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BIOTECHNOLOGICAL APPROACHES: A TOOL FOR ACHIEVING FOOD SUFFICIENCY

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Abstract

The development of agriculture has historically been based in the identification of a reduced number of species that have the appropriate features to be cultivated. But with increase in population food production will need to double as more people adopt a western diet. The predicted changes in rainfall and temperature, and an increase in extreme weather events (floods and droughts) all pose significant risks to agriculture. Also, with the horticulture's dwindling fortunes, biotechnology has to be rescued. The objective of this review is to provide comprehensive overview of the application of biotechnological approaches to improve the nutritional quality of our food. In this case, the following issues were critically assessed: the origin and definitions of plant biotechnology; successful application of biotechnology in fruit and vegetables production; the effect of the biotechnological application on the nutritional quality of fruit and vegetables; the challenges associated with the biotech fruits and vegetables and the need for biotechnology in the production of food in the 21st century. The

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available scientific literature shows that the developed biotechnological approaches have the potential to enhance the yield, quality, and shelf-life of fruits and vegetables in the midst of the global climate change, water scarcity, population increase, and ever-increasing demand for food. To make sure

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that the current debates and complexities surrounding the human safety and environmental considerations addressed, various stakeholders in the private sectors, agriculturalists, biotechnologists, scientists, extension agents, farmers, and the general public are engaged in policy formulations, seed-embodiments, and products developments.

INTRODUCTION

The development of agriculture has historically been based on the identification of a reduced number of species that have the appropriate features to be cultivated. From several international reports, it can be concluded that out of approximately 500,000 species of flowering plants, around 30,000 of them might have something edible, and around 4000 have been considered as cultivated crops (Sanchez-Monge, 1992) at some period of the evolution of human societies. However, at this moment, only 120 plant species are important for local communities of which 30 provide 90% of the calories that people use for their living. Three main cereals: wheat, rice and maize, provide about 50% of the energy we obtain from plants.

The UN predicts that 9.2 billion people are likely to occupy our planet by 2050 (Abano and Buah, 2015). This is a population increase of 50 %, but food production will need to double as more people adopt a western diet. The predicted changes in rainfall and temperature, and an increase in extreme weather events (floods and droughts) all pose significant risks to agriculture. For example, 4 million tonnes of rice are lost annually due to floods in India and Bangladesh alone. The global distribution of certain crop pests and diseases is already expanding. For example, wheat stripe rust appeared in South Africa for the first time in 1996 and in Western Australia in 2002. The notorious tobacco whitefly has also steadily spread northwards over the past two decades from the tropics into temperate regions, infecting and spreading viruses to horticultural crops such as tomatoes, cucumbers, and beans. In addition, one of Europe's most destructive insect pests of brassica crops, the diamond-back moth, is now regularly appearing on UK crops.

Food insecurity exists when people lack sustainable physical or economic access to enough, safe, nutritious, and socially acceptable food for a healthy and productive life. Food insecurity is part of a continuum that includes hunger (food deprivation), malnutrition (deficiencies, imbalances, or excesses of nutrients), and famine. There are many complex reasons for which an individual becomes food insecure. Food insecurity can result from declines in agricultural production as a result of declining soil fertility and water stresses. Sub-Saharan Africa's (SSA) dependency on rain-fed agriculture makes it vulnerable to climate change and variability which is a major threat to food security. Biotic (pests and diseases) and abiotic stresses (e.g., droughts, floods) result in major crop losses and consequent increases in food prices. Changes in climate and increases in extreme weather events, such as floods and drought, have become major challenges to stability of food supply and people's livelihoods in the sub-Saharan Africa. These weather events have made it more difficult for farmers to earn a stable income. In addition, climate change impacts have resulted in an increase of pest and diseases, which in turn has led to the misuse and abuse of pesticides with their negative effects on human health and the environment (Abano and Buah, 2015; Osei, et al,2014).

Another major challenge to achieving food security in the sub-Saharan Africa is the high rate of population growth, which increases the amount of food needed to adequately feed people in the sub-region. By 2020, the number of food insecure people in Sub-Saharan Africa (SSA) is projected to exceed 500 million out of a total population of roughly 1 billion. In other words, without any significant increase in investment or change in historical trends of major indicators, more than half of the region's population will consume less than the nutritional target of 2100 calories per day per person. Contrary to SSA's projections of future food insecurity, the number of food-insecure people in Asia is projected to decline from 433 million in 2010 to 320 million in 2020. The total number of stunted children is also expected to reach 64.2 million in 2020. This chapter will focus on the contribution of plant breeding to a more sustainable food sufficiency.

Current Horticultural Systems and Potential for Contributing to Food Security

Global production and exports of horticultural crops are rising steadily (Spore 2007). The overall challenge is to achieve sufficient horticultural production and fulfil the growing world demand to facilitate the socioeconomic development of farmers in developing countries, while preserving the environment and reducing risks for human health and ecosystems. However, yield increases have been smaller than area growth and have been negligible or even negative in the least developed countries. While experience shows that horticulture can offer good opportunities for poverty reduction because it increases income and generates employment, care must be taken that small and poor farmers are not excluded from the opportunities in these market sectors. Consequently, we argue that development agencies must put more emphasis on horticultural research and development, especially in the following priority areas: genetic improvement, safe production systems, commercial seed production, postharvest facilities, and the urban/pre-urban environment (Spore 2007).

Horticulture's Dwindling Fortunes: Plant Breeding to the Rescue

When people invented agricultural technology about 10,000 years ago, human cultures and several other life forms were largely altered by the new inventions. The agricultural evolution heralded the era of changing plant forms; with genetics, and later plant breeding, serving as agents of change. Prior to the evolution, plants existed in unattractive wild forms with enormous inherent yet-to-be-tapped genetic benefits. Humans' quest for food, feed, fuel, and fibre drew them to the jungles in search of resources. We later realized that so many of those wild plant forms possess the traits and attributes that will support all life forms for all generations. However, the gap between wild plants and the domesticated plant types to which we are accustomed today is remarkably huge; widest and most dramatic in many cereal, fruit, and vegetable crops, where the ancestors may be almost indiscernible. Out of the existing huge number of plant species, only about 500 were known to have been domesticated worldwide for the use of man.

Notable among the earliest domesticated and “genetically” transformed wild plant types were horticultural crops like cabbage (Brassica oleracea), tomato (formerly Lycopersicon esculentum, now S. lycopersicum), and others that are grouped under the heading of ‘brassicas’ cauliflower, Brussels sprouts (Osei, et al., 2014).

Tomato, for instance, had a huge transformation from its wild ancestor into its current food form. It is probably hard for anyone to believe that today’s beautiful and juicy tomato vegetable was once considered lethally poisonous! Wild tomato versions were small, cherry-like yellow fruits which were later “genetically” transformed into big juicy red fruits through several generations of natural selection and breeding (Osei, et al., 2014).

In the course of breeding for agronomic and economically important traits in horticultural crops, we see plant breeders achieve a horticultural crop variety having a narrow genetic base as a result of rigorous selections for genetic and morphological uniformities. Hence, the problem of narrow genetic diversity in crops generally has been partly created by plant breeding. Major crops that are bred for high productivity are reaching yield ceilings as a result of dwindling genetic variability. Yield (genetic yield potential or production) here means the harvestable biomass that one may achieve by growing a particular genetic material (Ribou et al. 2013).

Generally, improved agronomic crop management that entails fertilization, integrated pest and disease control, environmental-friendly and timely weed control, improved water availability through modern irrigation systems has resulted in an upsurge in realized yields in agriculture over time; increased genetic yield potential has not made substantial contribution. The yields of many conventional horticultural crops have plateau, so much that breeders no longer achieve ground-breaking success of a “bump” from their efforts at breeding for yield increase. The genetic implication is that the individuals in the population of an elite crop germplasm now have so many genes in common and consequently differ in too few gene loci. Since yield is a complex polygenic trait, crossing individuals that share many identical loci may not produce the kind of complementarities that is needed at the loci that control yield in other to achieve heterosis, “Heterosis is the

phenotypic superiority of a hybrid over its parents in growth rate, reproductive success and yield" (Lippman and Zamir 2007).
Interestingly, the solution to the problem of narrow genetic base with the attendant yield ceiling or yield plateau lies with plant breeding. Plant breeders are always eager to diversify their base genetic resources through introduction or introgression, mutation, hybridization, and through molecular breeding. Biodiversity is a key agricultural resource that is needed for improvement. Breeders look for novel alleles in introduced germplasm in order to improve their local adapted genetic materials. Relative wild and weedy species of agricultural crops are collected and conserved on the anticipation that they serve as repositories of favourable novel alleles that can be introgressed into conventional species for genetic improvement and diversification. Mutagenic agents such as radioactive substances are employed to create useful variations; though the rate of success is usually very slim. Genetically diverse individuals in a population are often systematically crossed in order to achieve hybrids that share the characteristics of the parents. During the last 20 years, molecular markers have entered the scene of genetic improvement in a wide range of horticultural crops. Among the major traits targeted for improvement in horticultural breeding programmes are disease resistance, fruit yield and quality, tree shape, floral characteristics, cold hardiness, and dormancy.
The importance of fruits and vegetables (F&V) in the diet of mankind cannot be over emphasized. Many reviews have reported the wide range of determinants of desirable quality attributes in fruits and vegetables such as nutritional value, flavour, colour, texture, processing qualities and shelf-life (Bapat et al, 2010; Vadivambal and Jayas, 2007). The understanding of the fundamental processes that influence fruit set, maturation, and ripening are required to manipulate fruits and vegetable yield and quality. Biotechnology has played a significant role in this respect. Report by Bapat et al (2010) revealed the constraints surrounding the extensive reproductive cycle in some fruits and vegetables that have long juvenile periods, the complex reproductive biology, high degree of heterozygosity, inter and intra incompatibility and sterility of breeding of fruits and vegetables plants such

as tomatoes, orange etc. for improvement. Typically, biotechnology technique such as genetic modification is used in F& V to enable plants tolerates the biotic and abiotic stresses, and plant resistances to problematic pests and disease, which may provide higher nutritional contents, and extend the shelf-life of the produce. The objective of this study was to provide a critical review of the use of biotechnological approaches to improve nutritional quality of fruits and vegetables.

Biotechnology: Origin and Definitions

A review by Uche (2004) well documents the origin and various definitions of the word biotechnology. The term biotechnology is viewed today as the novel technique capable of reshaping global agriculture (Buttel, 1989) even though it has been practiced by ancient farmers. Evidence support the fact that as far back as 6000BC, yeasts were used in baking and brewing, and the use of living organisms such as bacteria and molds for fermentation was indispensable in the preparation of diet by people in ancient civilization (Bud, 1991). Therefore, ancient farmers could be thought of as the first biotechnologists (SPORE, 1996). In another definition, OTA (1989) described biotechnology as 'any technique that uses living organisms, or substances from these organisms to make or modify a product, to improve plant and animals, or to develop microorganisms for specific uses'. Additionally, Persley's (1992) view of traditional biotechnology covers well established and widely used technologies in brewing, food fermentation, conventional animal vaccine production, and many others based on the commercial use of living organisms. In recent times, advanced biotechnology techniques involve the use of induced mutations, marker-assisted selection, homologous recombination, genomics, and genetic modifications (Gellatly and Deniss, 2011). The major ones are the tissue or cell culture, cell fusion, embryo transfer, recombinant DNA, and age-old fermentation technique. Table 1 presents the biotechnological approaches developed so far for crop production.

Today, plant biotechnology has been defined as comprising a range of advanced methods, which lead to a variety of improvement, true reproduction, and a very large number of individual plants, which are exactly the same as the parent variety (SPORE, 1996). In the mist of recent global challenges such as increasing population, increasing demand for food, climate change, and water scarcity, plant biotechnology has become a necessity for growth and yield performance to meet the food needs of today. The production of quality fruits and vegetables with improved shelf-life is no exception.

Table 1: biotechnological approaches developed for crop production

Technology	Application
Meristem and bud culture	Micro propagation for commercial purpose, genetic conservation and exchange of material
Zygotic embryo culture	Inter-specific crosses
Anther and microspore culture	Haploid production
Cell and tissue culture	In vitro selection, soma-clonal variation, embryogenesis, artificial seeds
Chromosome engineering	Zn gametes for inter-specific crosses
Protoplast culture	Fusion for somatic hybridization
Genetic engineering	Gene transfer
Molecular markers (RFLPs)	Aid to breeding programmes
Monoclonal antibodies	Diagnosis of plant diseases (pathogens)
Recombinant DNAs	DNA transfer
Induced mutations	Inter-specific DNA crosslinks
Marker-assisted selection	Aid breeding programmes
Homologous recombination	DNA transfer
Genetic modification	Improve crop varieties using molecular biology and plant breeding techniques
Genomics	Cell or tissue at the DNA, mDNA or protein levels

Source: Gellatly and Dennis, 2011

Genetically modified crops

Biotechnology encompasses a wide range of technologies and they can be applied for a range of different purposes, such as the genetic improvement of plant varieties and animal populations to increase their yields or efficiency; genetic characterization and conservation of genetic resources; plant or animal disease diagnosis; vaccine development; and improvement of feeds. Some of the technologies may be applied to all the food and agriculture sectors, such as the use of molecular DNA markers or genetic modification, while others are more sector-specific, such as tissue culture (in crops and forest trees), embryo transfer (livestock) or triploidization and sex-reversal (fish). Higher productivity holds the key in the fight against rural poverty. Biotechnology promises to boost productivity and thus raise rural incomes, much in the same way that the green revolution did in large parts of Asia during the 1960s to 1980s. Productivity gains encompass essentially all factors of agricultural production. This may mean higher crop and livestock yields, lower pesticide and fertilizer applications, less demanding production techniques, higher product quality, better storage and easier processing, or enhanced methods to monitor the health of plants and animals. One type of technology, however, has given rise to a host of concerns and questions, namely

Genetically Modified Organisms (GMOs)

GMOs are those organisms that have been modified by the application of recombinant DNA technology or genetic engineering, a technique used for altering a living organism's genetic material. With the rapid advances in biotechnology, a number of genetically modified (GM) crops or transgenic crops carrying novel traits have been developed and released for commercial agriculture production. These include, inter alia, pest resistant cotton, maize, canola (mainly Bt or Bacillus thuringiensis), herbicide glyphosate resistant soybean, cotton and viral disease resistant potatoes, papaya and squash. In addition, various transgenic crops are under development and not yet commercially released with traits for biofortification, phytoremediation and production of pharmaceuticals, such

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as rice with high level of carotenoid for production of Vitamin A (e.g. golden rice) and bananas with vaccines.

Commercial cultivation of transgenic crops started in the early 1990s. Herbicide tolerance and insect resistance are the main GM traits that are currently under commercial cultivation, and the main crops are: soybean, maize, canola and cotton. GM crops are now commercially planted on about 100 million hectares in some developed and developing countries.

Argentina, Brazil, China and India are the largest developing-country producers of transgenic crops. The choice of GM crops varies among the developing countries, with insect resistant cotton being the most important commercially produced transgenic crop in Asian and African countries, while herbicide-resistant soybean followed by insect-resistant corn is predominant in the Latin American continent.

The need for biotechnology in fruits and vegetable production

A number of challenges have called for the application of biotechnology in the production of fruits and vegetables. These are population increase, water shortages, climate change, high perishability or postharvest decays, and short shelf-life associated with fruits and vegetables. Fruits and vegetables by their intrinsic properties require more waters and in the face of water scarcity throughout the world, biotechnology will be required to develop fruits and vegetables that can withstand water stress and still be able to produce good crop of high quality and yield. For instance, during the last century, world population rose from 1.6 to 6 billion creating huge challenges for agriculture. However, new technologies increased crop yields drastically so the predicted catastrophic starvation and resulting conflicts did not occur. There are still serious challenges to be faced. World population is anticipated to rise to 10 billion by 2050 (Abano and Buah, 2015). Freshwater, vital for agricultural productivity, is becoming scarce and climate change could increase temperature, drought, and uncertainty. New crop varieties need to be developed quickly to meet these challenges and biotechnology will be needed to enhance existing technologies to achieve this.

So far, biotechnology has been successfully used to develop insect and herbicide resistance in a limited number of crops. In the future, the actual metabolism of the crop plants will be altered to produce new varieties or species that are tolerant against environmental stresses. In addition, the nutritional value of crops such as rice will be enhanced. Crops will also be used to harvest the sun for biofuels to replace fossil fuels and reduce the emission of CO_2. Some of these new crop plants are already in field trials and will be available to farmers in the near future (Gellatly and Dennis, 2011). Postharvest decays of fruits and vegetables are a major challenge throughout the world. The degree of postharvest loss through decay is well documented. In the industrialized countries, it is estimated that about 20–25% of the harvested fruits and vegetables are decayed by pathogens during postharvest handling (Sharma et al, 2009; Singh and Sharma, 2007, Droby, 2006; Zhu, 2006; El-Ghaouth et al., 2004). The situation is far more exasperating in the developing countries, where postharvest decays are often times over 35%, due to inadequate storage, processing and transportation facilities (Abano and Sam-Amoah, 2011). The use of synthetic fungicides such as benomyl and iprodione to control postharvest diseases of fruits and vegetables are well known in scientific literature (Zhang et al, 2007; Singh and Sharma, 2007; Korsten, 2006; Zhu, 2006; El-Ghaouth et al., 2004; Fan et al, 2000).

The health and environmental concerns associated with the continuous use of synthetic fungicides have alarmed legal enforcers and consumers to demand greener technology and quality products from the food industry as well as the scientific community. In the past 20 years, microbial antagonists like yeasts, fungi, and bacteria have been used with limited successes to reduce postharvest decays in fruits and vegetables (Sharma et al, 2009; Zhang et al, 2007; Droby, 2006; Korsten, 2006; Zhang et al, 2005; Roberts, 1990; Droby et al., 1991; Wisniewski and Wilson, 1992). For instance, fungal diseases like grey mould, powdery mildew, and downy mildew in grapes do notable only cause losses in yield but also reduce wine quality (GMO Compass, 2006). However, the advances in biotechnology can be employed to develop fruits and vegetables with improved quality and shelf-life.

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According to Lers (2012), the ability to maintain the quality of stored F&V during postharvest storage is highly related to the physiological, biochemical, and molecular traits of the plant from which they derive. These traits are genetically determined and can be manipulated using genetic breeding and/or biotechnology. Published research results have revealed potential genes, which when manipulated can be used to improve postharvest qualities of crop plants. The application of this biotechnological knowledge should not only lead to major improvements in postharvest storage of fresh fruits and vegetables but as well better human food supply.

Biotechnological approaches applied to fruits and vegetables.

The transfer of genetic material from one organism into the DNA of another called transgenic application has been widely used in fruits and vegetables. Tolerant plants to biotic and abiotic stress, higher nutritional contents and extended shelf-life are some of the advantages of transgenic plants. In addition, once a useful transformation is obtained, vegetative propagation, which is the normal method of multiplying in several fruit plants, provides unlimited production of the desired transgenic lines. Recently, reports indicate that recombinant DNA technology has been used by scientists to delay ripening in fruits and vegetables in order for farmers to have the flexibility in marketing their produce and ensure consumers good quality produce from their farms (Bapat et al., 2010). Transgenic grapes were developed for modified auxin production, fungal and virus resistance as well as fruit quality and colour modifications (DeFrancesco, 2008). Costantini et al. (2007) transformed grape cultivar Thompson Seedless with an ovule-specific auxin-synthesizing (DefH9-iaaM) gene and observed that average number of inflorescence per shoot in transgenic grape lines doubled was as compared to control.

The Dynamics of Ripening and Perishability in Fruits and Vegetables

Fruit ripening and softening are major attributes that contribute to perishability in both climacteric and non-climacteric fruits. Fruits and vegetables such as tomato, banana, mango, avocado etc. take about a few days after which it is considered inedible due to over-ripening. The spoilage includes excessive softening and changes in taste, aroma and skin colour. This unavoidable process brings significant losses to both farmers and consumers alike. Even though ripening in F&V can be delayed through several external procedures, the physiological and biochemical changes associated with ripening is an irreversible process and once started cannot be stopped (Prasanna et al., 2007; Martínez-Romero et al., 2007).

African and other third world countries put people at increased risk of food crises (e.g., the population of Niger increased from 2.5 to 15 million from 1950 to 2010). According to some estimations done by FAO, Africa will produce enough food for only about a quarter of their population by 2025 if the current growth rate continues. Certain groups of people are particularly vulnerable to food insecurity, including women (especially low income pregnant and lactating women), victims of conflict, the ill, migrant workers, low-income urban dwellers, the elderly, and children under five.

The consequences of food insecurity relates to significant environmental and socio-economic problems such as extreme poverty and malnutrition. Poverty is unmistakably the driving factor in the lack of resources to purchase or otherwise procure food and many people cannot afford food because of poverty. Poverty, combined with other socioeconomic and political problems, creates the bulk of food insecurity around the world. Malnutrition is also a direct consequence of food insecurity and the underlying cause of death of more than 2.6 million children each year, a third of under-five deaths, and a third of total child deaths worldwide. Nutritional consequences of insufficient food or under-nutrition include protein energy malnutrition, anaemia, vitamin A, iodine and iron deficiencies. Iron deficiency contributes to the deaths of young women during pregnancy and childbirth. It is a leading cause of anaemia. African countries have among the highest risk of iron deficiency in the world. Malnutrition results in high rates of infant and maternal mortality coupled with disease and disability. The aggregate costs of food and nutrition insecurity in Africa impose a heavy burden on efforts to foster sustained economic growth and improve general welfare.

In short, no matter what the arguments are, there are an estimated 870 million chronically undernourished people in the world, 98 % of who live in developing countries (FAO 2012). There is a strong correlation between the level of development and food security (Food Security Network 2012). Food security is dependent on a strong and sustainable food system which comprise of production, processing, distribution, marketing, acquisition, and consumption of food. These are lacking in many developing countries making them food insecure. Food insecurity is a fact and not a myth. Food insecure countries/ regions must put proper structures in place to overcome undernourishment. The best way to overcome undernourishment is to produce sufficient quantities of food at places where it is easily accessible and affordable to those who need it. The backbone of food production is the development of crop varieties and sustainable food production systems. The breeding of horticultural crops is especially crucial because vegetables and fruits are the best suited to provide vitamins that helps to overcome "hidden hunger" in addition to hunger itself.

Importance of Biodiversity in Plant Breeding

Plant breeding involves the selection of plants with desirable traits. These desirable traits can be classified broadly as yield potential, resistance/tolerance to biotic stresses and quality which includes appearance, taste, cooking or processing character and nutritional value. Plant breeders, therefore, need plant populations that have wide variation/diversity for all kinds of traits to make selection possible and to create new genotypes. Biodiversity is therefore the foundation of plant breeding. There cannot be breeding for a trait if variants of that trait do not exist. This makes it crucial to preserve a set of genotypes (germplasm) that are representative of the variation within a species.

Genetic diversity is the greatest resource of the plant breeder, the breeding and promotion of modern varieties is a threat to the maintenance of genetic diversity. This is because seed companies promote only a few uniform varieties with the desired traits and this could lead to genetic erosion. For example, 52 % of vegetables grown worldwide receive breeding attention;

of these only 17 % are found in large scale breeding programmes (Dias 2011). Vegetable biodiversity is reported to be eroding at a rate of 1.5–2.0 % per annum (Dias 2011). The challenge of genetic erosion is mitigated by international efforts at conserving large amounts of germplasm of various crops in gene banks around the world (Centre for Research in Agricultural Genomics CSIC-IRTA-UAB-UB CRAG Building).

In a developing economy like that of our sub–region, there are many limitations that must be resolved if we must participate in this 'gene revolution'. These include

- Insufficient Funding
- Capacity building – human and infrastructural requirements
- High costs of research – capital intensive.
- The lack of coherent research strategy and the impact of legislation are tampering the successful use of new tools and methods in plant genetics to conventional farming.
- Absence of regulatory systems for the approval and monitoring of the products of biotechnology in the system.
- Lack of intellectual property laws to protect inventions and patents will limit the potential for profitable applications of biotechnology to many crops.
- Poor Public – Private sector linkage
- Lack of Advocacy and Public awareness (Isoun, 2004)

Conclusion

The application of biotechnological approaches to improve nutritional quality of fruits and vegetables were reviewed. It was evident that developed biotechnological approaches have the potential to enhance the yield, quality of fruits and vegetables to meet the demands of the 21st century. Food self-sufficiency cannot be achieved without plant breeding. Over the years, the horticultural industry has benefited immensely from the breeding of improved varieties. Thousands of varieties of horticultural crops have been bred for various characters including higher yields, tolerance to biotic and abiotic stresses and end-user traits. However, many challenges still exist especially in the area of changing consumer preferences and emerging pest and diseases. The challenge with biotic and abiotic stresses is expected to become worse with climate change. Plant breeders in sub-Saharan Africa must therefore combine conventional and biotechnology approaches in order to develop varieties that will meet current and future challenges. The full benefit of the knowledge can be reaped if there is total commitment by all stakeholders regarding increased and sustained funding increase agricultural and less cost and time for registration and commercialization of new traits.

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