratories and research labs of NARS and international research partners can help transform the food systems and agricultural economies of WCA (Agyeman and Mbuya, 2022). The paper is presented to the Plant Breeders Association of

Nigeria (PBAN) delegates as an overview of how Plant Breeding output contributes to attaining the SDGs targets particularly food and nutrition security, poverty reduction, economic growth, health and wellbeing, biofuel production, etc.

Sustainable Development Goals (SDGs)

The 2030 Agenda is a major milestone in sustainable development. Beginning in 2016, it sets the globally applicable framework for national and international efforts to find shared solutions to the world's topmost challenges, such as extreme poverty, climate change, environmental degradation, and health-related crises. The 2030 Agenda applies to all states, whether north or south of the equator and determines international guidelines and priorities for sustainable development up to 2030. It is intended to help strengthen economic growth, promote human welfare, and protect the environment. It also takes up aspects such as peace, the rule of law, and good governance, which are all essential to sustainable development. At the heart of the 2030 Agenda are the 17 Sustainable Development Goals (SDGs), and their 169 targets. They balance the economic, social, and ecological dimensions of sustainable development, and place the fight against poverty and sustainable development on the same agenda for the first time. The SDGs are to be achieved around the world, and by all United Nations member states, by 2030. This means that all states are called upon equally to play their part in finding shared solutions to the world's urgent challenges. In addition, incentives are to be created to encourage non-governmental actors to make an increasingly active contribution to sustainable development.

Overview of the 17 Sustainable Development Goals (SDGs) (UNDP, 2023; SDGs. https://www.globalgoals.org/goals/)**:**

1. End poverty in all its forms everywhere
2. End hunger, achieve food security and improved nutrition and promote sustainable agriculture
3. Ensure healthy lives and promote well-being for all at all ages
4. Ensure inclusive and equitable quality education and promote lifelong learning opportunities for all
5. Achieve gender equality and empower all women and girls
6. Ensure availability and sustainable management of water and sanitation for all
7. Ensure access to affordable, reliable, sustainable and modern energy for all
8. Promote sustained, inclusive and sustainable economic growth, full and productive employment and decent work for all
9. Build resilient infrastructure, promote inclusive and sustainable industrialization and foster innovation
10. Reduce inequality within and among countries
11. Make cities and human settlements inclusive, safe, resilient and sustainable
12. Ensure sustainable consumption and production patterns
13. Take urgent action to combat climate change and its impacts
14. Conserve and sustainably use the oceans, seas and marine resources for sustainable development
15. Protect, restore and promote sustainable use of terrestrial ecosystems, sustainably manage forests, combat desertification, and halt and reverse land degradation and halt biodiversity loss
16. Promote peaceful and inclusive societies for sustainable development, provide access to justice for all and build effective, accountable and inclusive institutions at all levels
17. Strengthen the means of implementation and revitalize the global partnership for sustainable development

From the above 17 SDGs, there are many agricultural elements, particularly those concerning plant breeding, in the targets. Malnutrition in all its forms – under nutrition, micronutrient deficiencies, and over nutrition – remain a significant development challenge in Nigeria (The Federal Republic of Nigeria, 2019). Recognising nutrition as a multi-sectoral issue that must be simultaneously addressed by multiple sectors, plant breeding in particular, is very crucial for the attainment of the key national, regional, and global food and nutrition objectives. The Comprehensive African Agricultural Development Programme (CAADP), the Malabo Declaration, and the Sustainable Development Goals, among other frameworks, call at various levels – national, regional and global – for agricultural action that systematically address poverty (SDG 1), and translate to a sustainable reduction of hunger and malnutrition (SDG 2), good health and wellbeing (SDG 3), professional training of plant breeders (SDG 4), gender equality and empower women farmers (SDG 5), affordable renewable energy through biofuel varieties (SDG 7), decent work and economic growth (SDG 8), promote sustainable agro-based industrialization and foster innovation (SDG 9), reduce inequality within and among countries through agriculture (SDG 10), make cities and human settlements inclusive, safe, resilient and sustainable through food self-sufficiency (SDG 11), responsible consumption and production (halve per capita global food waste at the retail and consumer levels and reduce food losses along production and supply chains, including post-harvest losses) (SDG 12), development of climate resilient varieties (SDG 13), life below water (protect marine and coastal plants ecosystems to avoid significant adverse impacts, by strengthening their resilience, and take action for their restoration in order to achieve healthy and productive oceans) (SDG 14), Life on land (promote fair and equitable sharing of the benefits arising from the utilization of genetic resources and promote appropriate access to such resource) (SDG 15), through partnerships (SDG 17), resulting in peace, justice and goal of plant breeding in relation to SDGs is to contribute to the implementation of Agenda 2030, particularly goals 2 (zero hunger), goal 5 (gender equality), goal 10 (reduce inequality), goal 12 (responsible consumption) and goal 13 (fight climate change) as well as 2063 Agenda of the African Union and the Maputo Declaration (NEPAD, 2003; UNDP, 2023). Partner innovation platforms can be set up to discuss concept of contract farming. This allows plant breeders, industries and small farmers to work together, agree on the product and have specifications on what they want. The breeder develops the ideotype of the variety desired of such quality for the industry, thus, reassures the farmer of market.

Role of Plant Breeding

Plant breeding is the science and art of changing plants genetically. It strengthens the management of risk inherent in food production, improve the sustainability of the production base in targeted areas. It contributes to resilience of food systems. Plant breeding has great potential to reduce poverty (SDG 1), improve availability and accessibility to diverse food (SDG 2), create jobs (SDG 8), good health (SDG 3), affordable clean energy through biofuel (SDG 7), economic development (SDG 8), climate smart varieties (SDG 13), life under water (SDG 14), life on land (SDG 15), partnerships for the goals (SDG 17), leading to peace, justice, and strong institutions (SDG 16). Nigeria has committed to CAADP Framework, ECOWAS Zero Hunger Initiative, Malabo Declaration, International Conference on Nutrition (ICN2), commitments and the SDGs (The Federal Republic of Nigeria, 2019). Plant breeding produces improved crop varieties with increased nutrient content, decreased anti-nutrients, increased ease of preparation and improved food safety (Global Food Security Index, 2014), among others.

Breeding new crops is important for ensuring food security and for developing sustainable agriculture by developing crops that minimize agriculture's impact on the environment. Food security is defined as the availability and the access of food to all people; whereas nutrition security demands the intake of a wide range of foods which provides the essential needed nutrients. Plant breeding links agriculture, livelihoods, and health. Intensification of agriculture

often called Green Revolution was closely tied to progress made in selecting and improving crops and animals for high productivity (Ado, 2009a). Plant breeding has greatly increased the yields of important staple food crops and for many people, this has meant more food availability and trade opportunities. Improved varieties have the largest effect as yields can be more than double those of traditional varieties. Plant breeding can help palliate poverty in many ways. Farm households that adopt improved varieties can benefit directly from higher yields and incomes. The indirect impacts of plant breeding such as cheaper food and more jobs can also improve the living standards of the wider population.

How does plant breeding research translate into reductions in poverty and food security? The most important pathway was increased agricultural productivity which leads to direct on farm benefits. However, it also contributes to lower food prices, higher wages and greater employment in rural labour markets both agricultural and non-agricultural. As an added benefit, cheaper food also reduces urban poverty as the civic poor spend nearly half their income on food.

Plant breeding research capacity is an important factor in building food security and economic stability. Furthermore, new and better targeted technologies are essential to this process and a well-developed and well supported agricultural research system is a prerequisite not only for the design of these technologies but also for their dissemination and adoption. The overall benefits of plant breeding include food security, improved productivity, marketing and processing, efficient land and water use, increased animal production and fish catches, improved nutrition, reduction in post-harvest losses and value addition, and diversification of production leading to improved livelihood (Ado *et al*., 2009). An estimated 80 percent of the increase in global food production must come from growth in crop yields. To this, the new demands for food stock for an expanding bioenergy sector should be added (Ado *et al*., 2009). Substantial and sustainable reduction in malnutrition will remain a significant challenge without effective engagement of plant breeding. With at least 5% of the global burden of under nutrition in Nigeria, and more than 14 million malnourished children, addressing malnutrition is indispensable for economic and social development. Nutritive sensitive intervention in agriculture, social protection, and education are required. Causes of malnutrition include poverty, food insecurity, inadequate health services and care giving, and poor sanitation and hygiene. Food security is more than producing enough of the major commodities. Food security should enable populations to have a diverse diet that provides all essential nutrients. Full human cognitive and physical development are a result of a balanced diet that supplies adequate energy, protein, micronutrients and other essential elements.

Plant breeding solves the problem of challenges that exist in the seed sector. It is very important to engage the private sector in this process because they are the ones who will challenge the breeders and they are the first beneficiaries. Plant breeding intervention can reach the poor who are most at risk of hunger and malnutrition. Plant breeding has a unique role to play in harnessing the SDGs because it is the source of food, it also affects the income of the majority of people. It can influence food prices as well as women's control over resources. Focused training on linking plant breeding with nutrition is a necessary component of the efforts to improve food and nutrition security in Nigeria to attain the SDGs. Plant breeding develops low cost interventions to increase access to and consumption of affordable nutritious diets. Malnutrition does not result just from a lack of food. Other contributing factors include health care practices, and education. However, food choices from plant breeding products determine diet quality which is crucial to good nutrition. The food choices are framed by the local context of food availability, accessibility, affordability, and appeal (The Federal Republic of Nigeria, 2019). In view of the fleetly growing global demand for food, it is estimated that food production worldwide will need to have doubled by 2050. By 2030, halve per capita global food waste at the retail and consumer levels and reduce food losses along production and supply chains, including post-harvest losses. To develop improved crop varieties, the federal and state governments should increase their support (funding, research infrastructure development) for plant breeders for developing high

yielding and early maturing crop varieties and for research in developing water, heat/drought tolerant and pest and disease resistant crop varieties. Farmer perspectives should be integrated in such schemes and farmers supported to access the improved seeds (Shehu *et al.,* 2022). Plant breeding develops crop varieties that are adapted to changing climatic conditions. Plant and animal biodiversity increase resilience to changing environmental conditions and stress (drought, salinity, flooding, etc.). Plant breeding enable crop production in more extreme climates resulting from climate change and water scarcity. The possibility of maintaining genetic purity and mass production of seedling through *in vitro* propagation should be explored (Ado and Abubakar, 2008).

Achievements of Plant Breeding for SDGs

Provision of adequate food supply to satisfy the needs of the whole population has always been one the pressing needs of every country (Shehu *et al.*, 2022). Plant breeding can address SDGs through improved livelihoods and interventions with income generating activities for at risk groups by making nutritious foods more accessible (available and affordable), more nutrient-dense, and acceptable culturally. Plant breeding can result in increase in access to healthy diets as well as increase resilience of vulnerable households to economic and climate change related shocks. The goals of gender equality (SDG 5), Climate Change (SDG 13), partnerships (SDG 17), have large and unrealized synergies. Agriculture is a focal point for Action for Climate Empowerment to support provision of climate change mitigation varieties such as extra-early and drought tolerant crop varieties. Gender is a cross-cutting priority in all multi-stakeholder partnerships. Agricultural growth in the WCA region has been driven largely by area expansion. Nonetheless, during the period (2008-2012), there were modest increases in sub-regional-wide yields, particularly for cereals and root and tuber crops (Table 1).

Table 1. Average yields (kg/ha) for selected commodities in West Africa (1990-2021)

Commodity	1990-1999	2000-2009	2008-2012	2013-2018	2019-2022
CEREALS					
Wheat	1,902	1,359	1,699	1,499	1,457
Paddy Rice	1,640	1,672	2,009	1,850	1,919
Maize	1,258	1,556	1,715	1,644	1,712
Millet	700	845	736	675	723
Sorghum	838	938	980	931	964
OTHER CROPS					
Yams	10,593	10,543	11,277	8,556	8,447
Cassava	10,023	10,653	12,338	9,539	9,029

Source:https://www.fao.org/faostat/en/#data

Increases of up to 3-5t/ha for maize, 1-5t/ha for sorghum and millet, 3t/ha for wheat and 2-5t/ha for rice have been recorded using improved germplasm and other technologies. In the semi-arid zone, a number of short cycle improved maize, sorghum, millet and cowpea varieties have been released and are adopted by farmers. Sustainable improvements in agricultural system productivity depends on improved capacity to overcome biotic and abiotic stresses such as desert encroachment, excess moisture, acid soils, poverty and socio-political problems (Ado, 1998, 2008a,b). Over the last few decades there has been a remarkable increase in the productivity of field crops much of it due directly to the accomplishment of the plant breeder (Ado, 1996). The slight reductions in average yields observed in Table 1 for wheat, yams, and cassava during 2019-2022 were mainly owing to unfavourable environment and not the genotypes.

A summary of catalogue of crop varieties released and registered in Nigeria as at April, 2022 is given in Table 2. The crops include early and extra-early, *Striga* resistant, Nitrogen use efficient varieties, tolerant to drought, resistant to insects, viruses and fungi, improved limited amino acids levels, high beta-carotene content, etc. Since the inauguration of the National Committee on registration and release of crop varieties, livestock breeds and fisheries in 1989, a total of 711 improved crop varieties had been developed and released by NARS from 42 crop species (Anon., 2022). Some of the varieties had been developed in collaboration with registered national and international seed companies, International Crops Research Institute for the Semi-Arid Tropics (ICRISAT), International Centre for Maize and Wheat (CIMMYT) Mexico, and International Institute of Tropical Agriculture (IITA) Ibadan. The varieties released are high yielding, resistant to abiotic and biotic stresses and have improved nutritional quality. *Striga,* maruca and stem borer resistant varieties stabilize yields in spite of the presence of the biotic stresses. Early and extra early varieties escape drought and can be produced twice per season if the rainy period is extended. They are also suitable for late planting. Others tolerate drought so that acceptable yields are obtained under drought stress and higher yields if there are no drought. Others such as quality protein maize (QPM) have enhanced nutritional quality which reduces nutrient deficiency diseases especially among vulnerable groups, babies and lactating mothers (Ado, 2012). The nutritional benefits of QPM were expressed in terms of the efficiency of feeding people prone to malnutrition (Ado, *et al.,* 2008). Incremental yield gains lead to higher economic benefits, household food security and smoothening seasonal availability.

Table 2. Summary of Catalogue of crop varieties released and registered in Nigeria

S/No.	Crop	Botanical name	No. of varieties
1	Cassava	*Manihot esculenta* Crantz.	54
2	Castor	*Ricinus communis*	2
3	Cotton	*Gossypium spp.*	17
4	Cowpea	*Vigna unguiculata*	43
5	Soy bean	*Glycine max* L. Merr.	26
6	Forage legumes	*Centrosema spp., Chamaecrista spp., Aeschynomeme spp., Stylosanthes spp.*	9
7	Groundnut	*Arachis hypogaea* L.	29
8	Maize	*Zea mays* L.	183
9	Pearl millet	*Pennisetum glaucum* Burm. Stapf & Hubbard	12
10	Rice	*Oryza sativa*	75
11	Rubber	*Hevea brasiliensis*	14
12	Sesame	*Sesamum indicum* L.	5
13	Sorghum	*Sorghum bicolor* L. Moench	56
14	Sugar cane	*Saccharum officinarum* L.	21
15	Tomato	*Lycopersicon esculentum* Mill.	17
16	Wheat	*Triticum aestivum* L.	18
17	Yam	*Dioscorea spp.*	32
18	Amaranthus	*Amaranthus hypochondriacus L and A. cruentus L.*	7
19	Sokoyokoto	*Selocia argentia* L.	3
20	Corchorus	*Cochorus oliterius*	3
21	Okra	*Abelmolchus esculentus*	4
22	Solanum	*Solanum macrocarpon*	4
23	Pepper	*Capsicum frutescens*	7
24	Melon	*Citrullus lonatus* Thumb.	2
25	Cocoa	*Theobroma cacao* L.	14
26	Cashew	*Anacardium occidentale* L.	1
27	Kola	*Cola nitida*	3
28	Coffea	*Coffea arabica* L.	2
29	Oil palm	*Elaes guineensis*	1
30	Coconut	*Cocos nucifera* L.	3
31	Date palm	*Phoenix dactylifera*	1
32	Raphia palm	*Raphia hookeri* Mann & Wend	1
33	Sweet potato	*Ipomea batata*	9
34	Irish potato	*Solanum tuberosum*	6
35	Sweet orange	*Citrus sinensis*	11
36	Tangelo	*Citrus paradise* x *C. reticulata*	1
37	Kenaf	*Hibiscus cannabinus*	3
38	Sunflower	*Helianthus annus* L.	4
39	Cabbage	*Brassica olaracea*	2
40	Oat	*Avena sativa*	2
41	Acha (Fonio, Hungry millet)	*Digitaria exilis*	2
42	Ginger	*Zingiber officinale*	2

Source: Anon., 2022

Bio-fortifying staple food crops consumed by the poor can help reduce micronutrient malnutrition by providing a basic "nutritional floor" upon which other interventions, such as conventional fortification and supplementation can build upon. As the food crisis shows no signs of abating, bio-fortified crops are especially timely. Up to one third of the recommended daily iron intake can be provided through fortified beans (Ado, 2008a, and b).

Climate change is credited as one of the main drivers behind the traits that can arm agriculture against the impact of future changes. Traits such as drought resistance or salinity tolerance or water logging tolerance in maize, will become essential as crops around the world have to adapt to new climate conditions. Climate change is having the most negative impact in the poorest regions of the world, already causing a decrease in yields of most major food crops owing to droughts, floods, increasingly salty soils and higher temperatures. Climate change is likely to enhance the spread of pests and alien species, biodiversity losses and increased human and animal diseases. Raising productivity through improved irrigation will be crucial to ensuring food security as weather patterns shift. Genetic modification through plant breeding holds the key to developing climate-resilient crops (Ado, 2008a). Plant breeding which improves germplasm is critical to the success of the agricultural, horticultural and forestry industries in Nigeria and the lucrative regional and international seed markets. Private sector is involved in business aspect of forestry operation through commercial development of forest resources, forest industries and trade. Raphia palm is perhaps the most exploited species on the forest belt of Nigeria for palm wine and it offers a good source of long fibres for the pulp and paper industry. Crops that are hitherto classified as food crops are gradually becoming industrial crops with attendant increase in demand and price. Maize, for example, apart from its growing use in feed industries, it is now used for malting, industrial starch, confectioneries, syrup, dextrin as well as in pharmaceutical, textile, food and beverage industries. Improved sorghum germplasm is being used by breweries for malt production. Value addition has provided opportunity for the establishment of many cottage industries. These translate into more jobs for the teeming population, income generation and poverty reduction as enshrined in the 7-point agenda of the Federal Government (Ado, 2008b).

To achieve the SDGs, the global food system must be transformed so that it is more productive, more inclusive of poor and
marginalized populations, environmentally sound and resilient, and is able to provide healthy and nutritious food to all. Four critical aspects of this transformation include: "Boosting the small; Transforming the Big; Losing Less; and Eating Smarter" (Elechi *et al.,* 2022). CORAF has noted that to address food system challenges, there is need to prioritize actions that promote food security in the sub-region. This is largely because, the number of food insecure people has been on an upward trend since 2014 and almost quadrupled between 2019 and 2022. The countries with the highest projected numbers of food insecurity are: Nigeria (19.45 million), the Niger (4.4 million), Burkina Faso (3.45million), Chad (2.1 million) and Mali (1.84 million). A significant deterioration of food insecurity in 2022 was also projected for Sierra Leone, Guinea and Benin (FAO, 2022). According to FAO, Households are food secure when they have year-round access to the amount and variety of safe foods their members need to lead active and healthy lives. At the household level, food security refers to adequate food for meeting the dietary needs of all members of the household.

CORAF's achievements under the WAAPP include: the release of 37 new technologies by national centres of excellence, which improved yields by at least 15 percent compared to the control technology; adoption by ECOWAS of regulations for the registration of genetic materials and pesticides; development of a web-based information system on agricultural technologies and research skills; and the operation of a harmonized monitoring and evaluation system for data collection, analysis, and reporting. The higher the rate of food insecurity, the higher the risk of developing chronic illnesses such as heart diseases. The burden is, therefore, placed on the healthcare system. In a study, food-insecure households spent about $6,100 on medical care in a

year as compared to $4,200 for food-secure households, which is a 45% increase in costs. Productivity growth in basic staples confers strong benefits across food systems through higher incomes to farmers and lower food prices to consumers, and thus remains afundamental priority. But diet quality is key, pointing to the need to extend the search forproductivity growth beyond staples to include nutrient-dense foods such as vegetables, legumes and animal-source foods, ideally within diversified, integrated production systems backed by improvements in post-harvest management of these highly perishable food items. Such diversified production systems tend to generate higher incomes for farmers, allowing them to diversify their diets from market sources. Diversified systems can also be more resilient to agro-climatic and socio-economic shocks. Key challenges lie in empowering women (e.g. through technologies and practices that not only enhance productivity but also save time), and also in scaling up beyond localized successes (World Bank, 2013).

Bio-fortification, the process of enhancing micronutrient content of foods through breeding, is a promising new intervention to improve nutrition through agriculture, with both proven nutritional efficacy and growing farmer and consumer demand for several bio-fortified crops such as oranges, sweet potatoes and high-iron beans (Omamo, 2016). Agriculture is pivotal to economic development and more of the efforts to revive the economy should therefore be tied to it (Ado, 2017). Nigeria will not achieve reasonable economic growth, poverty alleviation and improvements in food security without productivity increases through plant breeding (Ado, 2013). Expanding food production through enhanced productivity constitutes the cornerstone of policies, strategies and programmes seeking to attain sustainable solution for food security. This is essential to the increasing demand for food, fodder, fibre and biofuel production (Ado *et al.,* 2009). Plant breeding develops plants that survive abiotic and biotic stresses, and plants that have more nutrition and that can have new uses and be able to benefit the farming community, the economics of farming as well as the environment. New crop varieties will be needed, and in some cases farmers will have to shift to growing new crop species. The areas that are currently the most food-insecure will be worst affected and will have the greatest need for new crop varieties that are tolerant of drought, high temperatures, flooding, salinity and other environmental extremes. Plant genetic resources will be vital in adapting crop production to the effects of climate change. Diverse species, varieties and cultivation practices allow crops to be grown across a wide range of environments.

The general lack of attention given to plant breeding in the international climate change arena, results largely from lack of awareness. While in the agricultural sector there is a clear understanding of the need to maintain and sustainably use genetic diversity in order to respond to ever-changing production conditions, there is an urgent need for greater awareness of the roles and values of plant breeding for food and agriculture among those engaged in climate change discussions. Crops, livestock, forest trees and aquatic organisms that can survive and produce in future climates will be essential in future production systems. This will require revising the goals of breeding programs, and in some places it is likely to require the introduction of varieties and breeds, even species, that have not previously been raised in the local area. Breeding programs take time to reach their goals and therefore need to start many years in advance. Genetic resources for food and agriculture are among the keys to efficiency, adaptability and resilience in production systems. They underpin the efforts of local communities and researchers to improve the quality and output of food production. It is vital that the genetic diversity needed to adapt agriculture and food production to future changes is not lost because of neglect in the present (Ado and Usman, 2015).

Future Plant Breeding

Future plant breeding requires improved support for Agricultural Research in both human and infrastructure, due to emerging cutting-edge technologies and demand for more climate resilient varieties. Research and development (R&D) as a percentage of GDP ranges from 0.3 percent to 1

percent in most African countries, as compared to European countries (Finland 3.5 percent, Sweden 3.9 percent), USA (2.7 percent), as well as Japan, Singapore and Korea (2-3 percent). In 2015, only Burkina Faso, Mali, Niger and Senegal in the West African sub-region had public agriculture expenditure of about 10 percent of GDP, the target fixed by the Maputo Declaration (2003). Gambia, Ghana and Togo were on the threshold of reaching this target. Nigeria devoted 6 percent of GDP to agriculture and the remaining West African countries less than 5 percent (Essegbey *et al.,* 2015). In addition, funding for agricultural R&D in three West African countries, namely Nigeria, Ghana and Cote d'Ivoire, accounts for only 12 percent of total national R&D funding. Support for health R&D for the three countries in 2015 was almost 40 percent of total R&D funding. IFPRI (2011) notes that investments in agricultural research and development (R&D) in the WCA sub-region increased by more than 20 percent from 2001-2008. According to Stads (2011), the CORAF countries employed more than 4,000 full-time equivalent (FTE) of SSA region's total research capacity. It is worth noting that public agricultural R&D spending varied considerably across the CORAF countries, for example, Nigeria, Ghana, and Cote d'Ivoire invested $404 million, $95 million, and $43 million in agricultural R&D, respectively, whereas Gabon and The Gambia spent just $2 million and $3 million, respectively, in 2008 (Agyeman and Mbuya, 2022).

Commodity groups, private industries, State and Federal Agencies should support the infrastructure and long-term commitment required to develop superior crops for production and global consumption and train the next generation of plant breeders to address the needs of a growing population with fewer inputs and decreasing arable land (Ado, 2017). Plant breeding output has a major role to play in improving the nation's economic competitiveness, industrial transformation and improved quality of life. Continued development of improved varieties and markets and a realistic understanding of farmers' needs remain critical. Patience and the commitment to steady funding are crucial as lead times for plant breeding average roughly a decade. Long-term commitment to agricultural research remains essential. Research on genetically engineered crops can produce a wide range of drugs, vaccines and other pharmaceutical proteins. This research will open the door to less expensive and more readily available drugs (Marvier, 2007). Today maize fields in the US are being turned into factories producing not just food, but drugs, vaccines, enzymes and antibodies. This is achieved through the synthesis or isolation of genes that code pharmaceutical proteins, followed by the transfer of these genes into the deoxy-ribonucleic acid (DNA) of crop plants. These transferred genes, or 'transgenes', can potentially come from different plant species, an animal (including human) or a bacterium. The genetically modified crops are then cultivated and harvested. A genetically modified maize produces lipase, a digestive enzyme used to treat patients with cystic fibrosis. Maize is one of the crops considered for possible oral delivery mechanism for vaccines because it can be eaten raw; thereby avoiding the protein denaturing that occurs during cooking (Sala *et al*., 2003). Maize is generally recognized as safe for ingestion and therefore can be used as an inactive carrier, suitable for drug delivery.

Conclusion

The poor attention given to plant breeding in the attainment of SDGs is owing to lack of awareness. While in the agricultural sector there is a clear understanding of the need to maintain and sustainably use genetic diversity in order to respond to ever-changing production conditions, there is an urgent need for greater awareness of the roles and values of plant breeding for food and agriculture. It is vital that the genetic diversity needed to adapt agriculture and food production to future changes is not lost because of neglect in the present. Plant breeding is a potent and indispensable resource for addressing SDGs including climate change, water and energy supply constraints and for meeting the food needs of the expanding population as well as support the country's industrialization. It also ensures healthy and sustainably produced food, which is the cheapest, most accessible, affordable and desirable choice for all. Sustainable impact of

harnessing the potential of plant breeding towards attainment of SDGs can only be possible through collaborations with the various stakeholders along the crops value chain. A multi-pronged inter-sectoral and integrated approach bridging diverse actors is needed to harness the potential of plant breeding to meeting the SDGs in Nigeria. To promote access to food, Nigeria should use the uptake of quality science, plant breeding, technology, and innovations, access to markets, free trade and common regulatory frameworks to facilitate agriculture and food systems transformation in the region (CORAF, 2019).

Plant breeding is necessary to boost the performance of small and large scale crop production to achieve food and nutrition security and obtain high incomes. There is need to review the position of plant breeding research budget in the NARS to accelerate attainment of the SDGs. To increase the resilience and productivity of farmers, plant breeding is the foundation upon which a strong edifice can be constructed. Even though not much has been done by most institutions and countries, but there are hopes for a food secure future. A supportive policy environment is needed to foster sustainable commercialization of plant breeding research outputs for rural development, poverty reduction and economic transformation of the country and the region. Agricultural technology

development should be co-financed by all tiers of government as well as private sectors, producers and community organizations. Increased and more stable public funding is necessary for effective research and extension activities.

Recommendations

Free interaction among policy, research and private sector players with a focus to encourage thought-provoking transformations across Agricultural Research and Technology Development especially variety development is advocated to attain the SDGs.

Government and Institutions to provide enabling environment for modern plant breeding activities such as marker assisted selection and genome editing. Efforts should be made to strengthen enabling policy and advocacy environment for development of improved crops and improve access to them in a sustainable manner.

Stakeholders should support the development of improved varieties, aligning policy, boosting private sector finances, connecting food and environmental agendas in food systems transformation.

Plant breeding should be supported by aligning policy and private sector finance connected to variety development in the National Agricultural Research System (NARS) for attainment of relevant SDGs. There should be alliances with civil society, international agencies, consumer groups, etc. for funds mobilization to procure machineries and equipment necessary for molecular plant breeding.

Support for development of a large number of bio-fortified varieties to meet national standards and nutritional needs is advocated.

The Alliance for a Green Revolution in Africa (AGRA) apart from the capacity development of plant breeders in Africa may also consider provision of infrastructure such as machineries and equipment to the trained personnel especially those at PhD level to enable them put into proper practical use the training they have acquired in their respective countries.

Private sector should be involved more in variety development initiatives by engaging qualified plant breeders or collaborating with public institutions by sponsoring variety development projects towards attainment of the SDGs.

Countries need to address the challenge of inadequate food utilization through reduction of malnutrition among vulnerable groups; the increase of access to quality food, make improved seeds more available and affordable, safe water, sanitation and hygiene practices; the reduction of morbidity from common communicable diseases; the fortification of foods with micronutrients; and enforcement of dietary diversification to improve the nutritional quality of food consumed by households.

Regional trade of seeds among the West and Central African countries need to be effectively carried out so as to make quality seeds accessible and readily available to farmers across the sub-region.

Reviewing breeding strategies and priorities crop-by-crop and region-by-region so as to ensure that the products of crop-improvement programmes are relevant to the challenges the world will be facing when the products are ready for release at the end of the crop improvement cycle (five to ten years into the future).

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