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Role of Agricultural Biotechnology in climate change mitigation

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Abstract

Climate change is a one of the major challenge that is already affecting people and the environment worldwide. Average global temperatures of earth have been rising day by day over the last century. The problem is not just changing temperatures; it is a changing climate—or a change in the weather patterns that people and ecosystems have become accustomed to over time. Emissions of carbon dioxide and other greenhouse gases from human activities, primarily burning of fossil fuels such as coal and oil are the major culprits for climate change. Therefore, Climate change is the most serious issue on earth which needs to be focused for a better and sustainable development. In this context biotechnology could contribute to the adaptation and mitigation of climate change impacts. Green house gas emission can be reduced through the use of modern biotechnology which ultimately leads to increase food security. The present paper discuss about the conventional and modern biotechnological approaches to address climate change adaptation and mitigation for improved crop productivity and food security.

Keywords: Climate change, mitigation, carbon sequestration, agricultural biotechnology

I. INTRODUCTION

Climate change represents change in the state of the climate that can be identified (e.g., by using statistical tests) by changes in the mean and/or the variability of its properties, and that persists for long period. As per the reports climate change may be due to natural internal processes or external forcing such as modulations of the solar cycles, volcanic eruptions, and anthropogenic changes in the composition of the atmosphere or in land use (IPCC, 2014). Changes in the earth's orbit, gases in the atmosphere and anthropogenic influences are the main causes which lead to change in climate. Certain types of gases in the atmosphere have the property of absorbing part of the solar radiation reflected by the earth's surface. These gases are called as GHGs which prevent the radiation from being reflected into space and cause a warming of the atmosphere. GHGs emission is mainly due to industrialization and other activities include carbon dioxide, methane, nitrous oxide, hydroflurocarbons (HFCs), perflurocarbons (PFCs) and sulfur hexafluoride (SF6). Over the years, their concentrations in the atmosphere have shot up due to industrial activities and the associated burning of fossil fuels and deforestation. It clearly indicates global climate has been changing in recent times.

Climate change can be mitigated by using fossil fuels, reforestation, and reducing green house gases etc (IPCC, 2014). To feed the ever increasing world's population, there is need to increase the yield of agriculture production. Therefore, special efforts are needed to overcome this global challenge and adapting to biotechnological route will be a crucial factor in this scenario. Thus biotechnology could contribute by mitigating the impacts of climate change through reduction in green house gases, and crop adaptation for biotic and abiotic stresses. In this context, the present paper tries to highlight the role of biotechnology in climate change mitigation.

Agricultural Biotechnology

Agricultural biotechnology includes fermentation techniques, tissue culture, mutation and recombinant DNA techniques, genomic science, use of molecular markers for breeding and genetic modification using transgenes to create biotech crops. Tissue culture is the cultivation of plant cells, tissues, or organs on specific nutrient media. Under the suitable conditions, an entire plant can be regenerated from a single cell. Disease-free, high quality planting material is produced through *in vitro* techniques (Anthony and Ferroni, 2011). Higher yields can be achieved due to advances in breeding and it also fulfils the needs of rapidly increasing population.

In addition, marker assisted breeding; an agricultural biotechnology tool is already a routine step in breeding of most crops where the gene and the markers for a specific trait are known. This technique is being efficiently used in introgression of important genes into various crops including bacterial blight resistance in rice, increased beta carotene content in rice, cassava, and banana, and submergence tolerance in rice etc.

Genetic engineering is one of the modern agricultural biotechnology tools that are based on recombinant DNA technology. It involves the alteration of genetic makeup of an organism using "recombinant DNA technology." This makes the use of specific enzymes to cut, insert, and alter fragments of DNA that contain one or more genes of interest. Transgenics can be developed through manipulation of individual genes and to transfer genes between species. There is rapid progress in these technologies where genes can be manipulated from diverse sources, and transferring into microorganisms and crops to confer resistance to pests and diseases, tolerance to herbicides, abiotic stresses and many more. Thus the role of biotechnology is of extreme importance in the context of changing climate and food security especially in third world countries.

II. Climate change mitigation through Biotechnology

A. Reduction of Green House Gases

The main cause of green house gas (CO_2, CH_4 and N_2O) emission is due to the deforestation, use of inorganic fertilizer etc. The Green revolution through Biotechnology is one of the most reliable answers to mitigate climate change through use of biofuels, carbon sequestration and reduce fertilizer usage (Treasury, 2009).

B. Use of Biofuels

Agricultural techniques play important role to overcome the negative impacts on agricultural productivity and environment. We can reduce the adverse effect of CO_2 emission by using biofuels production both from traditional and GMO crops such as sugarcane, oilseed, rapeseed, and jatropha (Sarin *et al.*, 2007; Treasury, 2009). Efficiency of farming system can be increased by using bioethanol and biodiesel instead of fossil fuels. Perennial non edible oil-seed producing plants will help in cleansing the atmosphere and production of biodiesel (Jain and Sharma, 2010; Lybbert and Summer, 2010). Bio-fuel from the advanced biotechnology has solved the problem of energy to a great extent.

C. Carbon sequestration

Carbon sequestration removes carbon, in the form of CO_2, either directly from the atmosphere or from the combustion and industrial processes. Strategies such as soil carbon sequestration can be used to mitigate the increase of atmospheric CO_2 concentration. Soil erosion can be prevented through conservation practices that may also sequester soil carbon and enhance methane (CH_4) consumption (West and Post, 2002; Johnsona *et al.*, 2007). Genetically modified crops such as Roundup Ready™ (herbicide resistant) soybean led to sequestration of 63,859 million tones of CO_2 (Fawcett and Towery, 2003; Brimner *et al.*, 2004; Kleter *et al.*, 2008). The need for tillage or ploughing can be reduced with the help of genetically modified crops.

We can modify the plants through genetic engineering so that they can take more carbon from atmosphere and convert it to oxygen. Soil fertility can be increased with the help of mixing microbes in the soil. In this context modern environmental biotechnology has gained an immense importance to overcome these impacts.

D. Reduced use of fertilizers

The use of agricultural chemicals has led to the contamination of the environment with hazardous toxic chemicals which ultimately affect the biogeochemical cycles. Formation and release of greenhouse gases (particularly N2O) from the soil to the atmosphere is mainly occurs due to the use of inorganic nitrogenous fertilizers namely ammonium sulphate, ammonium chloride, ammonium phosphates etc (Brookes and Barfoot, 2009). A biotechnology-based fertilizer is one of the solutions to reduce the adverse effects of fertilizer.

Biotechnology offers an advantage to reduce the application of artificial fertilizer. Nitrogen-fixing characteristics of *Rhizobium* inoculants were improved by using genetic engineering techniques (Zahran, 2001). It also involves the induction of nodular structures on the roots of cereal crops such as rice and wheat offer a bright prospect of non-leguminous plants being enabled to fix nitrogen in the soil (Kennedy and Tchan, 1992; Paau, 2002; Saikia and Jain, 2007; Yan *et al*., 2008). Cultivation of nitrogen-efficient genetically modified canola has shown significant reduction in the amount of nitrogen fertilizer that is lost into the atmosphere or leached into soil. HT crops allow farmers to use non-selective chemicals to control weeds after crop emergence, which reduces the risks associated with conservation tillage or no-till strategies.

E. Biotechnology for biotic and abiotic stresses

Agricultural biotechnology could contribute to the crop productivity through the development of strains that are resistant to biotic stresses such as insects, fungi, bacteria and viruses. *Bacillus thuringiensis* (*Bt*) gene is introduced into corn, cotton, and soybeans which imparts resistance to insects, pests such as the European corn borer, but harmless to humans and relatively environmentally benign. GM crops have been proved to be the valuable tool for integrated pest management. Herbicide tolerance trait is introduced into corn, soybeans, and canola. Also genetically modified potatoes, cassava and other crops that are resistant to biotic stresses are in development and some are already been commercialized (Barrows *et al*., 2014).

As like biotic stresses, abiotic stresses also one of the challenging areas to be focused for sustainable development. Salinity, drought, extreme temperatures, oxidative stress etc includes in abiotic stresses which directly affect on agriculture and environment. Plant biotechnology in combination with breeding is one of the important approaches for abiotic stress tolerance in crops. It involves selection and growing of drought tolerant crops that can allow harsh conditions on marginal lands.

Molecular breeding approaches for abiotic stress tolerance are dependent on up regulation of stress- related genes. Genetically modified crops resistant to drought, salt and heat tolerance viz., Arabidopsis, tobacco, maize, wheat, cotton, soybean, pearl millet, tomato, rice, *brassica* have been developed by several workers (Hong *et al*., 2000; Jaglo *et al*., 2001; Yamanouchi *et al*., 2002; Hsieh *et al*., 2002; Zhu, 2001). Genome sequence of various microbes and plants has opened an advanced era where we can manipulate genes for stress tolerance and can change the climate within short time.

Table 1. Climate change mitigation through conventional agricultural biotechnology approach (Mtui *et al*., 2011)

Measure	Biotechnology	Application	Reference
Climate change mitigation: Reduced use of fertilizer	No-till practices Agroforestry	Coffee and banana and horticultural farming Mycorrhizal and actinorrhizal symbiosis	West and Post, 2002; Johnsona *et al*., 2007; Powlson *et al*., 2011. Franche *et al*., 1998; Zahran, 2001
Carbon sequestration	Biofuels production	Bioethanol from sugarcane Biodiesel from jatropha, palm oil	Lybert and Summer, 2010 Sarin *et al*., 2007; Lua, 2009; Jain and Sharma, 2010
Adaptation to climate change: Adaptation to biotic and abiotic stresses	Tissue culture Agroforestry	Drought tolerant sorghum, millet, sunflower Shading coffee and banana plantations.	Apse and Blumwald, 2002 *Franche et al*., 1998

Table 2. Climate change mitigation through modern agricultural biotechnology approach (Mtui *et al*., 2011)

Measure	Biotechnology	Application	Reference
Climate change mitigation: Reduced use of fertilizer	Engineering herbicide resistance to reduce spraying Engineering nitrogen fixation	GM soy beans GM canola Genetic improvement of *Rhizobium*; inducing N-fixation to non-legumes	Fawcett and Towery, 2003; Brimner *et al*., 2004; Kleter *et al*., 2008 Zahran, 2001; Yan *et al*., 2008
Carbon sequestration	Green energy	GM energy crops	Lybert and Summer, 2010

	Nitrogen- efficient GM crops	N-efficient GM canola	Johnsona *et al*., 2007
Adaptation to climate change: Adaptation to biotic and abiotic stresses	Molecular marker assisted breeding for stress resistance Engineering drought tolerance Engineering salt tolerance Engineering heat tolerance	Drought resistant maize, wheat hybrids GM Arabidopsis , Tobacco, maize, wheat, cotton, soybean Drought resistant Pearl millet GM tomato, rice GM Arabidopsis, GM *Brassica* Sp.	Wang *et al*., 2001, 2003 Hong *et al*., 2000; Jaglo *et al*., 2001; Yamanouchi *et al*., 2002 Hsieh *et al*., 2002; Jaglo *et al*., 2001; Zhu, 2001.

III. Conclusions

This paper discussed about the role of agricultural biotechnology in mitigating climate change effects. In this context, biotechnology can positively contribute towards climate change mitigation through reduction of green house gases, carbon sequestration, use of biofuels, reduced use of fertilizer, and adaptation for biotic and abiotic stresses etc. This can ultimately play an important role in improving agricultural productivity and food security, and at the same time protecting our environment from adverse effects of climate change.

BIBLIGRAPHY

[1] Anthony, V. M. and Ferroni, M. 2011. Agricultural biotechnology and smallholder farmers in developing countries. *Curr. Op. Biotechnol*., **23**: 1–8.

[2] Apse, M. P. and Blumwald, E. Engineering salt tolerance in plants. *Curr. Op. Biotechnol*., **13**: 146-150.

[3] Barrows, G.; Sexton, S. and Zilberman, D. 2014. Agricultural Biotechnology: The Promise and Prospects of Genetically Modified Crops. *J. Economic Perspectives*, **28** (1): 99–120.

[4] Brimner, T. A.; Gallivan, G. J. and Stephenson, G. R. 2004. Influence of herbicide-resistant canola on the environmental impact of weed management. *Pest Manag. Sci*., **61**(1): 47-52.

[5] Brookes, G. and Barfoot, P. 2006. GM Crops: The first ten years – Global socio-economic and environmental impacts in the first ten years of commercial use. *J. AgBio. Forum*, **9**(3): 139-151.

[6] Fawcett, R. and Towery, D. 2003. Conservation tillage and plant biotechnology: How new technologies can improve the environment by reducing the need to plow: CT Information Center, USA, (http://www.ctic.purdue.edu/CTIC/Biotech.html).

[7] Franche, C.; Laplaze, L.; Duhoux, E. and Bogusz, D. 1998. Actinomycorhizal symbioses: Recent advances in plant molecular and genetic transformation studies. *Crit. Rev. Plant Sci.*, **17**(1): 1-28.

[8] Hong, Z.; Lakkineni, K.; Zhang, K. and Verma, D. P. S. 2000. Removal of feedback inhibition of *delta*-pyrroline-5-carboxylate synthase results in increased proline accumulation and protection of plants from osmotic stress. *Plant Physiol.*, **122**: 1129-1136.

[9] Hsieh, T. H.; Lee, J. T.; Yang, P. T.; Chiu, L. H.; Charng, Y. Y.; Wang, Y. C. and Chan, M. T. 2002. Heterogy expression of *Arabidopsis* C-repeat/dehydration response element binding factor I gene confers elevated tolerance to chilling and oxidative stresses in transgenic tomato. *Plant Physiol*., **129**: 1086-1094.

[10] IPCC. 2014. Climate Change 2014: Impacts, Adaptation, and Vulnerability. Intergovernmental Panel on Climate Change (Eds. J. Houghton, et al.). Cambridge University Press, Cambridge, UK.

[11] Jaglo, K R.; Kleff, S.; Amunsen, K. L.; Zhang, X.; Haake, V.; Zhang, J. Z.; Deits, T. and Thomashow, M. F. 2001. Components of Arabidopsis C-repeat/dehydration response element binding factor or cold-response pathway are conserved in *Brasicca napus* and other plant species. *Plant Physiol.*, **127**: 910-917.

[12] Jain, S. and Sharma, M. P. 2010. Prospects of biodiesel from Jatropha in India: A review. *Renewable and sustainable Energy Rev*., **14**(2): 763-771.

[13] Johnsona, J. M. F.; Franzluebbersb, A. J.; Weyersa, S. L. and Reicoskya, D. C. 2007. Agricultural opportunities to mitigate greenhouse gas emissions. *Environ. Poll.*, **150**(1): 107-124.

[14] Kennedy, I. R. and Tchan, Y. T. 1992. Biological nitrogen fixation in non-leguminous field crops: Recent advances. *Plant and Soil*, **141**: 93-118.

[15] Kleter, G. A.; Harris, C.; Stephenson, G. and Unsworth, J. 2008. Comparison of herbicide regimes and the associated potential environmental effects of glyphosate-resistant crops versus what they replace in Europe. *Pest Manage. Sci.,* **64**: 479-488.

[16] Lua, H.; Liua, Y.; Zhoua, H.; Yanga, Y.; Chena, M. and Liang, B. 2009. Production of biodiesel from *Jatropha curcas* L. oil. *Comp. Chem. Eng.,* **33** (5): 1091-1096.

[17] Lybbert, T. and Sumner, D. 2010. Agricultural technologies for climate change mitigation and adaptation in developing countries: Policy options for innovation and technology diffusion. ICTSD-IPC Platform on Climate Change, ATS Policy Brief 6 (http://ictsd.org/i/publications/77118/).

[18] Mtui, G. Y. S. 2011. Involvement of biotechnology in climate change adaptation and mitigation: Improving agricultural yield and food security. *Int. J. Biotechnol. Mol. Biology Res*., **2**(13): 222-231**.**

[19] Paau, A. S. 2002. Improvement of *Rhizobium* inoculants by mutation, genetic engineering and formulation. *Biotechnol. Adv.*, **9**(2): 173-184.

[20] Powlson, D. S.; Whitmore, A. P. and Goulding, K. W. T. 2011. Soil carbon sequestration to mitigate climate change: A critical re-examination to identify the true and false. *Eur. J. Soil Sci*., **62**: 42-55.

[21] Saikia, S. P. and Jain, V. 2007. Biological nitrogen fixation with non-legumes: An achievable target or a dogma? *Curr. Sci*., **93**(3): 317-322.

[22] Sarin, R.; Sharma, M.; Sinharay, S. and Malhotra, R. K. 2007. Jatropha-palm biodiesel blends: An optimum mix for Asia. *Fuel*, **86**(10-11): 1365-1371.

[23] Treasury, H. M. 2009. Green biotechnology and climate change. *Euro Bio*. p.12, Available online at http://www.docstoc.com/docs/15021072/Green-Biotechnology-and-Climate-Change.

[24] Wang, W.; Vinocur, B. and Altman, A. 2003. Plant responses to drought, salinity and extreme temperatures: Towards genetic engineering for stress tolerance. *Planta*, **218**: 1-14.

[25] Wang, W.; Vinocur, B.; Shoseyov, O. and Altman, A. 2001. Biotechnology of plant osmotic stress tolerance: Physiological and molecular considerations. *Acta Hort*., **560**: 285-292.

[26] West, T. O. and Post, W. M. 2002. Soil organic carbon sequestration rates by tillage and crop rotation: A global analysis. *Soil Sci. Soc. Amer. J.*, **66**: 930-1046.

[27] Yamanouchi, U.; Yano, M.; Lin, H.; Ashikari, M. and Yamada, K. 2002. A rice spotted leaf gene Sp17 encodes a heat stress transcription factor protein. *Proc. Natl. Acad. Sci*., **99**: 7530-7535.

[28] Yan, Y.; Yang, J.; Dou, Y.; Chen, M.; Ping, S.; Peng, J.; Lu, W.; Zhang, W.; Yao, Z.; Li, H.; Liu,W.; He, S.; Geng, L.; Zhang, X.; Yang, F.; Yu, H.; Zhan, Y.; Li, D.; Lin, Z.; Wang, Y.; Elmerich, C.; Lin, M. and Jin, Q. 2008. Nitrogen fixation island and rhizophere competence traits in the genome of root-associated *Pseudomonas stutzeri* A1501. *Proc. Nat. Acad. Sci*., **105** (21): 7564-7569.

[29] Zahran, H. H. 2001. Rhizobia from wild legumes: Diversity, taxonomy, ecology, nitrogen fixation and biotechnology. *J. Biotechnol*., **91**: 143-153

[30] Zhu, K. J. 2001. Plant salt tolerance. *Trends in Plant Sci*., **6**(2): 66-71.

