Assessing the Benefits and Risks of GE Crops:
Evidence from the Insect Resistant Maize for Africa Project

H De Groote, S Mugo, D Bergvinson, and B Odhiambo

Background

Genetically engineered crops have been highly successful in developed countries, increasing yields and profits without negative health or environmental effects. However, the technology has generally not been well received in Europe, where environmentalists and green activists are worried about irreversible environmental damage. Moreover, European agriculture has a consistent overproduction problem, so yield enhancing technologies are not of critical importance. Expected benefits to the European consumer are also small. Therefore, Europe has accepted the precautionary principle, which imposes very stringent regulations and requirements of risk assessment on GE crops, basically banning them for the time being. In 2004, Europe approved the importation of the first GE maize food, but use of GE maize seed is generally not allowed.

African countries are caught in a quandary—should they embrace the technology to help feed their hungry people, or rather protect them from potential dangers? Potential advantages of the technology include: increased yield (for the only continent that has benefited little from the Green Revolution), increased food security (for the only region in the world where the percentage of malnourished children is expected to rise during the next 20 years), and a technology easy to disseminate (for a region where extension services have collapsed and liberalization is lagging).

Despite these potential benefits, deployment of GE crops in Africa remains highly controversial. Among the arguments against them are: GE crops would not respond to small farmers' priorities; their traits would not reply to a particular demand; and seed would be expensive. Another argument alleges that GE technology would only be beneficial to the agro-businesses, which can protect their interests through Intellectual Property Rights (IPR) and 'terminator' genes, and make farmers dependent on new varieties while they lose biodiversity of their old ones. Further, GE crops could pose serious risks to the environment through the development of resistance in target insects, gene flow into weeds and local varieties, and from the disruption of non-target organisms. Moreover, African countries might not be sufficiently equipped with the appropriate biosafety regulations to make an informed choice. Finally, it is argued that poor people, if given a choice, would not necessarily opt for GE crops but might prefer other solutions.

We argue that African farmers and consumers have the right to choose their own technologies, based on the best available knowledge[1]. African scientists need to develop and test GE crops on the alternative precautionary principle, that is, poor farmers and consumers risk being denied a chance to improve their livelihood based on an academic debate in which they cannot participate. On this principle, the Insect Resistant Maize for Africa (IRMA) project was launched in 1999, using both conventional breeding and biotechnology, and combining the best available science, biophysical as well as social. After five years of research in the first phase, it can be shown how most, but not all, concerns against Bt maize can be answered.

Overview of research results

Research shows that demand for Bt maize is likely to be high. Not only is maize the major food crop in Kenya but, after progress in the 1960s and 1970s, maize yields and production have stagnated while production per capita has decreased. While more maize is grown in the high-potential zones, the level of poverty is higher in the low-potential zones (**Fig. 1**).

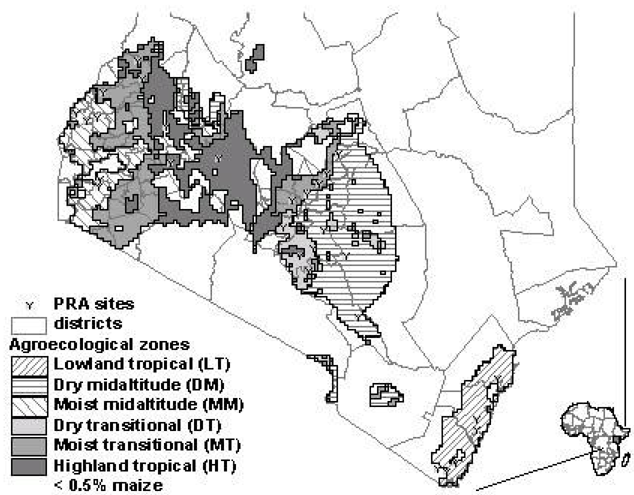

Figure 1. Maize agroecological zones of Kenya, with the Participatory Rural Appraisal (PRA) sites.

During participatory rural appraisals (PRA) with 43 villages, more than 900 farmers explained which varieties they grow and why, and expressed the constraints and pest problems they face. Most farmers grow local varieties, except for in the high-potential zones. The two major criteria for variety selection are early maturity and yield, in addition to three other important traits—tolerance to drought, field pests, and storage pests. The three major constraints to maize production were cash constraints, lack of technical expertise and extension, and problems with maize seed—high cost, poor quality, and low availability. Pest problems are usually found among the top six constraints. The two most important pest problems farmers encounter are stem borers and weevils, which rank in the top three in all agro-ecological zones.

Yield losses due to stem borers were calculated based on farmers' estimates from a survey of 1400 farmers, and resulted in a first estimate of 12.9%[2]. These losses were higher in the low-potential zones (15–21%) than in the high-potential zones (10–12%). Next, yield losses were measured in 150 farmers' fields using a simple experiment comparing protected and unprotected maize, leading to an estimated loss of 13.5%, totaling 0.4 million tons annually, valued at US$ 80 million[3] (**Fig. 2**).

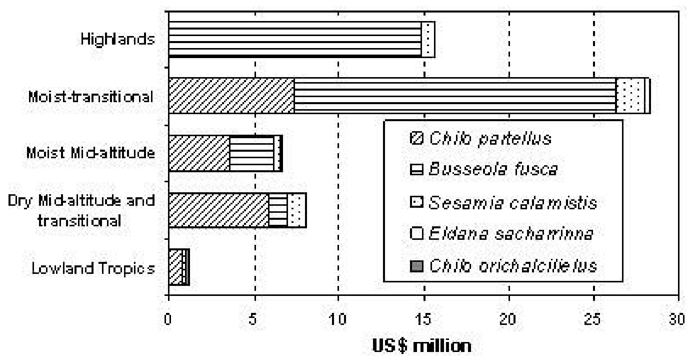

Figure 2. Estimated crop losses in maize due to different stemborers in Kenya, by agroecological zone (Source: De Groote *et al*., 2003).

Supplying the Bt technology for Kenyan maize production does not pose major technological problems. IRMA, working within the regulatory system, introduced several samples of maize leaves with different Bt genes (one per plant) for bioassays[4]. Effective Bt genes were found against all major stem borer species, except for one, *Busseola fusca*, which dominates in the higher altitudes and is economically more important (**Fig. 3**). In bioassays of multiple genes per plant, however, higher levels of efficacy were found. These events will now be tested in the recently approved biosafety greenhouse, followed by trials in an open quarantine facility[5]. Moreover, a review of relevant Intellectual Property Rights, including a Freedom to Operate review, concluded that there are no patents filed in Kenya that would restrict the use of Bt genes in maize. Finally, local seed companies have shown great interest in adopting the technology, as long as the costs are reasonable. The estimated demand and supply were combined in an economic surplus model, which calculated a modest profitability with the currently available Bt genes[3]. The project would be highly profitable if a gene or combination of genes can be found against *B. fusca*. More than two thirds of the benefits would go to the consumer through a reduction in prices.

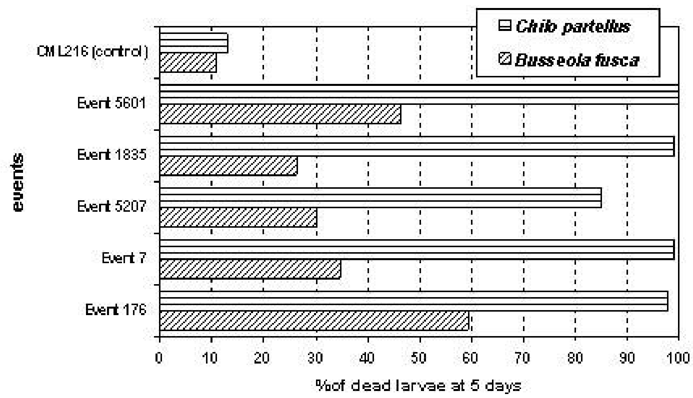

Figure 3. Mortality of the two major stemborer species in Kenya, fed during bioassays on maize leaves containing different Bt events.

Demand and supply need to find one another through markets, within the regulatory framework. Biosafety guidelines were established and Institutional and National Biosafety Committees set up to implement these. Over the years, these committees have become experienced and efficient in dealing with biosafety applications, partially due to the experience and interaction with IRMA. An analysis of the seed sector found that liberalization has increased the number of companies and varieties dramatically, but overall markets are still dominated by one company and a limited number of varieties, especially in the highlands. Moreover, the amount of improved maize seed sold has not increased over the years.

The PRAs also showed that farmers often recycle seed, including hybrids, and that they mark selected plants for this purpose. A study of the credit sector showed that formal agricultural credit has basically collapsed and has been replaced by small, informal finance groups. Farmers who have access to this type of credit use half of it for agriculture, which allows them to double their use of improved maize seed. Regular discussions with farmers, consumers, and institutions during annual stakeholders meetings, group discussions, and other fora reveal that farmers are generally very enthusiastic about Bt maize, while scientists, consumers, and the general audience are cautiously optimistic.

During a survey in Nairobi, few consumers objected to the use of GE crops for food, although they have concerns about risks for environment and biodiversity. Interestingly, upon learning that the Bt gene is dominant (and can therefore be recycled) farmers requested that the project also consider transformation of their local varieties.

Farm surveys showed that most areas have enough alternative hosts that form natural refugia and prevent the build-up of resistance against the toxins. No relatives of maize exist in Africa, so the gene cannot cross into weeds. Farm surveys and PRAs also indicate that biodiversity does not decrease with agricultural intensification. Although the number of local varieties does decrease with intensification, the total number of varieties does not. In the high-potential areas, farmers typically use more varieties than in the low-potential areas, so that their biodiversity indices are higher.

Conclusions

The results of the different studies show how most objections to Bt maize cannot be substantiated. First, it is indispensable to work with Bt maize and introduce it in an experimental setting so that farmers, consumers, and policy makers can make informed decisions. These results indicate that Bt maize responds to an important constraint and that farmers are very interested. Consumers are likely to benefit too, and they do not express strong objections. The poorer farmers in the low-potential areas will benefit relatively more, since they have relatively higher losses, and poor consumers will benefit relatively more since they spend proportionately more of their income on maize. Bt maize is likely to be commercialized by local companies, since there are no restrictive IPRs involved, and thus extra costs will be low. Because the Bt genes are dominant, farmers will not become dependent on the seed industry since they can recycle their seed. Their recycling methods, moreover, are likely to select for the Bt gene and, over time, incorporate the gene into local varieties.

However, local varieties are likely to become contaminated, and this process could be irreversible. IRMA has taken samples of all local varieties in the different zones to deposit in the National Genebank. Further, natural refugia might be insufficient in certain areas. This could be countered by pyramiding several Bt genes in appropriate varieties or mixing seed with sufficient amounts of non-Bt maize. The study of the effects of Bt maize on non-target organisms has not yet been initiated, but identification of these organisms has started and comparative studies will start immediately with field trials.

Acknowledgements

The financial support of the Syngenta Foundation for Sustainable Agriculture is highly appreciated. The views expressed in this paper are the authors' and do not necessarily reflect the policies, or opinions of their respective institutions.

References

1. De Groote H, Mugo S, Bergvinson D, Owuor G & Odhiambo B (2004) Debunking the myths of GM crops for Africa: the case of Bt maize in Kenya. Paper presented at the American Agricultural Economics Association's Annual Meeting, Denver, Colorado, August 1-4, 2004

2. De Groote H (2002) Maize Yield Losses from Stemborers in Kenya. *Insect Science and its Applications* **22,** 89-96

3. De Groote H, Overholt W, Ouma JO, & Mugo S (2003) Assessing the impact of Bt maize in Kenya using a GIS model. Paper presented at the Conference of the International Association of Agricultural Economics, Durban (South Africa), August 2003

4. Mugo S, Taracha C, Bergvinson D, Odhiambo B, Songa J, Hoisington D, McLean S, Ngatia I, & Gethi M (2004a) Screening cry proteins produced by Bt maize leaves for activity against Kenyan maize stem borers." Paper presented to the 7th Eastern and Southern Africa Regional Maize Conference and Symposium on Low N and Drought Tolerance in Maize, Kenya, 2002. In Friesen, D. and A. F. E. Palmer (eds.). Integrated Approaches to Higher Maize Productivity in the New Millenium. *Proceedings of the 7th Eastern and Southern Africa Regional Maize Conference,* Nairobi, Kenya, 11 - 15 February 2002. Mexico, D. F.: CIMMYT, pp. 102-105

5. Mugo S, De Groote H, Songa J, Mulaa M, Odhiambo B, Taracha C, Bergvinson D, Hoisington D, & Gethi M (2004b) Advances in Developing Insect Resistant Maize Varieties for Kenya within the Insect Resistant Maize For Africa (IRMA) Project. In Friesn and A. F. E. Palmer (eds.). Integrated Approaches to Higher Maize Productivity in the New Millenium. *Proceedings of the 7th Eastern and Southern Africa Regional Maize Conference*, Nairobi, Kenya, 11 - 15 February 2002. Mexico, D. F.: CIMMYT, pp. 31-37

Hugo De Groote
h.degroote@cgiar.org
Stephen Mugo
S.mugo@cgiar.org
CIMMYT

Regulatory News

Patent Challenges to AgBiotech Technologies in 2004

Phillip B. C. Jones

The classic techniques appeared in the scientific literature 10 to 20 years ago: *Agrobacterium*-mediated transformation of plants, producing transgenic plants that express *Bacillus thuringiensis* (Bt) toxin for insect protection, and