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Review Article

Untapped potentials of Agricultural Biotechnology in Nigeria

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ABSTRACT: The field of biotechnology has witnessed a significant achievement over the past decades. Although biotechnology always sparked a great deal of ethical criticism, the advancement has continued to offer an opportunity to address several social and economic challenges. The potentials of biotechnology remain underexploited in several fields in Nigeria. This review highlighted some untapped biotechnologies that represent an ample scope of biotechnology application used for the genetic improvement of plant and animal populations, conservation of genetic resources, and diagnosis of plant and animal diseases. Factors such as insufficient of funds to procure facilities, inadequate power supply, lack of sufficient trained manpower, lack of political will to support biotechnology has been limiting biotechnology's potentials in Nigeria. Therefore, it was recommended that attention should be given to biotechnology research and development to complement existing expertise in the national biotechnology sector towards maximizing its potentials.

Keywords: Biotechnology, genetic improvement, genetic resources, insufficient of funds, social and economic challenges.

INTRODUCTION

The 21st century is witnessing rapid progress in biotechnology that revolutionizes interventions on global issues such as food insecurity, poverty, disease, and hunger affect many nations. Biotechnological innovation is continually gaining increased recognition as an important tool for improving agricultural, pharmaceutical, industrial, and global health (Kim and Kwak, 2020; Lobo-Galo et al., 2021). Biotechnology is an important factor in alleviating the negative impact of global issues, as the approaches proffer solutions in a very short and reliable way (Najafi and Lee, 2014). Generally, Biotechnology is define as the application of science and technology to living organisms as well as parts, products, and models thereof to alter living or nonliving materials for the production of knowledge, goods, and services (OECD, 2013). Most developing countries (in Africa) are in the early stage of biotechnology, and the progress in Nigeria towards important scientific achievements is rather slow. A wide range of biotechnologies are currently emerging in Nigeria, and it comes with several challenges that hinder its progress (Olasoju et al., 2018). The advancement of biotechnology has great potential to tackles the problems that paralyze the performance of Nigerian small and medium-sized enterprises (Nasidi et al., 2018). However, this country is lagging in the utilization of vast biotechnology. It is important to broaden access to food and increase productivity via biotechnology while conserving natural resources (Ogbu, 2014). The Nigerian government is promoting sustainable agriculture toward achieving food security, but fails to increase investments in public agricultural research and development substantially. Biotechnology has not been funded adequately to increase productivity and conserve natural resources in Nigeria. This review highlighted the current status of agricultural biotechnology and identified the unexploited areas in Nigeria. The untapped biotechnologies represent an ample scope of biotechnology application used for the genetic improvement of plant and animal populations, conservation of genetic resources, and diagnosis of plant and animal diseases. Crop biotechnologies are continually witnessing progressive improvement in Nigeria. The progress includes; tissue culture-based techniques (Adetowubo et al., 2019; Mwangangi et al., 2019), mutagenesis, interspecific or intergeneric hybridization, genetic modification (Animasaun et al., 2020; Oluwakemi et al., 2020), marker-assisted selection (Eze, 2019;

Olasanmi et al., 2021) and disease diagnostics (Naidoo and Ihekweazu, 2020).

CREATION OF NEW GENETIC VARIATION

Plant breeder's ability to create new genetic variation has continued to improve over the years. The leading breeding and crop management applications in most developing countries (Nigeria inclusive) have come from non-transgenic biotechnologies. Science-based breeding practiced over the past century is based on genetic variation like induced mutagenesis, hybridization, controlled introgression of traits from diverse populations of the same or different species. A tremendous achievement has been achieved in crop improvement via mutation over the years. To date, about 3275 mutant varieties from over 220 plant species have been officially released worldwide (http://mvd.iaea.org/). Several species varieties were successfully developed through interspecific hybridization (Azeez and Faluyi, 2018; Lebot et al., 2019; Saini et al., 2016), which allows the combination of favorable traits from different species. Micropropagation for the mass clonal propagation of elite lines or disease-free planting material has been around in the country for some years; unfortunately, most university and national research institutes have not maximized this potential in biotechnology. Other means of creating new genetic variation include crossing with the assistance of methods such as embryo rescue and somatic embryogenesis. Colchicine is employed to induce chromosome doubling in tissue culture techniques. Chromosome doubling enhances methods such as somatic hybridization and haploid breeding to improve dozens of essential crops (Hooghvorst and Nogués, 2021; d'Hooghvorst et al., 2021). Somatic hybridization is a way of enhancing variation in crop species by importing genes or even whole chromosomes from other species that are not closely related enough for typical sexual crossing (Shuro, 2018).

The advancement in genomics facilitates transgenic breeding in a gene (cis or trans exogenous) with known function is directly transferred into elite crop varieties to generate desired traits. Molecular breeders have capitalized on recombinant DNA technology to create new mutants by insertional mutagenesis. This technique exploited Agrobacterium's natural mechanism to transfer tumor-inducing Ti plasmid into a plant genome for infection. Over the years, scientists replaced the *Agrobacterium* Vir genes with a specific gene of interest to be integrated into the plant genome. The inserted transfer DNA (T-DNA) might be responsible for the over-expression or silencing of specific protein expression depending on the function and the breeding programs' intents. Several techniques like *Agrobacterium tumefaciens*, gene bombardment or direct gene transfer via electroporation, microinjection, and polyethylene-glycol treatment of protoplasts are commonly used to integrate the construct into the plant genome. However, such mutants are challenged by lengthy and costly regulatory evaluation processes and negative public perception, making commercialization difficult (Ortiz Ríos, 2015). Hardly can this type of research be carried out in most national research institutes and universities. Nigeria should endeavour to be involved in creating variation via transgenic or gene-editing techniques to develop and enhance our local crops. Recently insect-resistant cowpea (SAMPEA 20-T) was developed by scientists at the Institute for Agricultural Research (IAR), Ahmadu Bello University, Zaria (Mohammed et al., 2013) in collaboration with several partners under the coordination of the African Agricultural Technology Foundation (AATF). Such research should be encouraged in Nigeria to enhance the genetic variation among our local varieties. Though the country is sceptical about genetically modified organism (GMOs), the more we get involved in such research, the more our country will be safe. Because Nigerian have actually been consuming GMO, even approval (Andrew et al., 2018; Christian et al., 2016).

SCREENING AND SELECTION

Breeders need effective and efficient methods to identify, select and propagate useful variants in addition to creating new genetic variation. Most mutants are still determined using the phenotype-based characterization of progeny to identify anomalies potentially caused by these induced lesions. Although induced mutagenesis has been practiced with outstanding success among Nigeria researchers in crop breeding programs, they have not earnest an enhanced molecular-based technology of targeting induced local lesions in genomes (TILLING). TILLING is a reverse genetic strategy that helps to detect the allelic series in the mutant crop. The principle involved genetic mutations screening from pooled DNA samples of large mutant populations and subsequent identification of individual mutants from the pooled DNA. There is no single national laboratory where this kind of research can be carried out in Nigeria.

Most breeders in Nigeria have continually engaged traditional methods to enhance variation, only a few have access to Marker Assisted Selection (MAS) and genomic screening. However, the costs and technical expertise required for MAS remain major challenges for most researchers in Nigeria. Molecular markers are used as highly effective research tools to uncover the genetic basis of complex agronomic traits such as drought or salt tolerance and pest/disease resistance. Molecular markers allow the screening of many more plants at a very early stage and prevent several years of laborious work in developing a new crop variety (Nadeem et al., 2018). Genome-wide association study (GWAS) has become a common strategy for decoding genotype-phenotype

associations in many species to discover variants with the advent of rapid genotyping and next-generation sequencing technologies. GWAS is an efficient and effective method for identifying new genes in complex phenotypic trait (Adewale et al., 2020; Rabbi et al., 2020). But only a few researchers can work in this direction due to inadequate research facilities in Nigeria. The little research done in this area is the product of foreign collaborative effort.

DISEASE DETECTION AND DIAGNOSIS

Biotechnology plays an essential role in the development of diagnostic assays in response to critical disease response need. It is well documented that biotechnology advances have allowed the detection of pathogens at the early stages of infection (Hariharan and Prasannath, 2021; Luchi et al., 2020). Such early intervention can obviate possible disease outbreak while the pathogen concentrations present is low. The advent of molecular diagnostic techniques has revolutionized the pathogen detection and speed of identification (Sapre et al., 2021). Molecular diagnostics uses quantitative polymerase chain reaction (PCR), fluorescence *in situ* hybridization, and protein (Western blot, enzyme-linked immunosorbent assay) detect of pathogens. Although diagnosis laboratories are beginning to spring up in Nigeria, most of them are focused on human diseases. Most of such a diagnosis lab is business-based rather than research-based. In other words, the technical know-how available is more of a protocol follower instead of a protocol inventor. Nigeria is seriously lagging in the exploitation of biotechnology in plant and animal disease detection and diagnosis. Most animal breeding biotechnologies such as artificial insemination and embryo transfer that can accelerate genetic progress are explored on a minimal scale in Nigeria. The uses of DNA vaccines and RNA vaccine, which confer both humoral and cellular immunity more effectively, are far superior and much safer than traditional vaccines are lacking in animal health (Pardi et al., 2018) (Liu, 2019). A combination of advancements in bioinformatics, genomics, and biotechnology is speeding up the drug development process and gene therapy (Behl et al., 2021; Katara, 2013). However, Nigeria is still unable to earnest the rapid drug discovery and development potential of biotechnology in plant and animal health.

GENETIC RESOURCE CONSERVATION AND MANAGEMENT

The loss of genetic resources has resulted in significant concerns about future food production and nutrition security. It is essential to conserve crop and animal genetic resources as a vital raw material for breeding to combat challenges that might likely occur from climatic change (Govindaraj et al., 2015). Also, serve as a source of material for scientific research and future germplasm development. The government of Nigeria has set up several institutional frameworks for the conservation of national plant genetic resources with different mandates (Justin et al., 2014). Their central plant genetic resources systems revolve around acquiring, maintaining, characterizing, and evaluating genetic resources. Techniques commonly employed include *in vitro* conservation, cryopreservation, micropropagation, and molecular marker technology. Despite the enormous institutional framework set up in Nigeria, there is a limited report of the institute involved in creating genetic variation through the advance in biotechnology, like gene modification and gene editing. The potential of biotechnology in genetic resource conservation and management is not maximized in Nigeria.

FACTORS THAT LIMIT THE POTENTIALS OF BIOTECHNOLOGY IN NIGERIA

Lack of funds to procure facilities is one of the major factors that impede the progress of biotechnology applications in Nigeria. No doubt, the scientist in the country is doing great, in strategic collaboration with other scientists from other countries (mainly developed countries) to carry out meaningful biotechnology research. The national government is seriously lacking the will and a system of improving fund availability to biotechnology research (Abideen, 2013). The available source of funds from the government is rather insignificant compared to the potential of research in Nigeria. However, it is crucial that the means of funding should be increased so different funds will be available for research in Nigeria. The high customs duties imposed on importing scientific equipment result in setbacks of biotechnology. Since biotechnology facilities are extremely expensive, it will be advisable for the government to remove value added tax (VAT) on biotechnology equipment and consumables. These will somehow motivate biotechnology research in Nigeria. Although the government is investing in biotechnology diagnostic laboratories, it must be clear that a full biotechnology research laboratory is quite different from a diagnostic center. There were only a few research laboratories in Nigeria equipped with biotechnology facilities. These should be in most university and national research centers. Most universities in Nigeria cannot run a good practical class for biotechnology students, and many graduates without the necessary skills.

Considering the expensive nature of most biotechnolgy equipment, inadequate power supply further constrains biotechnology research in Nigeria university and national research institute. For example, it is highly impossible to set up PCR or quantitative PCR experiments in an epileptic power supply environment, which will waste time and money because such experiments have to be repeated to

get a valid result. Many reagents are also stored in -20 and -80 refrigerators; only limited institutes can manage a constant electricity supply for -20 throughout the year. Similarly, it is impossible to run -80 degrees in most Nigeria institutes; thus, researchers face highly ineffective methods of storing the acquired biotechnology reagent.

Lack of sufficient trained human resources is another major factor that limits biotechnology research in Nigeria. However, many scientists are trying to acquire up-to-date knowledge in biotechnology abroad and because of poor biotechnology infrastructure at the national institutes, much of the acquired knowledge is redundant. Such unproductiveness consequently results in brain drain. Brain drain describes the migration of skilled workforce from developing countries to developed ones for better professional opportunities. Many of the trained Nigeria biotechnology scientists seek opportunities in an environment where they will be more relevant and productive, which weakened the capacity of national biotechnology research and created knowledge gaps. We are making a clarion call to Nigeria Government to invest in biotechnology research in Nigeria heavily, so that the most trained scientists who had left the country can come home and contribute to our dear biotechnology research.

The current government policies are also limiting the progress of biotechnology in Nigeria. Most policy-makers lack awareness or willingness to support biotechnology advancement (Opabode and Adebooye, 2005). To promote the exploitation of biotechnology, the Nigerian government has a national biotechnology policy that established institutes like National Biotechnology Development Agency (NABDA) and National Centre for Genetic Resources and Biotechnology (NACGRAB). It is important that the Nigerian government demonstrates the political will to increase biotechnology capacity for the established institute to maximize their untapped potential in biotechnology. More supports in the form of funds for research, a fund for equipment, a fund for training, and retraining should be made available to stimulate and create a conducive environment for research and development in Nigeria biotechnology research.

Negative feelings towards the end product of most biotechnology influence its acceptance by the public. For instance, Nigeria populace is very skeptical about genetically modified animal or plant. Nigeria is a party to the Convention on Biological Diversity and met the provisions of the Cartagena Protocol on Biosafety. Nigeria government established National Biosafety Management Agency Act, 2015, and signed into law the National Biosafety Regulations, 2017. The regulations allow research and development (R&D) activities involving GM crops in containment and confinement and commercially release GM crops. It also evaluates risk assessment and proposes risk management measures. National researchers in biotechnology should consider engaging media consultants to disseminate biotechnology advances widely and appropriately.

CONCLUSION

The uptake of biotechnologies in Nigeria is gradually increasing. However, the full potential of Biotechnology is unexploited in many plant and animal research area. It has been shown that most research in Nigeria is lagging in the application of biotechnology to enhance genetic variation and in the selection of vital mutant. It will be advisable for the government to revisit the national biotechnology policy and engage scientists who have hands-on expertise in various biotechnology research to develop a viable plan that will promote biotechnology in Nigeria. More attention should be given to biotechnology R&D to complement existing expertise in the national biotechnology sector towards maximizing its full potentials.

CONFLICT OF INTERESTS

The authors declare that they have no conflict of interest.

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