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The Role of Green Biotechnology through Genetic Engineering for Climate Change Mitigation and Adaptation, and for Food Security: Current Challenges and Future Perspectives

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Authors' contributions

This work was carried out in collaboration between both authors. Author AS designed the study, performed the statistical analysis, wrote the protocol, wrote the first draft of the manuscript and managed the literature searches. Author BA managed the analyses of the study. Both authors read and approved the final manuscript.

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ABSTRACT

Climatic change has a great challenge to almost all human activities over the years. Continuous increase in climate change could have a negative effect on global food security. In order to feed the current ever-increasing world population, there is a need to double the rate of agricultural productivity. Biotechnology through genetic modification can contribute their incredible roles positively towards reducing vulnerability of natural and human systems to climate change effects including greenhouse gas reduction, and increase agricultural production on less land in helping to meet future food by the adoption of GM-crop traits such as herbicide-tolerant crops, drought-tolerant crops, insect-resistant crops, and high-yielding transgenic crops which counters the negative effects of climate change. It is important that bio-safety regulatory systems to be established and good policies formulated on agricultural development with the use of sustainable agricultural biotechnology with public-private partnership to effectively utilize modern biotechnology to enhance food security and mitigate climatic changes. Currently, modern biotechnology has encountered

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enormous public debates related to risks and benefits of genetically modified organisms in terms of human health, environment, socio-economic, and ethical and cultural concern issues. However, safe application of modern agricultural biotechnologies is significantly contributing to the current and future climate change adaptation and mitigation efforts, and greatly improve agricultural productivity and food security to ensure food availability or access to food for all and efficient utilization of food resources globally. This will ensure that the GM-crops have no adverse effect on living organisms and the environmentally safe. Therefore, the aim of this review paper was to assessed the current challenges and future perspectives of biotechnology through genetic modification for climate change adaptation and mitigation, and food security.

Keywords: Adaptation, bio-safety; biotechnology; climate change; food security; genetic engineering; and mitigation.

ABBREVIATIONS AND ACRONYMS

DNA : Deoxyribonucleic Acids
FAO : Food and Agriculture Organisation
GE : Genetic engineering
GHGs : Greenhouse gases
GMO : Genetically Modified Organisms
IPCC : Intergovernmental Panel on Climate Change
ISAAA : International Service for the Acquisition of Agri-Biotech Applications

1. INTRODUCTION

Climate change is one of the most critical challenges currently facing humanity and continue to be a major global problem on sustainable development [1], due to climate change associated factors including unexpected climate change/ temperature rising, can be caused either by the Earth's natural forces such as solar radiation or human activities such as release of GHGs into the atmosphere results in global warming and changes in rain fall amount and patterns [2]. Climate change has a diverse effects on agriculture productivity and quality, rendering food supply less secure in global especially in developing countries [3], while the global population is regularly to increase [4].

Currently, there are two most common policies to climate change: (i) adaptation, which reduce the vulnerability of natural and human systems to climate change effects [5] and (ii) mitigation, which is another policy retort to climate change which reduces the negative impact of climate change through involvement of human action particularly by reducing the concentrations of GHGs [6], either by reducing their sources or by using fossil fuels more efficiently for industrial processes, switching from biomass to renewable energy and increasing their 'sinks' to remove more CO_2 from the atmosphere [5]. There are hard facts about what will definitely be the result of increase in the concentration of GHGs within the atmosphere, but no firm time scales are known [1].

Several research have been conducted on the potential impacts of climate change on agricultural productivity and food security may depend not only on changing climate condition, but also on the ability to adapt through changes in technology [2,7], however the over declining of food production per person has been putting billions of people food unsecured, extreme poverty, malnourished [8] and starved and unavailability of balanced diets in areas where hunger and malnutrition are endemic due to uncontrollable climate alteration [9]. According to FAO [10] food security is defined as the state achieved when food systems operate that "all people at all times have physical, social and economic access to enough and healthy food for an exciting human life".

Before considering, which technological approaches are best for reducing the effects of climate change on agricultural adaptation and mitigation and its impact on food security, it should be essential to determine which problems are visibly solved by technological tools and which can be solved by changes in the socio-economic or socio- political status [11].

Moreover, in order to feed the ever-increasing world population, there is a need to double the rate of agricultural production. Due to this, new or improved technologies could help feed the world [12]. As the world population growth is doubling, genetic engineering based biotechnological approaches can contribute their incredible roles positively by mitigating the impact of climate change through greenhouse gas (GHGs) reduction, crops adaptation and increase in yield on less land [4]. Previously, convectional biotechnology through tissue culture and convectional breeding as a realistic option that could solve problems of climate change. However, nowadays modern green biotechnology is a promise technology for significantly mitigating the negative effects of climate change through the use of genetically modified or transgenic crops for sustainable yield production and food security [3]. In this context, the main aim of this review was to assessed the roles of genetic engineering-based biotechnology for climate change mitigation and adaptation and for food security, and also address the question: What potential benefits and risks are in the innovation of this technology and practice?

2. NEW AREAS OF BIOTECHNOLOGY

Large scale solutions must be implemented immediately on the urgency of climate change [11]. For the development of crop traits and/or varieties that have a capability to grow in changing environment, green biotechnology through genetic modification techniques could have a large scale solution for taking immediate action to create sustainable agriculture through the creation of GM-crops that are designed to meet the challenges of a new climate era [1].

Biotechnological approach involves the practical application of biological organisms or their sub-cellular components in agriculture. The incredible technique currently in use called genetic engineering or genetic modification, which working towards creating crops that are resistant to environmental stress. Modern biotechnology has been playing a key role in the adaptation of agriculture to new climate realities or to address these coming problems by creating seeds that are tolerant of new agriculture conditions [13].

Genetic engineering or genetic modification refers to the manipulation of the genetic materials in living organism for creating genetically modified organisms (GMOs) or transgenic organisms using recombinant DNA technology and the gene-splicing techniques of biotechnology that enabling them to perform specific functions, which was impossible with the conventional breeding methods [14,15]. This technique is faster and efficient mechanisms for achieving desired resulting traits.

Moreover, practically several recent reviews that have critically assessed on genetic engineering based biotechnology having impressive progress over the past two decades in manipulating of genes into microorganisms and crops to give resistance to pests and diseases, herbicide-resistant, drought-tolerant [13], and produce nutritionally valued GM crops by reduction of saturated fats and increase the levels of unsaturated fatty acids, increase effectiveness of bio-control agents [16], production of drugs and vaccines in crops, and it also essential for the production and development of healthy foods with an essential minerals and vitamins such as the development of high vitamin-A golden rice and the recent development of two varieties of vitamin-A rich cassava lines (UMUCASS 42 and UMUCASS 43) [2]. Production of GM crops provides new ways to fulfill future food security requirements but may have risk associated factors [16].

Despite this, there are skepticisms or hesitation on the acceptability and adoption of this modern biotechnology in such countries which are even affected by climate change and food insecurity [17]. So that, more struggles need to be carried out to enlighten the populace on the benefits of biotechnology in enhancing agricultural productivity, food security and mitigating the effects of climate change. Mostly it could be overcome by a change in social policy and attitudes, because the major aim of this green biotechnology is to enhance productivity and maximize productive capacity of resources worldwide.

3. MODERN BIOTECHNOLOGY FOR CLIMATE CHANGE MITIGATION AND ADAPTATION

3.1 Modern Green Biotechnology for Climate Change Mitigation

According to the IPCC (5) prediction the global surface temperature will increase by 1.4-5.8°C by 2100 years due to increasing concentration of green-house gases (GHGs) which are majorly sourced by carbon dioxide (CO_2), methane (CH_4), nitrous oxide (N_2O), hydro-fluoro-carbons (HFCs) and sulphur hexafluoride (SF_6) emissions from agriculture [6]. Moreover, study has conducted by Feyssa and Gemeda [18] justified that the climate change mainly affect the rain-fed agricultural sectors in technologically and economically less developed countries like Africa. Due to drought by 2100, arid and semi-arid regions of Africa are expected to expand by 60-90 million hectares resulting in agricultural losses [5].

Of the many technology options the right technology delivered in the right way should be able to help reverse agriculture's impact on climate change and ultimately contribute to food security and distribute its benefit more equitably throughout the world [11,12].

Importantly biotechnological techniques must play a crucial role in the fight against climate change mitigation in worldwide to reduce green-house gases (GHGs) emission through use energy efficient farming and reduced synthetic fertilizer usage [4]. Genetically modified crops do not need as much maintenance as regular crops; farmers are not wasting as much fuel to power their equipment, resulting in a reduction of greenhouse gases emitted. Due to this simple yet effective implementation of genetically modified crops in farming leads farmers to expend less fuel as a result of not demanding to ride on farm equipment as long [1].

Uses of synthetic (inorganic) fertilizer such as ammonium chloride, ammonium sulphate, sodium nitrate, calcium nitrate in agriculture sector have led to contaminate the environment with hazardous toxic chemicals and contribute for the formation as well as releases of certain green-houses gasses (such as N_2O) by bringing from the soil to surrounding atmosphere when they interact with common soil bacteria. However, reducing the use of artificial fertilizer will invariably reduce nitrogen pollution of ground and surface waters, and the herbicide tolerant (HT) technology has contributed to increased production, improving weed control and providing higher yields [19]. Genetically engineered crops offer an advantage to reduce the use of these artificial inorganic nitrogenous fertilizer usage that stays in the atmosphere for more than 100 years, for instance genetically modified Canola which has shown significant reduction in the amount of nitrogen fertilizer that lost into atmosphere [4].

Modern green biotechnology also allows farmers to enabling the production of more fertile and resistant crops towards both biotic and abiotic stress by reducing demand for cultivated land, which is important for decreasing of overgrazing and deforestation; and fossil fuel-based inputs; use less and environmentally friendly less fuel usage by decreasing necessity and frequency of insecticides spraying application and reducing tillage using GMO crops such as sugarcane, oilseed; and practicing soil carbon sequestration (i.e. capture or uptake of carbon containing substances in particular CO_2 and increase the soil organic carbon content with implication of that increased soil carbon storage mitigates climate change) which is an important strategy to mitigate the increase of atmospheric CO_2 concentration by reducing the amount of conventional tillage or by leaving at least 30% of residue on the soil surface [19–21]. So that, to reduce the negative effects of artificial fertilizers, use energy efficient farming, the use of environmentally friendly GMO crop energy and practicing soil carbon sequestration are being encouraged.

3.2 Modern Green Biotechnology for Crop Adaptations to Environmental Stresses

Consequences of global climate change responsible for altering patterns of adaptation to several environmental stresses. According to Bianchi et al. [22] agronomical techniques of conventional landscape management has contributed significantly to crop adaptations that are resistant to biotic stresses (such as insects, fungi, bacteria and viruses), while the energy costs may overshadow its benefit to agriculture and also controlling of abiotic stresses including salinity, drought, water stress, extreme temperatures and chemical toxicity which have negative impacts on agriculture and natural status of the environment through fresh water use. However, the agricultural sector uses about 70% of the available fresh water and this is likely to increase as temperature rises, and about 25 million hectors of land is lost each year due to salinity caused by unsustainable irrigation [23]. The glyphosate containing sprays in pesticide-resistant crops destroy all weeds but the growth of the glyphosate resistant GM-crop is protected regardless of how much glyphosate is sprayed and consequently the glyphosate load of the land has been substantially increasing after the first few years of a slight reduction This showing that glyphosate has serious effects on the environment change and biodiversity with the development of herbicide-resistant weeds [24].

Despite many attempts there are no commercially available non-GM plants with traits that reduce the effects of abiotic stress. On the other hand, green biotechnology through genetic engineering should have been facilitated crop adaptation to abiotic stressful conditions and give priority to create a tolerant traits (such as drought, salinity, herbicide and pesticide tolerant), nutrient enrich crops, which are giving high yielding performance of GM-crops such as tomato, rice, maize, cotton, wheat and oilseed rape have been developed on food production [19]. The genetically modified drought tolerant maize MON87460 expressing cold shock protein-B, up to 20% increased yields under water stressed conditions [25,26]. Drought tolerance also involves increased production and vacuolar storage of a range of solutes, including proline, glycine-betaine and mannitol to try and maintain water balance, leaf wilting, abscisic acid related stomatal closure and altered photosynthesis patterns are also used to decrease transpiration water losses, along with altered root growth patterns to search for more water [27]. High nutrient varieties are produced using genetic modification for instance GM rice and maize that produce β-carotene, which can be converted by humans to vitamin-A [12].

Furthermore, in the progress of modern biotechnology, reports have been suggested on the production of herbicide-tolerant crops to reduce soil carbon sequestration because of using glyphosate based herbicides on GM-crops that reduced the need for tilling as a weed control strategy [13,21], the use of GM insecticide plants (often called Bt plants) particularly cotton, has reduced the use of external chemical insecticides, and then needed to reduce the adverse effects of CO_2 emission which have considerably assisted in mitigating the effects of climate change [28]. Living systems of fungal applications in agricultural biotechnology termed as Myco-biotechnology needed to solve environmental problems and restore degraded forest ecosystems [29]. Therefore, biotechnological approaches using genetic engineering would be most desirable and offer new improving stress resistance varieties [30].

4. MODERN BIOTECHNOLOGY FOR AGRICULTURAL PRODUCTIVITY AND FOR FOOD SECURITY

Currently, food security and sustainable agriculture have become a burning issue in worldwide. The primary factors for agriculture productivity such as plant and animal production for changing global climate and increasing global population unexpectedly [31]. The surprising consequence of climate alteration on agricultural productivity and food security has been predicted as a major concern area that needs an adequate solution in the near future. Gradual climate change increase and extreme weather events will decline agricultural production (yields), increased soil degradation and pollution through nitrogen run off as increasing use of chemical fertilizers [32], and then resulted state of food insecurity and malnutrition also increase now and near the future [33]. Previous studies have suggested that, Sub-Saharan Africa is the most susceptible and vulnerable places to climate change in the world, as a result of wheat yields have already begun to decline 22% [34], 14% rice and 5% maize by 2050 [35] demonstrate the scale of the threat to food security posed by climate change. It is also estimated to be the most food insecure region in the future world. The impacts of climate change on only rain-fed agriculture farmers are the most disadvantageous and vulnerable groups [36].

Demand for agricultural production is expected to grow considerably as the world populations significantly increase. Evidently, the current state of agricultural technology will not serve to meet the production challenge ahead. This implies that globally climate change climb and then food security will decline, unless it will need either additional land to be brought into crop production or adoption of innovative biotechnological tools for creation of stress resistance traits in order to enable sufficient food availability/ yield increase in the future [37]. The availability of food from GM-crops for global consumers can be improved by increasing the efficiency and effectiveness of our primary food production systems, reducing waste during food processing, improving access to food supplies and decrease food costs for consumers particularly in developing countries [4].

Biotechnology on its own may not be the cure-all for the world's problem of food crisis. However, biotechnology through genetic engineering presents outstanding potential to increase the efficiency of both crop improvement and animal production thereby enhancing global food production and availability in a sustainable way through increasing yield per unit area of land. This is achievable once the entire technology can be integrated into the traditional smallholder farming systems [38].

Instead of using wholly conventional application of good agronomical approaches such as landscape management, crop rotation or mixed farming and use of traditional and indigenous knowledge on pests and diseases controlling, the advanced biotechnology based techniques can help agriculture further to achieve higher yields and meet needs of expanding population with limited land and less water resources [4] and applying GE-based Bt-gene integrated pest management programs by giving farmers new pest control choices [39]. Biotechnology through genetic engineering by producing virus, fungi and insect tolerant crops lead to increased productivity and cost reduction using reducing the use of agro-chemicals, thereby making farming a more profitable and very important for the poor and food insecure farmers [16].

Debatably, some researchers have been criticizing the adoptions of genetic engineering-based approaches that having some influence on agricultural practices and also have neither produced a sustainable production nor limited agriculture's impact on climate change. For instance, as a result of private sector investing more in research and development the policies associated with agriculture involve a shift in innovation resources from public control licensing of IP to the private sector, which undermine the ability of poor and subsistence farmers to strengthen agricultural productivity [40,41]. Nowadays, advanced novel findings using new technologies for increasing crop productivity through sustainable agriculture that have been guaranteed for environmental conservation and for food insecure people should be a significant mission worldwide. Different transgenic pest and disease resistances have already been commercialized [38]. The currently applied commercialized GM-products (i.e., soybeans, maize, rapeseed and cotton) and commercialized GM-traits (i.e. herbicide tolerance and insecticide resistance) are mostly limited and common which can be promoted monocultures [42], and countries making a substantial shift to GM-crops where food security has shown no improvement (such as USA) even those experiencing famine, rely on the export of food to generate income [12].

In addition, the quantity of glyphosate herbicide used in GM agriculture has caused the evolution of resistance in weeds, leading to a return to tilling and the use of other herbicides for weed control [43] and the use of GM insecticide plants (i.e. Bt plants) is causing the appearance of secondary pests [44].

Regardless of controversies, the adoptions of genetic engineering-based technologies have enormous rewards of GM-crops have been largely successful in mitigating and providing numerous benefits to growers worldwide, sustainable growth seeks to increase food production from a decreased land area or on small land being used in agriculture [32]; by adoption of glyphosate based herbicide-tolerant (HT) crops, such as Roundup ready soybeans, sugar-beets and rapeseed that permit farmers to reduce the need for tilling as a weed control strategy and reduces the risks associated with conservation tillage and the reducing the CO_2 emissions in the atmosphere [13]. Research findings have been suggested that farmers used GM-crops have increased their income by 34.3% yearly since 2010 [45,46], as these GM-crops have reduced the usage of pesticide and insecticide/ herbicide by 37% and 18% respectively [47]. Moreover, whatever the comparative risks of genetic engineering-based biotechnology may be, they have several significances that compared with conventional and primitive agronomical technologies to generate higher yields. Plants grown on industrial agriculture farms are more resilient to stress than those grown by means of agronomic primitive conventional farms [16]. In addition, the adoption of industrial agriculture approaches contributes to sustainable societies by reducing poverty and improving food security.

5. BIO-SAFETY POLICIES IN MODERN BIOTECHNOLOGY FOR CLIMATE CHANGE AND FOOD SECURITY

The development of biotechnology for climate change and food security depends on clear national bio-safety policies. Currently, several countries have ratified the Cartagena Protocol on Bio-safety for modern biotechnology applications [42]. Bio-safety systems are key to maximizing the benefits from biotechnology in terms of environmental and health issues are addressed by scientific risk assessments [48]. Bio-safety laws must be put in place to ensure that the crops released should be environmentally safe.

For efficient regulation and implementation of bio-safety laws and ensure bio-security, it is necessary that public-private partnership be considered for efficient utilization of modern biotechnology for mitigating climate change and enhancing food security [41]. The government cannot handle the climate change or emission of GHGs it alone, rather it can be reduced with the formulation of good policies on agricultural development with the use of sustainable agricultural biotechnology for agricultural productivity and mitigation of climate change. This should be done to ensure that there is no harmful effect on man and the environment. The governmental bio-policy makers should be communicated with university and other institution leaders and also farmers through seminars, community services, workshops and panel discussions because farmers need to be informed about the technological potential and management requirements of GM-crops [49]. The more enlightened the farmers are, the easier to accept the technology.

According to industrial approach views GM-foods are safe. Careful application of biotechnology and genetic engineering will make life better, improve human health and welfare, and save time and money. However, adequate regulation, constant monitoring, and satisfactory researches are essential to avoid possible harmful effects from GM-food technology, and also proper risk assessment protocol should be used on GM-crops using well authenticated and up-to-date methods of chemical analysis to estimate the contents of its major and minor components and to compare their amounts to those of the corresponding parent line with respect to climate change and health care [16].

6. CHALLENGES AND FUTURES LINE OF WORK

Impacts of climate change are becoming evident for food insecurity, health safety problems and there is no indication that these will reverse in the foreseeable future; action must be taken now to adapt in a timely manner. As the world population is expected to reach 9 billion people by 2050, the demand for food is also expected to increase by 70%, and countries will need an additional more than 400 million hectare of land for crops [50]. Therefore, if we want to feed the world without destroying our resources, the science and technology should drive the development of modern agricultural technologies.

Modern biotechnology has encountered enormous public debates related to risks and benefits of transgenic or genetically modified organisms (GMOs) technology in terms of human health, environment, socio-economic, and ethical and cultural concern issues. Besides the great potentials of biotechnology for increased food production and agricultural productivity, the risks must not be neglected due to the direct manipulation in the genetic makeup of organisms. As human knowledge is limited, the existence of unknown risks cannot be ruled out with absolute certainty, neither for genetically modified or transgenic crops nor for any other technology such as conventional breeding and natural selection [38]. Some of the political, socio-economic, cultural and ethical concerns about modern biotechnology are related to the fear of technological “neo-colonialism” in developing countries, intellectual property rights, land ownership, customer choices, negative cultural and religious perceptions, and fear of the unknown [16,51].

The attitudes and interests of various stakeholder groups supporting or opposing modern biotechnology have led to polarized opinions. There have been opponent activists who dispute the safety of the technology, citing possible environmental risks that need to be considered include; the creation of more rigorous pests and pathogens, exacerbating the effects of existing pests, harm to non-target species, disruption of biotic communities and possible loss of species and genetic diversity within species [52]. However, biotechnology through genetic modification by creating the GM-crops have been benefitted the environment through decreased chemical pesticide use by 37% since 1996 [4]. Moreover, health associated risks include the possible occurrence of undesirable toxic by-products in the crops, the emergency and transmission of antibiotic resistances to microorganisms of human digestion and unknown allergic reactions by food consumers [38]. According to current scientific knowledge, there are no indications that genetically modified crops are more dangerous than traditionally-bred varieties. This does not mean that there are no risks at all. However, the predictable risks are not related to the biotechnological process but to the end-product to be released. Thus, risk assessment studies have been carried out on a case-by-case basis for each individual technology product [38].

Confidentially, modern biotechnologies have been playing a central role in order to overcome the challenges (such as threaten food productivity, safety concerns on health and environment, socio-economic, cultural and ethical concerns) presently encountered in development and application [1,13], through GM crop varieties that sustain farming in marginal areas and restore degraded lands to crop production [4]. Modern green biotechnology tools will significantly continue to make positive contributions to the current and future climate change adaptation and mitigation efforts, and food security during climate change, alongside a range of other means to ensure food availability, access to food for all, and efficient utilization of food resources globally. The extent to which green biotechnology will help to achieve based on several factors, including the rate of technological development, governmental and public acceptance of novel biotechnologies, consumer acceptance of genetically engineered food crops, and cost-effective in the future [52]. It must not be forgotten that biotechnology could also bring about substantial positive environmental effects, such as lower conventional pesticides applications or reduce agricultural area expansion into ecological fragile environment, must not be confined to the risk side only. However, a responsible management of biotechnology is a prerequisite for sustainable agricultural development and it requires that effective regulation for bio-safety wherever transgenic crops are to be developed and released [38]. Therefore, all concerned parties must increase collaboration so that successful activities may be carried out in the future for potential risks and benefits of utilizing modern biotechnology products. In addition, farmers and the public at large should be informed and involved in any decision-making process of GM-crops applications, risk assessment and risk management, because of farmer and public participation is one of the main platforms to address bioethical issues arising from GM-crops [53].

Under this review, some of proposed future solutions for major challenges to genetic engineering and biotechnology debates/ controversies though creation of genetically modified organisms in order to achieve food security and climate change adaptation and mitigation [4,5,52] described as:

- Arguments should be scientifically-driven; not politically or self-interest driven and each country in the world has a stake in effecting the reduction of CO_2 emissions.
- National science and technology institution should take a leading role to ensure food sufficiency, anxieties on negative effects of GMOs have to science based and should be studied case by case in specifying in details with true evidence.
- Governments ought to put in place appropriate national and/or global bio-safety and biotechnology policies and legal frameworks before adopting such technologies.
- Formulation of best biotechnology policy and institutional responses will be having to enhance information flows and promote agricultural development or adaptation and may also cover the way for more effective climate change mitigation on agriculture.
- Policies and institutions that promote economic development and reduce poverty will often improve agricultural adaptation and may also pave the way for more effective climate change mitigation through modern green biotechnology.
- Adaptation and mitigation in agriculture will require local responses, but effective policy responses must also reflect global impacts and inter-linkages.
- Research on GM-crops will have to be supported primarily by the public sector. It is, therefore, recommended that national governments and donors should fund a major expansion of public GM-related researches. GM-crops will need to be examined in obligatory short and long-term nutritional/toxicological tests with laboratory animals under controlled conditions and also find more reliable and safer genetic transformation techniques for the development of GM-crops.
- Frequently, climate change adaptation and mitigation and crop yield production workshops, seminars and panel discussions should be done, which are effective tools to solve the extreme temperature that leads to agricultural yield reduction and also will change the attitudes of peoples towards climate change solutions.

7. CONCLUSION

Concurrent efforts are required to establish a sustainable global food system with climate-resilient agricultural production systems, efficient use of resources, low-waste supply chains, and more consumer choice for healthy diets. Sustainable solutions through future technologies must produce and be useful to those who are now malnourished and starved [3].

Several researches have been studied in the appropriateness of using agronomical and conventional technology approaches having a direct way to reduce poverty by raising the productivity of those factors of production controlled by poor farmer [54], that reduce external inputs and on-farm costs of seeds, incorporate multi-cropping and livestock for balanced diets, promote ongoing farmer innovation under an appropriate IP rights framework and are produced by a public sector that offers the appropriate incentives [12], the export of genetic engineered-based industrial technologies that are fixed in particularly exclusionary IP instruments, such as patents [55].

Fortunately, other genetic engineered-based industrial technologies showing their promise for both increasing yield in yield-limited agro-ecosystems and for promoting food productivity what the present system has not been able to achieve. Genetically engineered products such as rice and canola varieties that use nitrogen more efficiently with less fertilizer applications have been developed, adoption of herbicide-tolerant biotech crops, such as soybeans and canola permit farmers to substitute application of broad spectrum herbicides, like glyphosates, for tilling operations that not only degrade the soil but also reduce soil carbon sequestration, this resistance varieties also reduce application of herbicide and insecticide sprays and has reduced CO_2 emission [20,21]. Crops tolerant to various abiotic stresses have been developed in response to climatic changes. Modern biotechnology has highly applicable for drought tolerant crops [19] such as maize and hybrid wheat, arabidopsis, tobacco, cotton, and soybean [30].

This review paper shows that safe development and application of genetic engineered-based biotechnology can contribute positively towards food security and climate change adaptation and mitigation through reduction of CO_2 emissions, carbon sequestration, reduced fuel use, adoption of environmentally friendly fuels, and reduced artificial fertilizer use, employing bio-fuels for improved soil fertility and crop adaptability. These measures are meant to improve agricultural productivity and food security, and at the same time protecting our environment from adverse effects of climate change. Therefore, a proper adoption of genetic engineered-based biotechnologies will not only contribute to increased yield and food security, but also significantly contribute to climate change adaptation and mitigation programs by overcoming environmental problem is very important.

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COMPETING INTERESTS

Authors have declared that no competing interests exist.

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