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APPLICATION OF BIOTECHNOLOGY IN ADDRESSING NEGATIVE EFFECTS OF CLIMATE CHANGE ON THE ENVIRONMENT AND AGRICULTURAL PRODUCTION IN UGANDA

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Introduction

The world's population is set to reach 9 billion by 2050, under these circumstances, there is an increasing need to provide food security for the ever increasing world population. However, this is amidst increasing challenges associated with rapid climate change occurring over the globe. Climate change is defined as the change in climate attributed directly or indirectly to human activity that alters the composition of global atmosphere. One of the predisposing factors causing climate change is the accumulation of greenhouse gases (GHG). Formation and release of greenhouse gases particularly the nitric oxides from the soil to the atmosphere mainly occurs due to the use of inorganic nitrogenous fertilizers such as ammonium sulphate, ammonium chloride and ammonium phosphates. Burning of fossil fuels for heating, transport and power generation, bush clearing for agriculture, deforestation and animal rearing (livestock) have resulted into emissions of greenhouse gases including carbon dioxide, methane, nitrous oxides and chlorofluorocarbons into the atmosphere. Climate change is associated with long-term shift in weather conditions mainly by changes in temperature, precipitation and winds. In Uganda, the drastic effects of climate change have had significant socio-economic impacts in particular through floods, prolonged droughts and changes in seasonal rainfall all over the country thus threatening food security. Considering the adverse impacts of climate change on agricultural production, agricultural production, it is imperative that measures are put in place to curb the effects of climate change and biotechnology has been considered as a probable solution in addressing climate change.

Biotechnology in Agricultural production

Biotechnology, a technique that uses living organisms or substances from living organisms to make or modify a product, improve plants and animals or develop microorganisms for specific purposes has been widely applied in a number of agricultural innovations in a bid to address the challenges associated with the increasing demand for food security for the growing world population. Among the biotechnological tools applied in agricultural production are plant tissue culture technique—an excellent opportunity for mass propagation of clean planting in the laboratory, vaccine technology which involves the use of modern immunology to develop recombinant DNA vaccines for improving control of livestock and fish diseases; crop biotechnology which involves modification of crops through genetic engineering, has been employed to generate crops that are tolerant to salinity, drought, extreme temperatures, disease resistance and oxidative stress among other desirable traits.



Application of Agricultural Biotechnology in addressing Climate change

Agricultural biotechnology has been applied in the management of the adverse effects of climate change as exemplified by; generation of transgenic plants carrying genes for water stress management which has seen the development of drought tolerant plants. These are able to grow and thrive in drought conditions, these crops can be utilised in ensuring food security for the world in circumstances of unpredictable climatic conditions. Such crops an example, in Uganda, genetically modified drought tolerant Water Efficient Maize for Africa (WEMA) has shown great promise for increasing food security. The overarching goal of drought tolerant crops for example rice and maize is to protect our crops from extreme weather that would otherwise compromise productivity in an epoch of global warming.



Figure: Bt Cotton resistant to the cotton bollworm

Genetically modified crops engineered with genes for heat shock proteins for example the *DREBIA* gene in *Chrysanthemum* have been developed. These crops can maintain a higher photosynthetic capacity and elevated levels of photosynthesis, compared to unmodified crops hence surviving the increasing temperatures.

Cotton carrying a Bacillus *thuringiensis*, (Bt) gene has been developed using modern biotechnological tools (genetic engineering). The Bt gene offers internal protection against insect pests like *Busseola fusca* and *Chillo partellus. This* genetically modified Bt cotton requires fewer regimes of pesticide and herbicide applications to control pests compared to the unmodified cotton plants thereby protecting the environment from excessive use of insecticides and herbicides.

GM crops which have a high "Nitrogen Use Efficiency" have been developed that use nitrogen more efficiently, so need less or no fertilizer. N_2O has a global warming potential 298 times greater than CO_2, and it stays in the atmosphere for more than 100 years. N_2O from agricultural fields is released when nitrogen fertilizers applied to crops interact with common soil bacteria. It is estimated that nitrogen fertilizer accounts for one-third of the GHGs produced by agriculture. Reduced fertilizer use also means less nitrogen pollution of ground and surface waters.

Genetically modified salt tolerant crops have been developed. These transgenic plants contain a salt tolerant gene from for example *Avicennia marina* a grey mangrove this allows the genetically modified plant to maintain high crop yield despite the increasing salinity of arable land. Staple crops like bananas, some horticultural crops and selected leguminous crops in the central part of Uganda can be genetically engineered with salt tolerance genes to enable them survive better under saline conditions. Subsequently, these plants will be able to tolerate salt and other ionic stresses hence increased agricultural production.

Plants can be modified through genetic engineering so that they can take more carbon from the atmosphere and release oxygen. Carbon, in the form of carbon dioxide is removed from the atmosphere through Carbon sequestration. It can also be sequestered from industrial processes and combustion. Soil carbon sequestration can also mitigate the increase of atmospheric carbon dioxide concentration. Genetically modified crops such as Roundup Ready ™ (herbicide resistant) soybean leads to sequestration millions of tons of carbon dioxide per year due to reduced number of herbicide sprays and reduced tillage. The need for tillage or ploughing is reduced with the help of genetically modified crops. Soil fertility can be increased with the help of mixing genetically modified microbes in the soil. Through modern biotechnology, adverse effects of carbon dioxide emissions can be reduced by using biofuel production from genetically modified crops such as sugarcane and maize. The use of more efficient biofuels instead of the fossil fuels is beneficial for the environment and to reduce carbon emissions. However, food production may compete with energy production when food/feed crops such as maize are used for biofuel production. This calls for generation of non-edible perennial oil-seed producing plants that can cleanse the atmosphere and increase the production of biodiesel. Bio-fuel from advanced biotechnology can solve the energy problem in Uganda to a great extent and also save the country from the challenges of climate change.



Recommendations

Considering the benefits Uganda stands to gain from safe and appropriate application of modern biotechnology such as increased yield production, herbicide and pest resistance, early maturing crop varieties, drought tolerant crop varieties and increased food and environmental security, to combating the negative effects of climate change like global warming, soil erosion, tropical storms and unpredictable seasons, Uganda needs to enact the national biotechnology and biosafety bill. This will allow the safe application and use of the enormous advantages of agricultural biotechnology in addressing the adverse effects.

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