Debunking the myths of GM crops for Africa:

The case of Bt maize in Kenya

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Abstract

Empirical evidence from research on *Bt* maize in Kenya puts to rest most concerns raised against GMOs (not responding to farmers' needs, expensive, benefiting agro-business, risk of decreased biodiversity), but does indicate that contamination of local varieties is likely and buildup of insect resistance possible, requiring careful monitoring and evaluation.

Key words: GMO, maize, Kenya, risk, environment

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The genetic modification (GM) of plants involves transferring genetic material from a plant or bacterium into a different species, in order to transfer desired traits such as insect resistance or herbicide resistance. GM crops are highly successful in the US, Canada and several other countries, with the area planted to GM crops rapidly increasing, especially for maize (James). This unprecedented rapid adoption has been attributed to increased yield, reduced labor and cultivation costs, reduced chemical inputs into the environment. However, GM crops have generally not been well received in Europe, in large part due to the fear of irreversible environmental damage through the release of GM crops into the environment. Moreover, Europe has already surplus production, so yield enhancing technologies are not that interesting and a strong farmers' lobby would rather protect its markets from external competition. Expected benefits to the European consumer are also small (Demont and Tollens, 2001). Therefore, Europe has accepted the precautionary principle: where the possibility of harmful effects on health is identified but scientific uncertainty persists, provisional risk management measures necessary to ensure the desired high level of health protection may be adopted (McMahon). In practice, however, this has lead to a *de facto* moratorium on the approval of GM products.

Africa is caught in between: should it embrace the technology to help feed its hungry people, or rather protect them from its dangers? The potential benefits of the technology are substantial. The technology is likely to increase yields, and this for a continent that has benefited little from the green revolution (Evenson and Gollin). Moreover, it could increased food security by increasing yields of food crops but also by reducing yield variability and risk, and this for the only region in the world where the number and the percentage of children who are malnourished is expected to rise in the next 20 years (Rosegrant et al.). Finally, the technology is embedded in the seed and is easy to disseminate, and this for a region where extension services have collapsed and market liberalization is emphasizing an increased role for the private sector (De Groote et al., 2002).

Despite these potential benefits, deployment of GM crops in Africa is controversial, and many concerns have been raised (Orton, 2003). Some of these concerns are general, and include food safety and ethical concerns. Others are specific to developing countries, especially Africa, in particular that they are not in the interest of the small-scale farmer, that they are dangerous to the environment, and that the institutional framework is not in place for their deployment (Table 1). GM crops would not be in the interest of small-scale farmers because they do no respond these farmers' priorities, their traits would not respond to a particular demand, and their seed would be expensive. On the contrary, GM technology would only be beneficial to the agro-business and seed companies, who can protect their interests through Intellectual Property Rights (IPR) and terminator genes.

Farmers would increasingly depend on the use of extra inputs such as herbicide and purchased seed of the new varieties, while loosing the biodiversity of their landraces, Moreover, GM crops are thought to pose serious environmental risks through gene flow into weeds and local varieties, and from negative effects on of non-target organisms. Institutionally, African countries might not be sufficiently equipped with the appropriate bio-safety regulations to make an informed choice, and lack democratic procedures through which poor consumers can express their choice.

Enhancing the debate through science and participatory research: the IRMA project

Principles

In this paper, we argue for a more balanced view and a science-based discussion based on following principles. First, biotechnology, and GM crops in particular, have high potential in improving; 1) crop productivity and actual production, 2) yield stability, and 3) the nutritional quality of major crops in Africa in ways that would not be possible using conventional technology (Nuffield Council on Bioethics). Second, these benefits should be carefully evaluated against the concerns formulated above. Third, African farmers and consumers have the right to choose their own technologies, based on the best available knowledge (Pinstrup-Andersen and Schiøler). Finally, to make informed choices possible, scientists need to experiment, adapt and test GM technologies in Africa, with all precautions in place and using participatory methods, so poor farmers and consumers are not denied a chance to improve their livelihood, based on an academic debate in which they cannot participate. Through careful experimentation, the necessary capacity and expertise will gradually be developed, in science as well as in institutions, to develop bio-safety protocols and regulations, to handle GM crops, and to assess impact. This hands-on experience makes it further possible to communicate with farmers, consumers and policy makers, to raise awareness, and to let farmers make an informed choice by letting them evaluate the technology and, if appreciated, trying and adapting it in their fields.

Based on these principles, the International Maize and Wheat Improvement Centre (CIMMYT) and the Kenya Agricultural Research Institute (KARI), with financial support from the Syngenta (previously Novartis) Foundation for Sustainable Development, launched the Insect Resistant Maize for Africa (IRMA) project in 1999. This project aims to develop maize varieties resistant to stem borers, a major maize pest in Africa, using both conventional breeding and biotechnology, and combining the best available science, bio-physical as well as social.

Development of the IRMA project

When CIMMYT approached the (then) Novartis Foundation, several elements were agreed upon: transformed plants would only carry the gene of interest but no selectable marker genes such as herbicide or antibiotic resistance, CIMMYT would only test and deliver transgenic crops in countries that have appropriate biosafety legislation or regulations, and only genes in the public domain would be used. The project is being implemented initially in Kenya, from where the results and experiences will be available to other interested African countries. Kenya was selected because of the importance of maize and stemborers here, the decline per capita maize production, and the positive regulatory and policy environment towards GM crops.

Formally, the objectives of the IRMA project are to (1) develop insect resistant maize varieties for the major stem borer species found in major maize production systems, (2) establish procedures for providing insect resistant maize to resource poor farmers, (3) assess the impact of insect resistant maize varieties in maize farming communities, (4) transfer technologies to develop, evaluate, disseminate, and monitor insect resistant maize varieties, and (5) plan, monitor, and document processes and achievements for dissemination to the Kenyan public and other interested developing countries. Activities have been carried out and results and achievements made.

Kenya is well positioned and prepared to utilize the novel technology involving genetically modified organisms. Kenya has the necessary biopolicies (see elsewhere in this paper), has experiences with other genetically y modified crops. A sweet potato with resistance to feathery mottle virus was tested in the field at four locations; a cassava with resistance to the white fly is being tested in KARI Kakamega, while an approval for Bt cotton was granted. The availability of facilities like biosafety laboratories, greenhouses and open quarantine field sites, that are run by a crop of scientists trained in biotechnology place Kenya at the forefront of research in Kenya.

All experiences in Kenya will be documented from where other African countries can learn. After the principal agreement, a first meeting between the organization was held in Nairobi in June 1999, followed by a planning workshop in August 1999. The workshop brought together scientists from KARI, CIMMYT and the Novartis Foundation for Sustainable Development. They consulted, shared information and planned the development and deployment of insect resistant maize in Kenya, using both conventional breeding as well as biotechnology and genetic transformation (Siambi et al., 2000), and produced a strategic work plan with objectives, log frames, timelines and responsibilities for each of the five identified project objective teams (KARI and CIMMYT, 2000).

After five years of research in the first phase of the project, including biotechnology, breeding, entomology, diagnostic research and impact assessment, a preliminary assessment of the technology can be made. Based on this research we document the supply of and demand for Bt maize, as well as the enabling environment and the farming systems in which it is likely to be deployed. We will show that most objections are not supported by the available evidence so far, although some concerns still remain, in particular the development of insect resistance and (Bt) gene flow into local varieties.

The demand for insect resistant varieties

Maize in Kenya

All available data and research result point in the same direction: demand for Bt maize in Kenya is likely to be high. Maize is by far the most important food crop in Kenya, and is both a subsistence and a commercial crop. It is planted on 1.5 million ha, which is more than 30% of arable land. The average annual production of the last 5 years is 2.4 million tons (FAOSTAT), or, for a population of 31 million, 79 kg/person. In the last decades, agriculture in Kenya has undergone major changes. After major progress in productivity during the 1960s and 1970s, maize yields and production have stagnated while production per capita has decreased. Consumption is estimated at 103 kg/person (Pingali, 2001), and Kenya is increasingly importing maize. Heavy state involvement was partly blamed, so agriculture went trhough an ambitious, donor-driven liberalization, involving maize marketing (prices and movements), seed production (the state monopoly was ended, and new entries became easier), and fertilizer markets (removal of import taxes and restrictions). However, the effect of liberalization was limited (De Groote et al., 2002). Factors include the limitations of maize marketing (with government interference and high price volatility), the on-going oligopoly of maize seed production, and the poor state of infrastructure, in particular roads and communications. To solve the threatening food crisis, markets need to be improved, but new technology is also urgently needed.

In Kenya, six major agro-ecological zones can be distinguished for maize production. Going from East to West, we first have the Lowland Tropics (LT) at the coast, followed by the Dry Mid-altitudes and the Dry Transitional (between mid- and highland) zone. These three zones are characterized by low yields (below 1.5 ton/ha) and, although they cover 29% of maize area in Kenya, they only produce 11% of the maize. In Central and Western Kenya we find the Highland

Tropics (HT), bordered at the West and East by the Moist Transitional (MT) zone. These zones have high yields (more than 2.5 t/ha) and produce 80% of the maize in Kenya on 30% of the area. Finally, around lake Victoria, we find the Moist Mid-altitude (MM) zone. With a medium yield (1.44 ton/ha), it covers 22% of the area and produces 9% of the maize.

Stem borer species are spread in all maize growing regions of Kenya. Stem borer species occupy over-lapping ecologies, including the two most important species. The spotted stem borer, *Chilo partellus* Swinhoe and other *Chilo* species are found in the lowlands and the mid-altitude areas and often kill the growing point of maize at an early stage to produce the symptom called "dead heart". The African stem borer, *Busseola fusca* Fuller, is mainly found in the highlands and the mid-altitude zone of western Kenya and reduces yield by tunneling the stalk and shank of the ear. The pink stem borer, *Sesamia calamistis* Hampson, and the sugarcane borer, *Eldana sacharina* Walker, are found in various areas in western Kenya. Resource poor farmers seldom use insecticides to control stem borer attack due to cost, availablity and lack of knowledge. When pesticides are used; they represent a large input expense, are often applied without protection and will often pose risks to the farm family, livestock and the environment. Bt maize offers farmers an effective and practical option for reducing stem borer damage in maize. Studies elsewhere have demonstrated the high effectiveness of Bt maize in controlling damage by neotropical stem borers (Koziel et al., 1993). The use of Bt maize could reduce the heavy reliance on pesticides for stem borer control.

Farmers, maize and stemborers

To judge if Bt maize would respond to a need of small-scale farmers, the IRMA project organized participatory rural appraisals (PRAs) in 43 villagesm spread over the different agroecological zones. More than 900 farmers participated in group interviews and explained which varieties they grow and why, and expressed the constraints and pest problems they face (De Groote et al., 2001). Most farmers grow local varieties, except for the high potential zones. The two major criteria for variety selection are early maturity and yield. Three other traits are generally important: tolerance to drought, field pests and storage pests. The three major constraints to maize production were cash constraints, lack of technical know-how and extension, and problems with maize seed: high cost, poor quality and low availability. Pest problems usually ranked in the top six constraints. The two major pest problems farmers encounter are stem borers and weevils, and more recently the larger grain borer which rank in the top three in all the agroecological zones. Striga is the most important problem in the moist mid-altitudes, but is not important elsewhere.

After establishing that stem borers are a major constraint to maize production, an attempt was made to quantify the crop losses they cause. Initial estimates were based on secondary data, followed by crop loss trials. Secondary data came from a 1992 CIMMYT/KARI survey of 1400 farmers, spread over the different agroecological zones, in which farmers were asked to estimate the incidence of stemborers and the crop loss caused (Hassan). Calculations based on these data resulted in an estimated yield loss of 12.9%, amounting to 0.39 million tons of maize (De Groote 2002). Next, crop losses were measured in farmers' fields, using a simple experimental where half of each field was protected with a systemic insecticide, and the other half was left unprotected (De Groote et al., 2002). The yield difference between the two plots was taken as an indicator of yield loss. The experiment was repeated in 150 farmers' fields, 25 in each zone, over 4 seasons. The weighted average for all zones was calculated at 13.5%, very similar to the farmers' estimates, ranging from 11% in the highlands to 21% in the dry areas. Total losses are then estimated at 0.4 million tons, valued at US$ 80 million, more than half of which occur in the moist- transitional zone.

Based on the importance of maize as a food and cash crop, farmers' perceptions on the importance of stemborer, and crop loss assessment, we can conclude that there is a large demand for the technology, especially if a effective gene against *B. fusca* can be found.

The Supply Side

Bt-maize is the common term for maize that is genetically engineered to contain a gene from *Bacillus thuringiensis (Bt)* that codes for the production of endo-toxins. These toxins have a crystalline form, hence the terms *cry* when referring to the gene. Several of these genes have been identified and tested, by public and private sectors and found to offer a high level of control against specific leptidopteran pests. Using modern molecular biology tools, genes from the soil dwelling bacterium *Bacillus thuringiensis* (Bt) are modified to enable their stable expression in plants following their introduction using one of two transformation techniques: biolistics or gene gun (Koziel et al. 1993) and by using the *Agrobacteruim tumefasciens* (Ishige et al. 1996). The Bt genes of interest encode for delta-endotoxins proteins. Upon ingestion by susceptible stem borers, the proteins released from the crystal and the protoxins are solubilized. The protoxins are then activated by insect gut proteases with the protein containing twofunctional domains: a beta-plated sheet that enables binding to the bush border membrane vesicles of the peritrophic membrane and an alpha helix that insert into the midgut epithelium to create a pore that compromises the integritiy of the stomach that ultimately leads to larval mortality (Gill et al. 1992). The Bt toxins are active against lepidopteran pests but are not toxic to humans nor livestock. *Bt-maize* offers farmers an effective and practical option for reducing stem borer damage in maize. Studies elsewhere have demonstrated the high effectiveness of *Bt-maize* in controlling damage by neotropical stem borers (Koziel et al., 1993). The use of *Bt-maize* could reduce the heavy reliance on pesticides for stem borer control.

International developments

The first Bt gene, the *cry1Ab* gene, was introduced in 1996 and has provided effective control against several of the primary pests of maize, principally the stem borers (James, 2003a). Its successful performance has resulted in its rapid adoption reaching 67.7 million hectares in 2003, with 99% of the area grown in 6 countries (James, 2003b). Although these varieties initially targeted primarily the market in developed countries, with an increasing proportion (30% now) grown by developing countries. In Africa, the only country where Bt maize is commercially grown, notably, South Africa grew to 84,000 hectares of Bt white maize for food in 2003, white (food) maize was introduced after (yellow) feed maize, and 87,000 ha was grown in 2003 (James, 2003b).

Development of Bt technology for Kenya

CIMMYT's Agricultural Biotechnology Centre (ABC) in Mexico, started transforming maize (in particular the variety CML 216) in the early 1990s, using the biolistic method. In this method, a "gene gun" is used to bombard gold particles coated with plasmids containing a truncated (or codon-modified), synthetic version of one of four cry genes. Earlier transformation events contained selectable markers such as herbicide or antibiotic resistance to identify putative transformation events. The modification facilitates stable expression of these genes in maize plants. A successful transfer of a gene, with or without markers, is called an event. The placement of the *cry* gene in the maize chromosomes is random. Molecular characterization, including mapping, is undertaken to determine how well these events are integrated into the maize, to ensure that they function properly and will be effective, and involves determining the location of the gene and the number of copies in the maize genome (the complete set of genes of an organism). Similarly, studies are done to determine the level of Cry protein in the mature seed (embryo and endosperm). Most events were found to express Bt toxins only in the embryo and not the endosperm (the part usually consumed) and toxin levels in these tissue were only 20% of those determined in leaf tissue (KARI and CIMMYT 2001, KARI CIMMYT 2002). Since the endosperm accounts for over 70% of the grain weight, the overall levels of Bt toxin in the grain is very low. Food safety studies by US government agencies have shown that Bt toxins do not bind to human intestines and are digested readily in humans and livestock, therefore, the low levels of toxin expressed in whole grain does not represent any food safety hazard for humans or livestock.

At the beginning of the project, the biosafety framework in Kenya was sufficiently developed (see details in next section) to process the applications to import the leaves from Bt maize, after approval of the research and facilities by the NBC. Afert the necessary permits were obtained, two batches of Bt leaves were imported, first the of several straight events (one gene each, still with markers) in January 2001, followed by a set of Bt leaves with combinations of different *cry* genes, in December 2002.

In leaf bioassays, larvae of the different stem borer species are put on Bt maize leaves. The efficacy of the Bt toxins in controlling the different species is than obtained from larval mortality and from the amount of leave tissue eaten by the larvae. Results show how cry 1Ab and cry1Ba genes are very effective against the *Chilo* species (almost 100% mortality after 5 days), but not as good against *Busseola fusca* (60%) (Figure 1). Combining either the *cry1Ac* or *cry1Ba* gene with *cry1Ab* in the same plant, however, enhanced the level of control for *Busseola fusca* without decreasing the effect on *Chilo partellus* and other species. Though complete control of *B. fusca* was not achieved, the results indicated that two-gene combinations enhanced effectiveness and could be useful in development of the “high-dose” strategy for stem borer control using Bt Cry proteins (Mugo et al., 2003).

The promising genes were further developed into “clean events”, without any antibiotic or other markers. An open quarantine site was constructed and an application was filed to bring in maize seed with the Bt genes, to test in the field. The National Biosafety Committee, however, requested that the tests first be held in a Biosafety Level II Greenhouse facility. Biosafety levels range from 1 (1= very low level, to work for example with common bacteria) to 4 = very high (for working with highly contagious diseases like the Ebola virus). Bt maize in Kenya is placed at a low category of biosafety, and the key feature of the level II greenhouse is the pollen screen that prevents pollen from escaping and crossing into nearby maize. The greenhouse was built at KARI’s Biotechnology Centre, and inspected and approved by the Kenya Standing Committee on Imports and Exports (KSTCIE) in the beginning of 2004. The application to import maize seed containing the Bt genes Cry1Ab and Cry1Ba and cross the genes into other maize lines has already been approved by the NBC (May 2004), and the permit to introduce the seeds is being prepared by KEPHIS. Only clean events, also called second generation events, will be imported.

The results of the supply side indicate that efficient Bt gene against the major stemborers can be found, with the potential exception of *B. fusca.* This information was incorporated into an economic surplus model to calculate the potential benefits of the technology, based on geo-referenced data from different sources, including the crop loss data, production data, prevalence of stem borer species, and adoption rates of new varieties (De Groote et al. 2003). In the first scenario, assuming an effective gene against *B. fusca* can found, the economic surplus of the project is calculated at $ 208 million over 25 years (66% of which is consumer surplus) as compared to a cost of $5.7 million, a very high profitability. Geographically, the project should focus on the high production moist-transitional zone. However, if such gene cannot be found, Bt maize technology would only be effective in the low potential areas, and adoption rates would be fairly low, although benefits would still exceed costs.

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The enabling environment:

The above results strongly indicate that there is a potentially large demand for, as well as an expected supply of good and efficient Bt maize varieties. However, supply and demand still need to find each other in the market within the existing regulatory framework. It is very important that the enabling environment is conducive for Bt maize (Tripp, 2003), including socioeconomic and political factors (Smale and De Groote, 2003). The most important factors are the regulatory system, the distribution or seed system, and the attitude of the different stakeholders towards this new technology.

The regulatory system

A first analysis of the regulatory system (Ely et al., 2002) found that it has become substantially more efficient in dealing with biosafety applications, partially due to the experience gained through the IRMA project. The developempent of biosafety regulations started in 1987 when the then Minister of Research Science and Technology set up a committee under the National Council for Science and Technology to determine the priorities for research in biotechnology. This committee, then named the National Advisory Committee on Biotechnology Advances and their Applications (NACBAA) first formulated the need for a coherent policy on biosafety. The committee, which consisted of the directors of different research institutes (such as KARI, KIPI, Keny Bureau os Standards SUCH AS?), recommended to the government that the NCST develop a policy on biohazards and ethics in biotechnology (Thitai et al., 1999).

In 1994, the Kenya National Environment and Action Plan, developed by the Ministry of Environment, and is approved by Cabinet, made the following recommendations pertaining to biosafety: i) to establish a National Commission on biotechnology and biosafety, ii) to formulate a scientific criteria for the safe use genetically modified organisms including methods or hazard identification and exposure assessment before GMOs are released into the environment to monitor the organism, genetic material and processes exposed to GMOs, iii) to make prior informed consent (FROM WHOM) a pre-requisite for all field testing, iv) to formulate a biosafety policy and regulations.

In 1997, the Kenya Agricultural Research Institute (KARI) produced draft guidelines for biotechnology and biosafety research in the institution. According to these guidelines an Institutional Biosafety Committee was formed to implement them. In 1998, the National Council for Science and Technology produced a draft of "Regulations and Guidelines for Biosafety in Biotechnology for Kenya" (NCST, 1998) which provided a base for the establishment, under its umbrella, of the National Biosafety Committee (NBC), in which different ministries, research institutes and farmer organizations are represented. The NBC encourages the establishments of Institutional Biosafety Committee (IBCs) in consultation with the relevant institutions. The NBC also has power to appoint task forces and to coopt any individual it considers necessary for more efficient performance of the functions. These guidelines also identified the National Council for Science and Technology as the competent authority in biosafety matters.

In 1999, with the support of the UNEP/GEF Biosafety Enabling Activity, the NCST produced the "Kenya Biosafety Framework" (Thitai et al., 1999) based on an assessment of the status of biotechnology and biosafety in the country. In 2000, the National Biosafety Strategies and Action Plan (NBSAP), published by the Ministry of Environment and Natural Resources, identified biosafety as an important area that required support for its advancement. On 15th May, 2000, during the Fifth Conference of Parties to the CBD, the President of Kenya signed the Cartagena protocol on Biosafety, Kenya was the first country to sign the Protocol. Kenya took part to the round table conference of Ministries held in May 2000 during the Conference of Parties 5 (COP) and supported the need for providing assistance to developing countries for biosafety capacity building activities. Also in 2000, the National Environment Co-ordination and

Management Act was enacted by parliament. This Act also emphasized the need to set regulatory framework for biosafety issues.

Within those acts and preparatory work, Kenya is now implementing the biosafety framework under the UNEP/GEF support project. To this end, a draft Biotechnology and Biosafety Policy, draft Biosafety Bill, and draft Biosafety Regulations have been developed. The draft Biosafety Bill is currently (mid-2004) under review by the office of the Attorney General to be tabled at Parliament later this year. The Biosafety Regulations cover areas of research and development involving the release of genetically modified organisms (plants, animals and microbes) and all aspects of recombinant DNA technology and use of biological products derived through genetic modification. They specify that NBC may allow the importation of biotechnology products, including GMOs, under the national quarantaine system, after assessing the adequacy of the tests done on the products in the country of origin. Containment facilities and other safeguards are required when carrying out work on GMOs. Hence biotechnology development, safety measures, institutional networking, and guidelines governing all application of biotechnology in Kenya are covered in the regulations and guidelines for safety in biotechnology. The guidelines are implemented by the different key regulatory agencies: the Kenya Plant Health Inspection Services (KEPHIS), the Department of Veterinary Services, the Kenya Bureau of Standards and the Public Health department.

In the case of Bt maize, the applicants (KARI and CIMMYT) first needed to make an application to KARI's IBC, to introduce Bt leaves or seed into Kenya. This application detailed the materials to be introduced, the research being proposed, the facilities to be used, the personnel to be involved, and the biosafety measures that will be taken during the introduction and the research Assuming all information provided is adequate for risk assessment, the committee submits the application to the NBC, who sends out the application to a team of experts for review. If that is satisfactory, the NBC approves the application, and stipulates the conditions under which the research is to be carried out, in particular biosafety facilities, guidelines, and appropriate skills of all personnel involved. If all conditions are satisfactorily addressed, including certification of the biosafety facilities through inspection by committee convened by KEPHIS, the applicants apply for plant importation permit from the appropriate regulatory agency, in this case KEPHIS. KEPHIS also oversees the research activities on a regular basis, including the entry of the GM material into the country, accompanying the material from the port of entry to the research site, and appropriate disposal of all GM material at the end of the evaluation.

Other factors in the enabling environment: IPR, seed systems and credit

To assure that the technology developed will be accessible to farmers without excessive costs, a review of Intellectual Property Rights (IPR) was commissioned. This study included a Freedom to Operate (FTO) review, and concluded that no patents had been filed in Kenya concerning the Bt technology, and therefore no IPR restrictions are expected (SwiftReviews). Moreover, when a company files for a patent in one country, it only has one year file for this patent in another country. Since all patented technologies under consideration by the IRMA projects have been patented for longer periods, no patents can be filed anymore in Kenya.

The seed sector is of particular importance to bring biotechnology products to the farmers (Tripp, 2001). An analysis of the sector, after visiting all seed companies and regulatory agencies, found that the liberalization of the seed sector (starting in the 1990s) had increased the number of companies and varieties dramatically, but that the overall market was still dominated by one company and a few varieties. Moreover, the amount of improved maize seed sold has not increased over the years. This was also confirmed by the PRA results, and a survey of seed distributors (Nambiro et al., 2002). From the PRAs we know that farmers commonly recycle their own seed, including hybrids. Many farmers mark selected plants in the field (in particular for early maturity) for seed recycling.

Several seed companies, through the stakeholders' meeting, have expressed strong interest in producing and distributing *Bt* maize seed. They would, however, prefer to transform and develop their own varieties. Farmers recycling practices, their keen interest in the trait as well as its visibility (stem borer marks are very visible in the field), are likely to lead to farmers selecting seed from plants not attacked by stem borers, preserving the gene in further generations.

A study of the credit sector showed that small scale farmers have no longer access to formal agricultural credit, but are increasingly using small, local and informal, savings and loan associations (Owuor et al., 2002). Half of the credit thus obtained is used for agriculture, and it doubles the use of improved seed. Improving the credit situation, maybe through supporting the informal finance sector, is likely to improve adoption.

Consulting with consumers and other stakeholders

To gauge the awareness and attitudes of the consumers towards GMOs, 604 consumers were interviewed at different points of sale (in supermarkets, posho mills, and kiosks) concerning their awareness and attitudes toward GMOs. Almost half of the respondents were aware of GM crops; people were appreciative of their benefits, but many worried about potential negative effects on human health and the environment, especially on local plant varieties.

Regular discussions with farmers, consumers and institutions during annual stakeholders meetings, group discussions and other forums, reveal that farmers are generally very enthusiastic about Bt maize, while scientists, consumers and the general audience are cautiously optimistic. A survey in Nairobi showed that consumers generally trust the regulatory agencies, and relatively few consumers object to the use of GM crops for food. 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.

From the different studies and experience, we find the enabling environment and attitudes of different stakeholders and institutions to be generally positive towards Bt maize. The regulatory process and seed release system is still slow, but improving. Varieties aimed at low-potential areas, however, would need a substantial push through extension and NGOs, farmer varieties can be

The natural environment

It was desirable to generate information on the actual and potential effects that the *Bt-maize* technology will have on target and non-target arthropods in maize-based cropping systems in Kenya. Baseline studies were done through field collections of these organisms to establish the diversity and relative abundance of target and non-target organisms in the five major maize agroecologies in Kenya. Field collections were made using three different trap types (basing, pitfall and sticky traps) to sample insect abundance and diversity every two weeks within farmers' fields. Sampling also included stalk dissections to collect stem borers that may have been attacked by biological controls which were allowed to emerge in an insectary. The insect within each sample were classified to genus and a dry collection of specimens for each family of insect was established. In addition, a digital database for the specimens was developed to enable researchers in other research stations to classifiy specimens in the future to at least family in order to monitor the impact Bt-maize will have on arthropod diversity and abundance. The data base includes digital photos of representative specimens. Collection data was geo-references to facilitate the use of geographical information systems (GIS) to track future monitoring efforts. The database will enable early monitoring of regions where insect species may be adversely affected by *Bt-maize* (Songa et al. 2002).

Another major concern regarding the use of Bt-maizee is the development of insect resistance. The strategy currently being used in developed countries is the concept of refugia whereby a non-Bt host crops is within close (<800m) of the Bt-crop to ensure that if a moth emerges from Bt-maize that it will intermate with a wild-type moth that emerged from a non-Bt crop. This strategy is designed to prolong the development of highly resistant biotypes of the pest by ensuring resistance alleles are maintained in a heterozygous state. In the USA, the area planted to a refuge should be 20%; however, it is not reasonable to expect that farmers in developing countries will plant a refuge given the amount of extension required to communicate the concept of refuge and the potential loss in production by planting a refuge. For these reasons, the IRMA project established research plots to establish the effectiveness of different alternate hosts that are commonly found withpercent refugia currently available in each of the two main maize cropping seasons.

Farmer surveys conducted from 2001-2003 revealed that in most maize-growing districts of Kenya an adequate natural refuge was available within the mixed cropping system in order to delay the development of stem borer resistance to the Bt toxins. In some commercial maize areas, however, this is not the case and therefore additional extension effort must be placed to train farmers on the importance of refugia to impede the development of resistant insect biotypes.

Gene flow is the third major environmental concern associated with the use of GM crops. This issue is particularly important for centers of origin, such as Mexico in the case of maize. In the case of Kenya, maize was an introduced species and so the impact of Bt maize on genetic diversity in Kenya is important but not as much as in the case of Mexico. However, gene flow is important in the case of gene movement between neighbouring farms, especially in the case of farmers who do not wish to use Bt-maize as a means of protecting their crop. To bettern understand how to manage gene movement, gene flow studies were conducted in Kenya using yellow maize as a source of contamination in white maize (yellow grain color is a domoninat traits as is the Bt gene). By planting white maize in the four cardinal directions away from a 1m square plot of yellow maize, we were able to estimate the rate of contamination. While there is a strong directional effect associated with the predominate wind direction. Since maize pollen is heavy, 75% of the maize pollen falls within 10m of the source plant and less than 0.2% contamination at 50m from the source due to the heavy nature of maize pollen,

Farm surveys and PRAs also indicate that biodiversity does not decrease with intensifications (De Groote et al., 2002). In the high-potential areas, farmers have adopted more improved varieties at the cost of local varieties. The number of varieties (and different biodiversity indices) has not decreased.

Conclusions

The results of the different studies conducted by the IRMA project clearly show that most objections to Bt technology are based on myths and misconceptions. The results allow us to systematically discuss the concerns, as presented in Table 1. On the general issues, consumers in Kenya do not have concerns on food safety or ethical concerns on unnatural scientific procedures. It has also become very clear that Bt maize responds to a problem perceived by farmers as very serious, and farmers are likely to adopt it. Without patents in Kenya, and the project's policy on IPR , local seed companies are likely to embrace the technology and benefit, while international companies have no comparative advantages. The price of Bt maize seed is not expected to be much higher than conventional maize seed. Although total benefits per farm would be higher in the high-potential areas, the benefit per ha would be roughly the same. Moreover, the relative benefit would be substantially higher in the low-potential areas and for the resource poor farmers, since their crop losses are relatively much higher.

With respect to the environment, there are no wild relatives of maize in the country, so no gene flow into weeds is possible. No effect on non-target organisms can be measured so far, but the project is putting substantial effort in cataloguing and analyzing current populations of these organisms. Preliminary results suggest that the impact of Bt maize will likely be favorable as it will reduce the application of broad-spectrum insecticides. Insect resistance can be managed through the availability of existing refugia due to the mixed-cropping system employed by most farmers in Kenya. Regions where refugia are not adequeate will be the focal point for training of extension and farmers alike. Since the development of maize agriculture has not led to a decrease in biodiversity, the development of Bt maize is also unlikely to decrease biodiversity. Moreover, farmers' recycling methods are likely to lead to a recycling of these plants which have the gene, leading to transformation of local varieties, an actual increase in biodiversity.

Institutionally, Kenya has demonstrated that it can develop a biosafety regulatory network and is capable of handling complicated applications. Although no formal systems exist to incorporate the opinion of the general consumer, the project has demonstrated that it can use participatory methods to work with farmers as well as consumers, and with the stakeholders at large. So far, these first efforts indicate enthusiasm from farmers and acceptance of consumers and other stakeholders, although with some reservations.

However, two major concerns remain. First, Bt gene can easily flow into local varieties, in particular since it is a dominant gene. The “irreversibility” of the technology is an important consideration and for that reason this project has been very thorough in characterizing potentially adverse environmental effects. The project has also established a collection of uncontaminated local varieties in the national gene bank. Second, resistance may develop in stem borer species such as *Busseola fusca* that are not completely controlled with existing Bt genes and events. Herefore, baseline studies to characterize non-target arthropods have been completed in the major agroecological zones, and studies to investigate the effects of Bt maize on non-target organisms will commence with the opening of the biosafety greenhouse and open quarantine site. Monitoring of farmers fields once Bt maize is introduced will be important for both resistance management and impact studies for non-target organisms.

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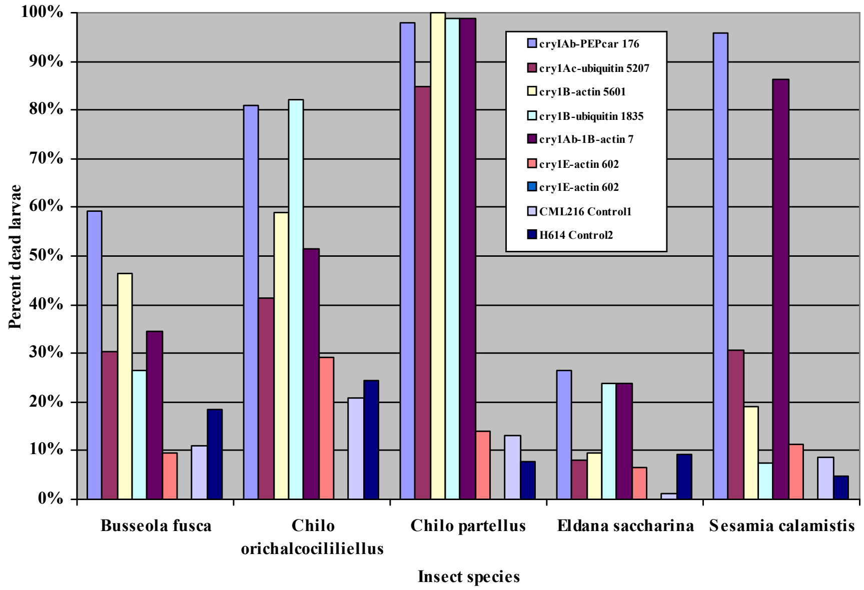
Table 1. Concerns to the deployment of GM crops in Africa.

Specificity	Category	Concerns about GM food and crops
General	Food safety	- GM food not safe for human consumption
	Ethics	- Genetic engineering is tampering with nature
Developing countries and Africa	Benefit to African farmers	- GM crops do not correspond to priorities set by African farmers - there is no demand for GM traits expressed by farmers - high cost of technology - not beneficial to small farmers, - beneficial to seed companies and multinationals
	Environment	- insect resistance can develop - GM genes can flow into weeds and local varieties - potential effect on non target organisms - decreased biodiversity
	Institutional:	- African countries have insufficient biosafety regulations - there is insufficient participation in decision making from poor farmers and consumers

Figure 1. Percent dead larvae of 5 stem borers species after feeding on leaves with 6 Bt gene events and two controls for 5 days.



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