



Assessing risks and benefits: Bt maize in Kenya

by

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Biotechnology and Development Monitor

No. 48, December 2001

Keywords: Kenya, Genetic engineering, *Bacillus thuringiensis* (Bt), Maize, Risk assessment.

Correct citation: Mwangi, P.N. & Ely, A. (2001), "Assessing risks and benefits: Bt maize in Kenya ." *Biotechnology and Development Monitor*, No. 48, p. 6-9.

This article examines current and future stemborer control options in Kenya, in particular the use of transgenic maize carrying genes from the insecticidal bacteria *Bacillus thuringiensis*.

As an extremely important staple food throughout East and Southern Africa, maize (*Zea mays*) has been a primary focus of agricultural research on the continent during and since the Green Revolution. Despite the development of *higher yielding varieties* (HYVs) and improved cultivation methods, Kenya has yet to attain self-sufficiency in the crop's production and is a regular importer of grain and recipient of food aid, especially in times of drought. Kenya's maize production system relies primarily on smallholder agriculture that uses minimal inputs and *open-pollinated varietie* (OPVs) of seed. This production system is common in the densely populated areas of the Central Highlands, Eastern coastal areas and Nyanza in the West. Large-scale maize production, characterized by monocultures of hybrid seed purchased each season, is only common in parts of the Rift Valley and Western Province, in areas around Kitale, Njoro and their environs.

As well as drought, stresses facing maize farmers in the country include pests and diseases, poor soil fertility, high costs of inputs and low maize prices. The significance of these factors varies across Kenya's agro-ecological zones. However, attack by stemborers and other insect pests is consistently cited as a major constraint on maize production everywhere in the country. Stemborers, including *Chilo partellus*, *C. orichalcociliellus*, *Busseola fusca*, *Eldana saccharina* and *Sesamia calamistis*, are estimated by Kenyan farmers to cause losses of around 15 per cent and in some areas are recognized as the most severe pest problem facing maize production. The insects are most destructive in the larval stage when they tunnel inside the stalk after hatching and are hence very difficult to control. Once inside, their feeding may lead to dead heart, reductions in the number of ears, or structural damage increasing the likelihood of falling in high winds. In some cases the pests also attack maize ears making the cob vulnerable to cob rots, such as *Aspergillus* fungi, which produce harmful aflatoxins.

Conventional methods of stemborer control that employ chemicals or biopesticide sprays, including those based on Bt, have not always been effective owing to the challenges of timing these applications and the resulting difficulties in eradicating the pest once it has infested the crops. For this reason, only

a minority of farmers use these techniques even in nations practising industrial maize production.

Benefits

Bacillus thuringiensis (Bt) is a species of bacteria found throughout the world. It was first discovered in Japan at the turn of the last century and noted for its insecticidal properties. Formulations consisting of the bacterial spores and isolated toxins were later developed as natural pesticides. Since the first of these came onto the market in the 1950s, Bt sprays have become a popular bio-pesticide mainly due to their extremely specific spectrum of action, relative safety towards humans and low environmental persistence. Such environmental benefits have led the *International Federation of Organic Agricultural Movements* (IFOAM) to recognize Bt formulations as an insecticide approved for use on organically certified crops. Recently researchers at the University of Nairobi, Kenya, have reported the discovery of local strains of Bt effective against *Chilo partellus*, *Busseola fusca* and *Sesamia calamistis*.

Recombinant DNA technologies have allowed the insertion of the Bt genes responsible for production of insecticidal toxins into the maize genome. As a result, the Bt maize plant produces the toxins throughout the various tissues over its life-cycle. In the USA, Bt genes that are effective against the European cornborer have been identified and successfully incorporated into maize. European cornborer larvae that penetrate the plant tissues are killed when they ingest the toxin produced in the Bt maize cells. The technology therefore delivers increased yields and a reduced need for insecticide sprays. As a result of these benefits adoption has been rapid and widespread; by 2000 Bt maize constituted a significant proportion of overall maize plantings in the USA, Argentina and Canada. Bt maize therefore seems to represent a promising technology for reducing losses from stemborer infestation in Kenya.

Risks

Most other countries however, especially in Europe, have been slower to adopt the new technology due to uncertainty over the risks that it may pose to the environment or to consumer health. Austria has exemplified this approach, blocking imports of Bt maize from the time of its initial acceptance by the European Commission in 1996 and remaining one of the few countries in the European Union where no GM crops have yet been cleared for release.

Other countries such as France and Portugal approved Bt maize for environmental release, later moving towards a more precautionary approach following wider regulatory debate. In Kenya the debate is in its infancy, however the primary "adverse effects" to be borne in mind are similar to those cited in Europe:

- Effects on non-target organisms (typified by conclusions drawn from initial studies on the monarch butterfly), on natural enemies of stemborers such as the green lacewing *Chrysoperla carnea* and on soil biota.
- The possibility that spread of the transgene to neighbouring conventional crops might lead to economic losses to those farmers aiming to preserve non-GM identity.
- Accelerated development of resistance among insect pests toward the Bt toxins used, potentially leading to ineffectiveness of the Bt maize and the related Bt biopesticide.
- Effects of the presence of antibiotic resistance genes used in the production of some Bt maize varieties, which were feared to cause increases in antibiotic resistance among clinically significant bacteria. Risk assessments in Europe diverged in several ways:

- in their interpretation of the available scientific data in situations of uncertainty or conflicting findings,
- in the extent to which they employed the precautionary principle,
- in the choice of a normative reference point such as organic or conventional "intensive" agriculture against which the new Bt maize technologies were assessed,
- in the degree to which various factors were considered "adverse effects". For example, the possible spread of the transgenes to neighbouring crops.

Recent European Directives 2001/18 (the amendment of the original deliberate release directive 1990/220) and 49/2000 aim to ensure labelling and traceability of all GM ingredients throughout the market introduction process and establish a minimum 1 per cent threshold for transgenic DNA and protein, below which products need not be labelled.

The Kenyan Context

On the African continent, Bt maize has been released commercially in South Africa on around 50,000 hectares following substantial agronomic, but not environmental testing. The *Insect Resistant Maize for Africa* (IRMA) Project, a partnership between the *Kenyan Agricultural Research Institute* (KARI) and *International Centre for Maize and Wheat Research* (CIMMYT) with financial support from the *Novartis Foundation for Sustainable Development*, is developing insect resistant (Bt) varieties suited to various agro-ecological zones in Kenya. No applications for release or commercialization of Bt maize in Kenya have so far been made by the private sector.

In Kenya, regulatory assessments for environmental release of transgenic crops are primarily dealt with by the *National Biosafety Committee* (NBC) of the *National Council for Science and Technology*. The NBC works in conjunction with institutional biosafety committees, *Kenya Plant Health Inspectorate Service* (KEPHIS), an autonomous government organ, the *Kenya Bureau of Standards* (KEBS) and other stakeholders.

Based on mammalian toxicity tests and the concept of "substantial equivalence", several strains of Bt maize have been declared safe for human consumption by the *United States Food and Drug Administration*. These conclusions, although contentious, are generally relatable to the Kenyan situation. Unlike food safety, however, environmental safety is region-specific and requires region-by-region evaluation and monitoring. Although little is known about the potential impact of Bt maize in Kenya, the Cartagena Biosafety protocol - which Kenya was the first country to sign - and national regulations require their assessment prior to release.

Whereas environmental release in the developed world may be recalled (as illustrated by *Starlink* Bt maize in the USA), in areas where small-holder agriculture, open pollinated varieties and seed-saving and exchange are more common, as in most areas of Kenya, releases are more likely to be irreversible. As a result local ecological risk assessments are even more vital. A two-year project to examine a wide range of ecological risks posed by Bt maize in South Africa and Kenya has recently received a grant from USAID. The project will be implemented by the *International Centre for Insect Physiology and Ecology* (ICIPE), the *South African Agricultural Research Council - Grain Crops Institute*, the *University of Nairobi* and *North Carolina State University* and represents a significant step towards qualifying these regionally specific risks. In addition, predictive as well as ongoing ecological and socioeconomic impact assessment is planned as part of the IRMA project.

The significance of the Losey *et al* and Hilbeck *et al* studies on the Monarch butterfly have been hotly

contested, and recent data suggests that some of the earlier popular concerns may have been exaggerated. Nevertheless, various ants, ladybirds, bugs and spiders are predators to stemborers larvae or pupae and over ten species of parasitoids of stemborer larvae have been identified in various parts of Kenya. Impacts on these organisms, especially lacewings and earwigs which feed on *Chilo partellus* and *Busseola fusca* whether through bi-trophic or tri-trophic routes, could have serious repercussions for small-scale farmers and must be investigated thoroughly before release.

Maize is a highly domesticated crop whose wild relatives occur only in Central America. Gene-flow leading to weediness is not therefore a significant risk for maize in either Africa or Europe. However, there are general concerns over contamination of well-adapted landraces of maize that have developed since the species' introduction in East Africa. These landraces are a vital source of genetic diversity for breeding locally adapted varieties and should be conserved (see Stabinsky and Sarno, 2001). In Kenya, potential loss of landraces is addressed by conservation of seeds at the national gene bank and the use of these landraces in the development of improved varieties. *In situ* conservation without contamination is a major challenge, since maize is wind pollinated with long dispersion distances. This, combined with Kenya's predominantly smallholder agriculture, makes it practically impossible to ensure non-contamination of landraces with the Bt gene. Issues of non-GM identity preservation in the field are yet to be addressed by Kenyan biosafety regulations.

Prolonged exposure of target insects to Bt toxins could enhance the development of resistance because of increased selection pressure. The high dose/refugia strategy has been the preferred method of insect resistance management in large-farm areas such as the USA, where no significant insect resistance has been reported since growing licenses for Bt maize were first awarded in 1995. The strategy adopted in each case will depend on the crop in question and on the various regulatory and socioeconomic conditions present in the jurisdiction. Options include licensing, labelling, central control of seed and continual monitoring of use of Bt seed and resistance development. For instance, in South Africa farmers are requested to plant 5-20 per cent refugia with Bt crops. It is not yet clear whether this strategy will be effective (or possible to implement) in smallholder farming systems. In addition, informal seed distribution systems and the possibility of introgression of Bt genes into local OPVs will reduce the effectiveness of labelling options and make enforcement of refuges more problematic.

Despite these difficulties, traditional mixed farming with other crops (so far not engineered with Bt) such as sorghum and pearl millet that are also hosts to maize stemborers may provide some refugia. Furthermore, many indigenous grasses (e.g. *Cenchrus ciliaris*, *Sporoborus marginatus*, *Melinis minutiflora*, *Kyllinga spp.*, *Panicum maximum*, *Pennisetum purpureum* and *Echinochloa haploclada*), which occur in the wild or as weeds in maize fields are alternative hosts to many stemborers and could also act as natural refugia. It is important to note however, that in order for these to be effective, maize farmers will need to adjust their cultivation practices to ensure that stemborers are allowed to emerge from these hosts before the crop is harvested. Incorporation of natural pest resistance through conventional breeding into the Bt plant (known as pyramiding) on the other hand, is an approach to insect resistance management that requires little adaptation of farming systems. This is one of the strategies being followed by the IRMA project. Again employing a biotechnological solution, the IRMA project has overcome the problem of antibiotic resistant genes used in the production of some Bt varieties by focusing on Bt maize products that do not contain antibiotic resistance marker genes.

Across all agro-ecological zones, most farmers in Kenya plant local varieties of maize. Although improved maize varieties dominate in the high potential zones, around a quarter of the

farmers in these regions also use local varieties. Depending on the efficiency of artificial selection (preference by farmers) and natural selection for the Bt trait including that resulting from pollen competition, it is likely that the toxin genes that are dominant will quickly spread to the fields and saved seed stores of farmers who use these varieties and never purchased the genetically modified crops. In this instance, Bt maize would therefore be one of the few approaches to stemborer control that require no adaptation of farming methods or extra external inputs by farmers. However, these benefits will obviously come at the expense of individual choice on the side of both farmers and consumers and may lead to further loss of maize biodiversity.

Although much effort is being made to raise awareness of these issues outside Kenya's biotech-aware minority by organizations such as the *Africa Biotechnology Stakeholders Forum* (ABSF), the task of providing adequate and appropriate education in rural areas is immense. This lack of awareness is one of the likely causes of a near absence of an anti-GM lobby in the country. Concerns over consumer and environmental safety have been raised by the Kenya Consumers' Organization and environmental groups such as the Greenbelt Movement. However the debate at present is confined primarily to government and research circles.

Socioeconomic assessments surrounding intellectual property, farmers' rights and equitable benefits of the technology have not been covered here, but should not be excluded in favour of environmental issues. Both socioeconomic and environmental risks need to be considered in a transparent decision making process that assesses the GM technology against existing alternatives. The multitude of novel risks involved in the release of transgenic maize therefore present several challenges to a country such as Kenya.

Alternatives to the use of Bt Maize

Traditional small-scale, low external input systems of maize farming based on multi-cropping, integration with livestock husbandry and seed saving are the norm in Kenya, with 98 per cent of farms covering less than 8 hectares each. This system of agriculture, despite its limitations, still manages to provide sustenance and food security to the majority of Kenyan households. Cultural control techniques involve the removal of the crop residue for fodder (or by burning) after the maize is harvested. This prevents repopulation of the fields by the progeny of any stemborers remaining in the stalks. This method may have negative effects on soil conservation as it can reduce soil fertility and increase the risk of soil erosion.

Neem extract or a small handful of pyrethrum marc with about 0.3 per cent Pyrethrin content placed in the heart of the plants at the critical time when the stemborers' eggs hatch, has been reported to almost completely control maize stemborer problems. Practices based on indigenous knowledge such as the application of soil, ashes or chilli powder to the whorl of the maize plant have also been recorded. In all cases, the timing of the applications is crucial and requires training for farmers unfamiliar with their use.

A number of *integrated pest management* (IPM) strategies have been tried in Kenya. The approach of classical biological control has been employed by ICIPE which has led a long running project to strategically release *Cotesia flavipes*, a parasitoid of the introduced stemborer *Chilo partellus*. The same institute has been pioneering habitat management practices highly compatible with traditional multi-cropping techniques. These involve various intercropping regimes with wild grasses such as Molasses grass (*M. minutiflora*), that repel gravid stemborer females and attract their hymenopteran parasitoids, and Sudan grass (*Sorghum vulgare sudanense*) or Napier grass (*P. purpureum*) at the

periphery of maize fields which, as highly susceptible trap plants, attract the stemborers away from the crop. Fodder legumes such as silverleaf desmodium (*Desmodium uncinatum*), which act to suppress parasitism by witchweed, (*Striga hermonthica*) are planted among the crop. Such "push-pull" strategies have been shown to result in substantial yield increases over maize monocropping in various areas of Kenya. Economic benefit-cost analysis in Trans Nzoia district, where zero-grazing cattle husbandry is common, showed that Napier grass/ desmodium and Napier grass/ Molasses grass strategies gave favourable returns in comparison to both insecticide intervention and untreated maize monoculture. Desmodium seed may be difficult to obtain in some parts of the country, especially in times of water stress. However, although Desmodium requires rainfall of 800 to 1000 mm annually, the green leaf *Desmodium intortun* is able to grow in much drier areas. In addition, the seed of both species is now being multiplied by individual farmers and women's groups, raising the possibility of opportunities for local microenterprise and income generation.

Conclusion

Bt maize represents a significant step in the control of stemborers of maize internationally. Regulatory approval of the crop has been stifled in some parts of the world, due to remaining concerns of environmental and consumer health. Kenyan officials and other stakeholders now face the difficult task of assessing these genuine but highly uncertain risks and weighing them against the benefits of the technology to the different sectors of Kenyan agriculture. Irreversibility of release, due to the widespread use of saved seed in Kenya, adds to the need for transparency, awareness raising and public involvement in these deliberations.

If the crop is released, this should be done in a way that ensures that the development of resistance in target insects is avoided. In addition, the long-term impact of this new technology on different sectors of Kenyan society and its environment must be monitored and assessed if the Kenyan example is to be a model for future reference.

IPM and LEISA-based alternatives to the protection afforded by Bt maize do exist, though these may also have their limitations. The appropriate choice will vary for each farmer depending on their own particular circumstances and the different options are not all mutually exclusive. Habitat management and other strategies may be strategically combined with Bt maize both for added stemborer control and also to provide the refuges necessary for insect resistance management. Indeed, if Bt maize is approved for commercial release in Kenya, farmers will not be faced with the choice of "biotechnology" against "alternatives to biotech- nology" but will have to decide what combination of strategies to use in combination with the Bt maize that is likely to accumulate in their seed stocks.

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