AGRICULTURE
Editorial

Biotechnology Contribution to Maize Production

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Biotechnology has contributed tremendous advances in maize production via different avenues, including application of effective biofertilizers, plant growth promoter andmore importantly development of transgenic traits resistant to herbicides and/or pests.

Maize is the premier monocotyledonous species for biotech research based on itstransformation characteristics, conventional and molecularbreedingadvances and monetary value in the agronomic marketplace. However, there are major factors that greatly limiting maize production. One of these factors is drought stress, to which Maize is highly sensitive, especially at critical times of the growing season, discouraging smallholder farmers from risking investment in best management practices including quality hybrid seed and fertilizer. Therefore, Drought tolerant hybrids are being developed for maize through conventional breeding, marker-assisted breeding, and biotechnology and will be licensed to local seed companies producing and selling hybrids for local farmers to help reduce smallholder farmer's risk from drought and provide better food security [1].

A public–private partnership "Water Efficient Maize for Africa" (WEMA) was established in 2008 to tackle the drought tolerance problem under local growing conditions as well as at managed drought sites. This partnership has provided access to WEMA for more enabling technology than has been previously utilized in any agricultural project in Africa.As agreed among WEMA partners, there will be no royalty for the transgenic drought tolerance trait and its associated technology as delivered to SSA smallholder farmers. Additionally, technology used in the project is expected to have considerable value to commercial farmers in and outside Africa. Furthermore, Conventional breeding with modern molecular techniques and biotechnology are helping to improve corn plant response to drought stress, and introduce novel drought tolerance genes into the plant.This could also ensure faster progress in improving both maize drought tolerance. The joint efforts of the project's breeders and regulatory scientists have enabled transgenic drought tolerance trials to be planted from 2008 to 2012 and Bt-insect protection trait to be tested in 2013 [1].

Considering the fertilizers impact, growth and yield of maize grain are highly responsive to nitrogen fertilization, where maize fields, worldwide, receive around 10 million metric tons of N fertilizer per year [2]. However, Nitrogen use efficiency (NUE), i.e. ratio of grain yield to N fertilizer supplied, of maize globally falls between 25-50%, indicating that more than half the N fertilizer applied to maize field is lost to the environment.On the other hand, hybrids developed with transgenic resistance to root feeding by corn rootworm (*Diabrotica* spp.) have led to larger and healthier root system and consequently greater N uptake. Similarly, transgenic maize hybrids with enhanced drought tolerance could also, indirectly, increase N uptake and utilization [3].

Application of bio fertilizers containing *Azospirillumbrasilense* and yeast *Rhodotorulaglutinis* at low rate of NKP (50%) mineral fertilizers, plus sulfur at recommended dose, gave comparable results for growth parameters of maize compared with 100% NPK [4].

Genetic engineering also helped developed Maize cultivarswith resistance to herbicides, including genetically modified transgenic (glyphosate and glufosinate) and non-transgenic (sethoxydim and imidazolinone) hybrids. One example is Maize cultivar with an *hra* transgene confer 1000-fold cross-resistance to ALS(acetolactate synthase)-inhibiting herbicides and the adoption of transgenic herbicide-resistant maize hybrids is ever increasing [5].

Maize hybrids carrying either herbicide-resistant or insect tolerant-traits have gained constant acceptance by farmers and consumers throughout the world, since its first introduction in 1990s. In 2007, over 17 million acres were planted maize with genes conferring herbicide tolerance, and nearly 23 million acres with insect-resistant traits. The total global acreage of maize with biotech traits is 24% of total acreage of maize and nearly 31% of globally planted biotech-traits cropsin 2007.On a value basis, this volume represents 47% of the total value of biotech crops planted that year, which highlights the monetary importance of this agronomic crop. Moreover, the acreage for herbicide tolerance and insect resistance in the same hybrid accounted for over 46 million acres (~ 18.5 million ha) in 2007, indicating farmers' preferencefor stacked traits over the stand-alone in their agronomic production systems [6].

The use of herbicide resistant maize allows the farmer to implement a simpler farming practice that utilizes a more effective means of weed control and also allows for large-scale application of no-till farming. Combining herbicide resistant maize with no-till hasresulted in a farming practice that requires less time in the field and less diesel fuel, leading to a reduction in overall overhead costs and areduction in carbon emission [7]. This reduction was figured using the USDA-developed energy calculator based on *Revised universal soil loss equation (ver. 2*),reporting an approximate 45% fuel savings associated with a change in maize agricultural practice from conventional tillage to no-till. The savings of diesel fuel (in gallons and US dollars) for 1000 acres (approx. 405 ha) of maize of no-till versus conventional till was an impressive US $9000 (USDA, NRCS, Energy Tools; http://ecat.sc.egov.usda.gov). The key to this widespread application of no-till is planting herbicide-resistant maize hybrids.

The no-till farming is made practical by using a pre-plant application of herbicide for weed burn down followed by drill planting of herbicide-tolerant seeds. And aside from the overhead savings, no-till farming has positive effects towards top soil conservation, thusreducing soil erosion and risk of soil compaction [8].

Saving is also figured when knowing that herbicide-resistant crops (e.g. Roundup Ready) generally require less herbicide than non-biotech crops.Planting of insect-resistant maize hybrids attributed to approximately 5% increase in yield in the United States and the total economic income benefit to farmers stood at US $306 million for the 2005 planting year and many farmers experience higher yield gains that vary according to pest density.

Genetic engineering also produced transgenic maize trait containing *Bacillus thuringiensis* ('Bt') genes (Cry1Ab, Cry1F) that code for lepidopteran-specific protein toxins for protection against lepidopteran pestslike European corn borer (*Ostrinia nubilalis*) and Mediterranean corn borer (*Sesamia nonagrioides*) [9].

Maize suffers substantial damage caused by *Macrophomina phaseolina* (charcoal rots), *Fusarium moniliforme* (foot rots and wilting) and Fusarium graminearum (root rots, stalk rots and wilting) in several areas. Since there are no cultivars in maize with complete resistance to soil-borne fungal pathogens, and fungicides are not potent enough to protect the crop from infection by these pathogens, development of biocontrol agents could be the best alternative to minimize the incidence of these diseases. Plant growth-promoting isolates of a fluorescent *Pseudomonas* sp. and two *Bacillusisolates*, obtained from maize rhizosphere, were found strongly antagonistic to these pathogens. Combined application of the two bacilli significantly reduced the *Macrophomina*-induced charcoal rots of maize by 56.04%. Treatments with *Bacillus* spp. and *Pseudomonas* sp. significantly reduced collar rots, root and foot rots, and wilting of maize caused by F.moniliforme and F. *graminearum*. All these isolates are very efficient in colonizing the rhizosphere of maize after inoculation. Application of *Bacillus* sp. also substantially controls seedling blight, root rots and stalk rots of maize whereas application of root-associated Ps.cepaceaas seed coating biocontrol agent could reduce the *Fusarium moniliforme*-induced infection of maize root by 23-80%. Trichoderma viride and *Pseudomonas* species are also capable of controlling stalk rots of maize [10].

Finally, the contribution of biotechnology to maize advances is reflected in the production of nearly 75% of the maize inthe United States containing biotech traits [6]. Furthermore, continuing to discover and develop new technologies in the agricultural sciences will greatly contribute to the food security. Development of second- and third-generation herbicide-resistant and insect-resistant traits that stack multiple modes of action will insure the beneficial aspects of this technology for years to come. Also, development of drought-tolerant maize is becoming a reality.

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