Pocket K No. 43

Biotechnology and Climate Change

Climate Change and its Effect in Agriculture

The continuing increase in greenhouse gas emissions raises the temperature of the earth's atmosphere. This results to melting of glaciers, unpredictable rainfall patterns, and extreme weather events. The accelerating pace of climate change, combined with global population and depletion of agricultural resources threatens food security globally.

The over-all impact of climate change as it affects agriculture was described by the Intergovernmental Panel on Climate Change (IPCC, 2007), and cited by the US EPA (2011)[1] to be as follows:

- **Increases in average temperature** will result to: i) increased crop productivity in high latitude temperate regions due to the lengthening of the growing season; ii) reduced crop productivity in low latitude subtropical and tropical regions where summer heat is already limiting productivity; and iii) reduced productivity due to an increase in soil evaporation rates.
- **Change in amount of rainfall and patterns** will affect soil erosion rates and soil moisture, which are important for crop yields. Precipitation will increase in high latitudes, and decrease in most subtropical low latitude regions – some by as much as about 20%, leading to long drought spells.
- **Rising atmospheric concentrations of CO_2** will boost and enhance the growth of some crops but other aspects of climate change (e.g., higher temperatures and precipitation changes) may offset any beneficial boosting effect of higher CO_2 levels.
- **Pollution levels of tropospheric ozone (or bad ozone that can damage living tissue and break down certain materials**) may increase due to the rise in CO_2 emissions. This may lead to higher temperatures that will offset the increased growth of crops resulting from higher levels of CO_2.
- **Changes in the frequency and severity of heat waves, drought, floods and hurricanes,** remain a key uncertain factor that may potentially affect agriculture.
- **Climatic changes will affect agricultural systems** and may lead to emergence of new pests and diseases.

In 2012, almost 40% of the world population of 6.7 billion, equivalent to 2.5 billion, rely on agriculture for their livelihood and will thus likely be the most severely affected.[2] To mitigate these effects, current agricultural approaches need to be modified and innovative adaption strategies need to be in place to efficiently produce more food in stressed conditions and with net reduction in greenhouse gas emissions.

Contribution of Biotech Crops in Mitigating Effects of Climate Change

Green biotechnology offers a solution to decrease green house gases and therefore mitigates climate change. Biotech crops for the last 16 years of commercialization have been contributing to the reduction of CO_2 emissions. They allow farmers to use less and environmentally friendly energy and fertilizer, and practice soil carbon sequestration.

- Herbicide tolerant biotech crops such as soybean and canola facilitate zero or no-till, which significantly reduces the loss of soil carbon (carbon sequestration) and CO_2 emissions, reduce fuel use, and significantly reduce soil erosion.

- Insect resistant biotech crops require fewer pesticide sprays which results in savings of tractor/fossil fuel and thus less CO_2 emissions. For 2011, there was a reduction of 37 million kg of active ingredients, decreased rate of herbicide and insecticide sprays and ploughing reduced CO_2 emission by 23.1 billion kg of CO_2 or removing 10.2 million cars off the road.[3]

Biotech Crops Adapted to Climate Change

Crops can be modified faster through biotechnology than conventional crops, thus hastening implementation of strategies to meet rapid and severe climatic changes. Pest and disease resistant biotech crops have continuously developed as new pests and diseases emerge with changes in climate. Resistant varieties will also reduce pesticide application and hence CO_2 emission. Crops tolerant to various abiotech stresses have been developed in response to climatic changes.

Salinity Tolerant Crops
Biotech salt tolerant crops have been developed and some are in the final field trials before commercialization. In Australia, field trials of 1,161 lines of genetically modified (GM) wheat and 1,179 lines of GM barley modified to contain one of 35 genes obtained from wheat, barley, maize, thale cress, moss or yeasts are in progress since 2010 and will run till 2015. Some of the genes are expected to enhance tolerance to a range of abiotic stresses including drought, cold, salt and low phosphorous. Sugarcane that contains transcription factor (OsDREB1A) is also under field trial from 2009 to 2015.[4]

More than a dozen of other genes influencing salt tolerance have been found in various plants. Some of these candidate genes may prove feasible in developing salt tolerance in sugarcane [4], rice[5,6], barley [7], wheat [8], tomato[9], and soybean[10].

Drought Resistant Crops
Transgenic plants carrying genes for water-stress management have been developed. Structural genes (key enzymes for osmolyte biosynthesis, such as proline, glycine/betaine, mannitol and trehalose, redox proteins and detoxifying enzymes, stress-induced LEA proteins) and regulatory genes, including dehydration–responsive, element-binding (DREB) factors, zinc finger proteins, and NAC transcription factor genes, are being used.

Transgenic crops carrying different drought tolerant genes are being developed in rice, wheat, maize, sugarcane, tobacco, Arabidopsis, groundnut, tomato, potato and papaya.[11, 12]

An important initiative for Africa is the Water Efficient Maize for Africa (WEMA) project of the Kenyan-based African Agricultural Technology Foundation (AATF) and funded by the Bill and Melinda Gates Foundation (BMGF) and Howard G. Buffet Foundations. Drought tolerant WEMA varieties developed through marker assisted breeding could be available to farmers within the next two or three years. Drought-tolerant and insect-protected varieties developed using both advanced breeding and transgenic approaches could be available to farmers in the later part of the decade.[13] In 2012, a genetically modified drought tolerant maize MON 87460 that expresses cold shock protein B has been approved in the US for release in the market.[14]

Biotech Crops for Cold Tolerance
By using genetic and molecular approaches, a number of relevant genes have been identified and new information continually emerges. Among which are the genes controlling the *CBF* cold-responsive pathway and together with *DREB1* genes, integrate several components of the cold acclimation response to tolerance low temperatures.[15]

Cold tolerant GM crops are being developed such as GM eucalypti, which is currently being field tested in the US by Arborgen LLC since 2010. Thale cress has been improved to contain the *DaIRIP4* from *Deschapsia antarctica*, a hairgrass that thrives in frosts down to -30C, and sugarcane are being introgressed with genes from cold tolerant wild varieties.[4]

Biotech Crops for Heat Stress
Expression of heat shock proteins (HSPs) has been associated with recovery of plants under heat stress and sometimes, even during drought. HSPs bind and stabilize proteins that have become denatured during stress conditions, and provide protection to prevent protein aggregation. In GM chrysanthemum containing the *DREBIA* gene from *Arabidopsis thaliana,* the transgene and other heat responsive genes such as the HSP70 (heat shock proteins) were highly expressed when exposed to heat treatment. The transgenic plants maintained higher photosynthetic capacity and elevated levels of photosynthesis-related enzymes.[16]

Forward Looking

Improved crops resilient to extreme environments caused by climate change are expected in a few years to a decade. Hence, food production during this era should be given another boost to sustain food supply for the doubling population. Biotech research to mitigate global warming should also be initiated to sustain the utilization of new products. Among these are: the induction of nodular structures on the roots of non-leguminous cereal crops to fix nitrogen. This will reduce farmers' reliance on inorganic fertilizers. Another is the utilization of excess CO_2 in the air by staple crop rice by converting its

CO_2 harnessing capability from C3 to C4 pathway. C4 plants like maize can efficiently assimilate and convert CO_2 to carbon products during photosynthesis.

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