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Current Status and Challenges of Agricultural Biotechnology in Nigeria: A Concise Review

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***Abstract*—The population of Nigeria is projected to exceed the United States of America (USA) by the year 2050. It is predicted that this could result in geopolitical and socioeconomic crises such as shortage of food and agricultural land. In the face of this impending calamity, it is essential to take remediation steps to safeguard the survival of future generations. One potential solution is to embrace modern agricultural biotechnology. Yet, the design, development, and adoption of agricultural biotechnologies in Nigeria remain low due to several socio-economic, ethical, health or political concerns. Besides, the slow rate of adoption and implementation of agricultural biotechnology can be ascribed to lack of knowledge, high costs, and inconsistent field performance. Therefore, this paper seeks to examine the historical and current status of agricultural biotechnology developments in Nigeria. It will also identify and highlight the various challenges plaguing agricultural biotechnologies in Nigeria. The findings revealed that agricultural biotechnology has the potential to address the looming challenges of the food crisis in Nigeria. However, the authors posit that the government and relevant research organisations, industry, and academic stakeholders need to design, develop, and implement more effective and sustainable strategies to ensure the growth and development of agricultural biotechnologies in the country. It is envisaged that the findings of this study will reinforce the debates on effective R&D and the implementation of the policies and programmes on agricultural biotechnology in Nigeria.**

Keywords*— *Agricultural biotechnology, Genetic engineering, GMO crops, Biosafety, Nigeria.

I. INTRODUCTION

Geographically, Nigeria is located in the Western part of Africa, with a land area of 923,768 km^2. It is the most populous black nation in the world, with a population density of about 100 persons per km^2 in the Northeast and West-central regions. Conversely, the population density of the Southern and North-eastern regions stands at 500 persons per km^2. According to global projections, the total population of Nigeria will exceed the United States by the year 2050 [1]. Since these figures are projected to soar even higher by the year 2100, Nigeria will likely be faced with a shortage of arable land and a significant decline in soil nutrient conditions [2]. Consequently, food shortages could arise, resulting from the inability to grow adequate food to feed the nation's predicted rise in population in the near future [3-5]. To accomplish this, agricultural production needs to be improved with modern technologies such as biotechnology [6], which could boost crop harvests and livestock production [7].

According to these studies [8-10] biotechnology is the technological application of any living organism, its derivatives or biological system based techniques to modify the product or processes for a particular purpose. Similarly, the IAASTD (2009) (International Assessment of Agricultural Knowledge, Science, and Technology for Development), describes biotechnology as "any technological application that uses biological systems, living organisms, or derivatives thereof, to make or modify products or processes for specific use" [11, 12]. In principle, biotechnology is the technological application of living organisms, systems, or processes to examine the science of life for further improvement of the value of

materials and organisms such as crops, livestock, and pharmaceuticals [13].

Biotechnology has evolved over the years, with numerous applications in agriculture, bioengineering, bio-manufacturing, biomedical engineering, among others [14, 15]. Scientific research in the field of agricultural biotechnology is often aimed at improving cheap plant varieties, increase yields, and address various challenges such as pest control in agriculture [12]. Therefore, biotechnology can potentially solve the impending crises of food shortage around the globe [16, 17]. Although not a silver bullet, agricultural biotechnology symbolises an imperative instrument required to meet future food demand and supply [18].

In recent times, the importance of agricultural biotechnology to food security has been debated interminably by agricultural stakeholders, governments, academics, environmentalists, consumer organisations and farmers [19, 20]. As a result, several ethical concerns have been expressed over numerous bioproducts developed over the years. Likewise, the value, life cycle, environmental impacts and purpose of the growing number of biotechnological applications are other concerns often raised in these debates [21]. Distinctively, the possible side-effect of these bioproducts on human health, safety, and the environment have taken centre stage in debates on agricultural biotechnology. For instance, Winfield [21] points out that the many applications of agricultural biotechnology developed so far are environmentally obstructive to sustainable agriculture and could undermine ecological agricultural practices in future.

However, James [22] opined that despite the widely publicised probable risks of biotechnological applications in agriculture, no reported case has been brought forward regarding its negative impact since 1996 when GMO crops were first commercialised. Furthermore, Winfield [21] argues that the advocators of the notion that agricultural biotechnology is the answer to the question of securing world's food supply are suggesting a technological solution to a problem that is mostly socio-economic and political, rather than technological, in nature. Despite these controversies, biotechnology is widely considered a potential tool to addresses the food shortages, arable land scarcity, along with improving the quantity and quality of food required to safeguard future generations [19, 20]. Furthermore, Adenle and Ammann [23] examined the agriculture implications of genetically modified organisms (GMOs) – an application of biotechnology in agriculture. The study observed that GMOs could potentially address existing problems such as pest and disease control, malnutrition, and food shortage [24-26].

Therefore, analysts estimate that the global acceptance and widespread consumption of bioproducts could soar particularly in developing countries like Nigeria [27, 28]. However, the design, development, and adoption of agricultural biotechnology in developing nations remain low, albeit due to several socio-economic, ethical, health or political concerns [29, 30]. Besides, the slow rate of adoption and implementation of agricultural biotechnology can be ascribed to lack of knowledge, high costs, and inconsistent field performance. Therefore, the objective of this paper is to review the current status, developments and key challenges of agricultural biotechnology in Nigeria. It is envisaged that the findings will avail agricultural stakeholders with knowledge on the prospects, challenges, and outlook on agriculture biotechnology in Nigeria.

II. Concepts of Agricultural Biotechnology

Ene-Obong [31] defines agriculture as the use of natural resources to improve or boost the production of livestock and crops required to sustain present and future generations. The application of biotechnology in agriculture reportedly boosts the efficient production of livestock, fish, crops, and trees through genetic coding. Therefore, agricultural biotechnology is conceptualised as the gathering and utilisation of different scientific techniques to modify plants, animals, and microorganisms [32]. Similarly, the FAO [10] defines agricultural biotechnology as "any technique that uses living organisms or substances from these organisms to make or modify a product". According to Dinali *et al.,* [32], these scientific techniques could be either conventional or traditional method like grafting, fermentation, stem-cutting, cross-breeding, pest control. The modern techniques include genetic modification or recombinant DNA technology (rDNA), also known as genetic engineering, tissue culture, bioprocess or cell fusion [31, 33].

A. Traditional Biotechnology

This is also known as conventional breeding, hybridisation or traditional biotechnology [34]. In principle, it is an ancient set of biotechnological practices in which each parent species bestows a large unquantified portion of its genetic constituent to the offspring. This can, however, result in the transfer of the desired and undesirable qualities or characteristics [35]. However, the undesired traits may only be removed through multiple successive crossing breeding and testing over generations. Several years may perhaps be needed before the preferred blend of qualities is accomplished. The time frame is even longer for perennial crops like trees and selected groups of livestock [26]. Nevertheless, the use of this technique for selecting phenotype is slow, time-consuming, and expensive. With modern biotechnology, conventional breeding techniques have become more efficient [34].

B. Modern Biotechnology

In the year 1865, Gregor Mendel recognised genes as the unit of inheritance through a process, which, after many years of research resulted in what is now termed modern biotechnology [36]. According to Asmelash [37], modern biotechnology is a novel technology typically also referred to as genetic

engineering, cell fusion or tissue culture. This type of biotechnology involves the application of the in-vitro nucleic acid method and direct insertion of nucleic acid into organelles or cells [38]. Furthermore, it involves the re-modification of the genetic structure of an organism by transgenesis or recombinant DNA technology without traditional sexual reproduction. Technically, when a gene is modified, it is expected to alter the individuality of such genome.

With the basic knowledge of DNA (deoxyribonucleic acid) over the last 50 years, researchers have developed ideas tailored towards increasing agricultural yield. This has been possible through different techniques reviewed in the literature [31, 33]. For instance, techniques like genetic engineering are employed to alter the genetic makeup of an organism through rDNA "recombinant DNA" technology. This technology involves selecting, altering or cutting into the DNA structure of species that hold one or many genes of interest. These include the traits that could aid agronomic performance, herbicide tolerance in addition to disease, and pest resistance. As a result, these traits can be identified, remodelled or improved to form the desired crop or animal species [6, 36].

Genetic engineering is a modern biotechnological technique that has speedily replaced traditional biotechnology. According to Kidd [39], this is because modern biotechnological techniques can reduce the typical traditional period of breeding from 10-12 years to about 2-3 years. The study by James and Krattiger [40], reported that since 1986, more than 2,053 field trials of transgenic plants had been set free into the natural ecosystem around the world. Therefore, the recent advances of modern biotechnology in agriculture have proven that it would be the saving grace of many developing countries with soaring demographics such as Nigeria. Conversely, there are many conflicts allied with modern biotechnology [41]. In many ways, modern biotechnology has significantly shortened the time dedicated to plants and animal products around the globe. Today, crops with larger seeds, shortened growing season, and long shelf life along with increased resistance to disease and pests, and better adaptation among other benefits of agricultural biotechnology [42, 43].

III. HISTORICAL OVERVIEW OF AGRICULTURAL BIOTECHNOLOGY IN NIGERIA

Historically, biotechnology has long existed in Nigeria, dating back to the traditions of preparing local alcoholic drinks like *burukutu*, which inexplicably involved the fermentation process. Similarly, the preparation of non-alcoholic drinks like *kunu*, and farmers' astuteness to opt for the best plants or bleed only the finest species of plants and animals are other examples. This period, which dates as far back as 10,000 years ago, is typically referred to as the age of domestication. Throughout this epoch, many improved varieties of plants with desirable qualities for propagation and animals for breeding were intentional domesticated [44-46].

The genesis of modern biotechnology in Nigeria is not well documented, although the history of improved food and agricultural productivity in Nigeria began with the Green revolution of the 1950s and 1960s [47]. In 1992, Nigeria jointly signed the Convention on Biological Diversity, which authorised the protocol in 1994 [48, 49]. The landmark event not only ushered in the era of active participation in the global discussions but also the implementation of the *Cartagena* Protocol. Similarly, these developments gave rise to the establishment of the National Biotechnology Development Agency (NABDA) of Nigeria [50]. According to its mandate, NABDA was directed to develop, design, and implement the nation's biotechnological policy. Furthermore, the agency was tasked with the directive to acquire, deploy, promote and facilitate biotechnology activities for home-grown and self-reliant national growth [50]. The establishment of NABDA also marked the adoption of the National Biosafety Guideline, which has the provision to approve field testing of bio-engineered crops.

Without delay, the agency and other stakeholders have swiftly moved to ensure the enactment of Bio-Safety bill into law. Based on the law, the Federal Government of Nigeria enacted the National Biosafety Act (NBA) in 2015 [51, 52]. Today institutions like SHESTCO (Sheda Science and Technology Complex), IITA (International Institute for Tropical Agriculture), NBMA (National Biosafety Management Agency), Monsonta and OFAB (Open Forum on Agricultural Biotechnology in Africa) many others are researching and regulating the biotechnology of plant and animal products for various agricultural applications [50].

A. Current status of Agricultural Biotechnology in Nigeria

In recent time, Nigeria has openly embraced modern biotechnology in agriculture. This was made evident when former President Goodluck Jonathan signed the Biosafety Bill (TEMP) into law in the year 2015 [50]. This law made way for the establishment of various biotechnological agencies. This law formally approved numerous research and field trials of transgenic crops and commercial testing phase for ultimate deployment to farmers. It also provided the legal framework for the utilisation of biotechnology in agriculture with the view to intensifying food security in Nigeria. However, the research and development (R&D) of transgenic crops in Nigeria is unquestionably still in its infancy. As a result, some organisations have built-up the essential mass of human capacity and the infrastructural necessities that can hasten the development of transgenic materials.

In 1998, Woodward et al., [53] reviewed research on biotechnology in Nigeria and other African countries. The authors reported that Nigeria has ongoing biotechnological research programs in the micropropagation of yam, ginger, cassava and banana. Also, the study listed other developments in the long-term preservation of yam, cassava, banana and medical plants. Other areas also include embryo

rescue for yam, genetic engineering of cowpea for insect and virus resistance along with alteration and rejuvenation of yam, cowpea, banana and cassava. Similarly, Nzeka [54] reported the most recent transgenic crops and ongoing field trials in different institutions in Nigeria. The details are summarised below [54]:

i. ABS (Africa Bio-fortified Sorghum) and Bt Cowpea are under examination in the Institute for Agricultural Research (Amado Bello University Zaria) in Kaduna State.

ii. Bio-Cassava + (plus) is under research at the National Root Crop Research Institute, Umudike, Abia State.

iii. "Super Cassava" with Vitamin A fortified is under development.

iv. Bt Cotton is about to go through field testing.

On the 1st of May, 2016, the National Biotechnology Management Agency (NBMA) accepted the request of Monsanto to commercially test Bt Cotton – MRC7377BG11 and MRC761BG11 species in Nigeria. Furthermore, the company's field trials of Bt corn MON89034 and NK603 were also approved by the government. Today, other crops are currently at different stages of confined field trials (CFTs) at different facilities within the country.

For instance, an advanced level has been reached on the alternation of local tomato varieties. Cowpea bio-engineering is at the groundwork as are the African Biofortified Sorghum (ABS), Bt Maize, Herbicide-tolerant soybeans, water use efficient (NEWEST) and virus-resistant cassava enhanced with zinc and iron (Cassava Plus) at different research stages. However, it is noteworthy to state that, both cassava plus and cowpea have been developed by Nigerian scientists and are currently undergoing trials in the United States (Plant Danforth centre, Missouri) and Australia, respectively. Table 1.1 shows the database for approved crops on field trials.

TABLE I. DATABASE OF CROPS APPROVED FOR FIELD TRIALS [55].

Name of crop	Trait	Developer	National collaborating institute	Regulatory status	Status as of December 2016
Maize	Stacked genes for insect resistance and glyphosate herbicide tolerance	Monsanto Nigeria LTD	Institute for Agricultural Research Zaria	CTF approved	Yet to commence
Cotton	Insect resistance	Monsanto Agriculture Nigeria LTD	Institute for Agricultural research Zaria	General release	Ongoing
Rice	Stacked with nitrogen use efficiency, water efficiency and salt tolerance	African Agricultural Technology Foundation	National cereal research institute Baddegi	CTF	Ongoing
Cassava	Bio cassava plus (pro-vitamin A, protein, iron) cassava mosaic, virus resistance and brown streak virus resistance	Danforth plant	The national root crop research institute, Umudike	CTF	Concluded
Sorghum (ABS)	Bioavailability of protein, zinc and iron	Africa Harvest	Institute for Agricultural research Zaria	CTF	Ongoing
Cowpea	Maruca insect resistance	CSIRO, Australia	Institute for Agricultural research Zaria	Multi-locations Trait	Ongoing

Despite these commendable developments, Nigeria has not commenced the commercial production of any biotechnology crop. In addition, the nation does not export any genetically engineered product or currently bans any genetically engineered biotechnological crops, farming or importation. Nonetheless, the importation of any biotechnological product requires a formal application and approval of the National Biosafety Management Agency [55].

B. Challenges of Agricultural Biotechnology in Nigeria

The implementation of agricultural biotechnology in Nigeria is currently moving at a slow pace. Many factors can, however, be recognised to hamper its progress. Some of these factors are discussed in this section. One of the most common challenges facing research in developing countries like Nigeria is lack of funding. Likewise, inadequate financing is identified as one of the significant challenges facing agricultural biotechnological research and development (R&D) in Nigeria. For instance, the total spending on agricultural research and development from 1975 to 1995 showed a negative growth rate of 2% [56]. Between the 1970s to the mid-'90s, spending on agricultural R&D reduced by 66.6% from US$ 130 million dollars. According to Beintema and Ayoola [56], the total budget for agricultural R&D and the superiority of national research institutions have declined in Nigeria. Therefore, this reflects, to some degree, the perception that research in agriculture is not prioritised. This is due to the notion that R&D for agricultural biotechnology is expensive and knowledge-intensive. With low funding, national research institutions within the country struggle to fund research programmes and retain its scientists. This could hinder qualitative and quantitative progress in biotechnological development.

The market unacceptability of agricultural biotechnological products is another major challenge. In Nigeria today, many citizens are unaware of

agricultural biotechnology, its product and ancillary issues related to its R&D, design, development and implementation. However, people who are aware of agricultural biotechnology are unwilling to consume its products, mainly due to widely reported safety issues publicised by anti-GMC groups. As a result, the general public and farmers in Nigeria need to be re-educated about biotechnology. Recently public sensitisation on GM products has been effectively carried out by pro groups like OFAB (Open forum on agricultural biotechnology) to heighten the understanding of biotechnology. Nevertheless, more is needed to improve the general understanding and acceptability of biotechnology in Nigeria.

Another major challenge is the inability to develop and facilitate useful research to establish collaborations among indigenous research institutes and scientists within the country. This drawback also impacts on funding and harmonisation, which wastes meagre resources on overlapping research and other correlated activities. Hence, the technicality of such procedures needs to be improved. Likewise, the acquisition of intellectual property rights and provision of an adequate lawful safeguard for the acquired rights is another hurdle that must be overcome for agricultural biotechnology to thrive in Nigeria.

Furthermore, political instability is also negatively impacting on biotechnology in Nigeria. With the recent signing of the biosafety laws, extremely polarised anti-GM debate by NGO has created political risks for governments' plans for GM. As a result, academics, politicians and policy-makers are increasingly becoming reluctant to take a stand on the release of biotechnological products [57]. Another obstacle hindering the progress of biotechnology in Nigeria is the weakness of the existing policy and framework guidelines [58-60] on biotechnologies, bio-safety, GM products and energy systems. The scope of this regulation needs to be extended and deepened as biotechnology has advanced dynamically worldwide.

IV. Conclusions

The paper presented a concise overview of the current status, key challenges, and opportunities for agricultural biotechnology in Nigeria. The history, current status, and challenges of developing and implementing agricultural biotechnologies were examined in the paper. Likewise, the various definitions, concepts, and types of biotechnology and its applications in various fields such as agriculture were highlighted. The findings indicated that agricultural biotechnology could effectively provide solutions to the impending crises of food shortage and loss of arable land in Nigeria. This is particularly important due to the rising population in Nigeria, low crop productivity, and the effects of climate change which are currently causing socioeconomic and environmental problems. The analysis of the current status of agricultural biotechnology in Nigeria indicated that the technology, along with R&D in the field is still in its infancy. Furthermore, the paper notes that numerous challenges plague the low pace of R&D in agricultural biotechnology in the country. Therefore, more research funding, technological advocacy, and wide enlightenment on agricultural biotechnology, its products and implications are urgently needed to address the challenges highlighted. Furthermore, the government, academia, industry and other stakeholders need to double down on efforts to develop and implement safe agricultural biotechnologies for various applications. In general, the authors envisage that the findings will add credence to the quest for effective R&D and the implementation of agricultural biotechnology in Nigeria.

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