Insect Resistant Maize for Africa: Lab to Field and Challenges along the Way

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I will provide some background on the challenges facing Africans and African researchers—with emphasis on the Kenyan experience—and the prospects for using science in general and biotechnology in particular to address some of our major problems.

Agriculture in Sub-Saharan Africa

In Kenya, as in sub-Saharan Africa as a whole, most people's livelihoods are tied to agriculture. Although we have large well managed farms that resemble those in the United States, the vast majority are smallholder operations, typically of 1 to 2 ha, that feed extended families of twenty or more people. On these small plots, crops are grown mainly for direct consumption, with the little left over being sold to cover school fees or saved to eventually purchase an ox. Some farmers can pay to have their land tilled by a tractor or ox-driven plow, but, as often as not, tilling is accomplished by women working for days with hand-hoes. Hybrid seeds, like fertilizer, are available, but considered a significant investment, and insecticides and herbicides even more so. Sometimes these chemicals are fake and do not work, and farmers may apply them incorrectly or at the wrong time. But, like farmers everywhere, they weigh the risks and

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benefits and invest their meager resources if they see a good chance of a return. The difficult situation at the ground level is reflected in the situation at the national and regional levels. Although two-thirds of sub-Saharan Africa's people live on small-scale farms and produce their own food, nearly a third of them are undernourished (FAO, 2001). The region simply does not produce enough food to adequately feed its population, and food production per capita is declining. Although land is relatively plentiful in comparison to other parts of the world, soil fertility, a key factor in productivity, is declining, leading to devastating infestations of the parasitic weed, *Striga*. Drought and its partner, crop failure, are regular visitors in sub-Saharan Africa. In the past, with all these constraints facing farmers, the one thing they could rely on was family labor. But with AIDS and the migration of the younger generation to urban areas, even this is no longer assured.

Times are tough for smallholders in Africa, and they were tough also for the farmers of South Asia before the Green Revolution—a revolution in agricultural production that bypassed Africa. Today, we in Africa are looking for our own Green Revolution to bring us to a new era of food security. But our Green Revolution will probably entail a range of agricultural advances on a number of fronts rather than the introduction of a new plant variety supported by a specific technology package (short-statured wheat and rice and intensified planting). One thing is clear: biotechnology will play a central role in Africa's agricultural revolution (Conway and Toenniessen, 2003; Toenniessen *et al.*, 2003).

Critical Role of Biotechnology

Why will biotechnology play such a critical role?

- Traits incorporated into a host plant (such as insect resistance or drought tolerance) do not require extensive training regimes for adoption by farmers. In Africa, where national budgets are called upon to meet pressing needs in education and health, agricultural extension services are usually under-funded. Reaching poor farmers, many of whom do not even have a radio, is a daunting task. Therefore, providing technologies that are literally carried within the seed itself is one of the most efficient ways to bring enhanced productivity to the field.
- Progress in solving many of our agricultural problems using conventional breeding has been very limited. Notable needs include drought and low-nitrogen tolerance, *Striga* resistance, and insect resistance. Although agronomic and crop-management measures can be taken, they are often beyond the means of our resource-poor farmers. By extending our plant-improvement horizons to include genes from other species, we dramatically increase our chances of producing plants that are relatively unaffected by environmental stresses and produce higher yields.

- We in Africa simply do not have the time to follow the timeworn footsteps of industrialized countries in developing our agriculture. We must leapfrog to new approaches and new technologies to meet our needs. A case in point, outside of the agricultural sector, is telecommunications. Land phone lines in my country are unreliable, expensive, and not plentiful. But within a short 5-year period, cell phones have become ubiquitous and people can, for the first time, communicate easily and reliably over long distances. I believe that similar leaps forward are possible in the realm of agriculture.
- Some of the traits that are available or are waiting in the wings will meet pressing needs at the grassroots level. Crops with higher levels of vitamin-A precursors and other critical micronutrients could significantly improve the health of my rural countrymen. Herbicide-resistant plants would significantly decrease the labor needed to manage field plots, thereby helping to meet the challenge posed by AIDS and urbanization. While, admittedly, there are costs to herbicides, if farmers see increased income, I can assure you they will find ways to purchase them. These same genetically modified (GM) plants could also allow our farmers to practice zero-till agriculture, thereby helping to conserve our soil resources.

Although the picture I have painted may in some ways sound bleak, we Kenyans are optimistic. We have a sound foundation of scientific researchers, we have established effective partnerships, we have a new government that welcomes innovation, and we are willing to embrace fresh approaches and technologies methodically and safely for the benefit of our countrymen and Africans in general.

David Hoisington

It is said in Kenya: “Without maize, there is no food.” This reflects reality far too often, especially for smallholder, subsistence farmers. And, as Chris pointed out, a host of abiotic and biotic factors threaten the harvest of these farmers, prominent among which are attacks from stem borers capable of destroying entire maize fields. These widespread pests eliminate approximately 15% of Kenya’s maize crop annually, valued at US$72 million. Current controls for stem borers vary in efficacy, cost, and importantly, potential environmental and health impacts. Clearly, solutions must be tailored to the farmers’ needs and capabilities and to local conditions in the various maize-growing areas. This is exactly the aim of the Insect Resistant Maize in Africa (IRMA) project.

IRMA Project

Launched in 1999, the IRMA project is a collaborative effort of the Kenya Agricultural Research Institute (KARI), the International Maize and Wheat Improvement Center (CIMMYT) and the primary donor, the Syngenta

Foundation for Sustainable Agriculture (http://www. cimmyt.cgiar.org/ABC/InvestIn-InsectResist/htm/InvestIn-InsectResist.htm). From the beginning, the goal was clear: *to deliver insect resistance for maize in a form familiar to farmers—the seed they plant*. Four guiding principles were established: IRMA should:

- be a model of good practice (including biosafety aspects), from which other countries can learn,
- serve as a pilot project for public-private partnerships and cooperation,
- employ state-of-the-art technology and methodology, and
- be transparent and open, with ongoing stakeholder dialogue.

Under IRMA I, which will be concluded at the end of 2003, there have been two broad approaches, both based on host-plant resistance: development of maize with conventional resistance (*e.g.*, tougher leaves and stalks), and development of transgenic varieties with *Bt* genes proven effective against the Kenyan stem borers.

Traditional breeding and screening procedures have produced promising maize lines with conventional resistance, which are presently moving toward delivery to farmers. On the transgenics front, source lines of the key *Bt* genes *cry1Ab* and *cry1Ba* have been developed and tested against the target pests *Busseola fusca, Chilo partellus, C. orichalcocillielus, Sesamia calamistis, and Eldana saccharina*. These lines are the basis for transferring the genes to germplasm adapted to Kenyan conditions.

A number of technical and philosophical aspects distinguish IRMA from biotech efforts elsewhere in the world, both in developed and developing countries.

- This project may be the only one attempting to use only publicly derived *Bt* genes. As such, we are not constrained by private-sector intellectual property strictures and, based on reports from our legal counsel, eventual deployment to farmers will likewise not be constrained. Incidentally, this frees us also from charges that we are being driven solely by agri-business profits or by a desire to control the seeds that farmers plant.
- Also, we have gone to great lengths to produce plants that are free of the antibiotic-resistance and herbicide-tolerance markers that are frequently used in the transformation process. Although this has added time and expense to our work, it directly addresses the concerns of some regarding the effects of these markers on the environment or human health. Along with most scientists, I do not think the risks posed by these markers are significant, but recognize that the scientific and public-awareness environments within which we work in that part of the world differs from those in the United States. We see the use of these "clean events," as a way to move the product to the farmers more quickly in the long term.

- A tremendous amount of work has gone into collecting baseline data on insect ecologies in the five major agroecosystems for maize in Kenya. This will allow us to thoroughly investigate what, if any, impact the *Bt* maize will have on nontarget species, particularly the natural predators and parasites of the stem borers. Although the *Bt* maize/monarch-butterfly controversy turned out to be a false alarm (Conner *et al.*, 2003), we are looking to be proactive with regard to all such concerns—be they false or valid. This work also complements the development of an overall integrated pest management (IPM)-based strategy for insect control.
- Insect-resistance management is a critical component of the *Bt* technology. In industrialized countries, refugias of non-*Bt* maize are used to prolong the efficacy of the technology. But for smallholder farmers, such refugias may not be feasible or enforceable. To meet this challenge, the project investigated the effectiveness and incidence of alternative host plants to serve as refugias. Some of these were found to occur naturally, while others would need to produce good economic returns to induce farmers to use them. A map of the country was produced that showed which areas would require farmers to have managed refugias and which areas would require no special management. Analysis showed that many of the areas with the smallest farms and poorest farmers had sufficient natural refugias such that no extraordinary measures would be required. Areas with large-scale, highly productive farms showed inadequate natural refugias, but these farmers would be the most likely group to successfully implement conventional refugias. All this information will be used by the project and extension providers as they plan how to best deploy the *Bt* maize.
- Because of the sometimes controversial nature of *Bt* maize, emphasis has been put on communication and education since the initiation of the project. Participatory rural appraisals were conducted with farmers throughout the country to document their practices and assess their needs, preferences, and production constraints related to maize. Communication efforts were directed particularly toward the news media, with a focus on achieving balanced coverage of GM-crop issues through workshops and rapport-building practices. Extension services and like-minded organizations have also been engaged to help familiarize these key audiences with the technology in anticipation of its expected deployment. Educational materials such as fact sheets and posters for agricultural shows are under development to enhance the acceptance of *Bt* varieties by a wide range of stakeholders. Of note, meetings have been held annually to update a broad range of stakeholders, including government agencies and the press, on progress and to provide an opportunity for them to shape the future direction of the project.

- Capacity building has progressed on a number of levels. A biosafety greenhouse and laboratory will be completed in early 2004, perhaps the first in sub-Saharan Africa outside of South Africa. An open quarantine site has been built and tested and will hopefully be host to the first GM-maize field experiments in East Africa. Kenyan scientists and technicians have been trained to operate these facilities, and their skills, related to running the requisite experiments and analyzing the data, have been enhanced. Furthermore, high-level delegations representing various Kenyan regulatory agencies have been taken on fact-finding trips to the United States and Mexico to familiarize them with biosafety, intellectual property issues, food, and environmental regimes in these countries.

Technology Transfer—Doing it Right

A GM-crop project run in the developing world, if done in earnest, is far more involved than simple technology transfer or corporate marketing. But "doing it right" is critical if such technologies are to be used for the benefit of resource-poor farmers in these countries. In the words of Per Pinstrup Anderson, winner of the 2001 World Food Prize and former director general of IFPRI: "The prediction so often heard that the poor in developing countries are unlikely to benefit from modern biotechnology in the future could well come true—not because the technology has so little to offer, but because it will not be given a chance."

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Q&A

Mary Robinson (Tilth Producers of Washington, Vashon Island, WA): Are you planning to enlarge the 400-meter isolation margin around your maize fields?

Hoisington: That's the minimum distance. Actually some of the first field trials may not even go to male maturity, so there would be no pollen. We can go to well over a kilometer I believe, in that area.

Robinson: So, currently what does industry feel is adequate isolation?

Hoisington: I would have to ask somebody in industry about that. Our understanding in Kenya, based on the requirements for a quarantine site for seed production, is 400 meters. So, we've used that.

Robinson: But, since pollen can travel 6 or more miles how does that work?

Hoisington: Like I said, that's the limits that we are using currently.

Robinson: But don't you feel that would be inadequate if pollen goes 6 miles?

Audience Member: Pollen will go 6 miles, but it's not viable.

Robinson: Really? Then why is maize contaminated in the United States now? Hmm, curious. Are you planning to give the seeds away, and what are the rules about saving the seeds?

Hoisington: All the products that we will make are freely available to the farmers who will be allowed to save their seed. That's why we actually want it to be in their variety.

Robinson: Okay. I would suggest that some of you grow corn the way I do, and maybe you will find out that the pollen is viable quite far away.

Tanya Barnett (WA Sustainable Food and Farming Network, Seattle, WA): Thank you for confronting food-security issues, and for your compassion. Related to the question about seed saving, I was an agro-forestry extension agent in Niger, West Africa—one of the countries high on the hunger list—and I began to see the displacement of native seed stocks, the genetic material that has been handed down through millennia. You are encouraging farmers to save their seeds. Can you talk a bit about what they can expect in terms of yields if they plant GM seeds the following year? My main issue is promotion of food security, so I am interested in what you have to say in terms of that potential insecurity. Thank you.

Hoisington: As I tried to indicate, that's one of the distinct advantages of some of the biotech options that we have. We don't want to introduce new varieties. We want to take the varieties that they are growing, and give them options to enhance insect resistance and other traits through biotech. So the variety is the same. It has one or two additional genes. They can still save the seed. They can plant the same diversity of crops. That is an extremely important option for them.

Anne Schwartz (Blue Heron Farm, Rockport, WA): I want to repeat Tanya's comments about your compassion. I've been involved with sustainable agriculture issues here for a couple of decades, and I want to assure several of the scientists here that the sustainable ag community in the United States talks about food security in developing nations, especially Africa. It is one of the issues that we see as critical for the planet. And like Tanya I do want to commend the work, especially as it is in the public domain. Those of us in sustainable agriculture realize that the cropping patterns that have evolved in the United States have led to many of our problems. As organic farmers, we rely on crop rotations to deal with endemic pests, and I totally appreciate the difference between a climate with a winter and one without. With all the effort put into educating locals about new high-technology crops, it would seem to me at least appropriate to also focus on the types of rotations and differential cropping systems that can help maintain insect control and pest control. I appreciate your description of current activities, but it does seem that there are other systems approaches.

Hoisington: Thank you. It may sound strange coming from a person supposed to be in charge of biotechnology, but I fully agree. Farmers need a lot of options and we are trying to determine if the biotech option has a role to play in those farming systems. Because, yes, there are crop rotations, and they are growing alternative crops. I love to see that. And that actually can work in our favor. We're actually then trying to improve one component of that farming system. If we can incorporate insect resistance into the maize that they are growing, then I think we can actually help the farmer.

Karen Ganey (Western Washington University, Bellingham, WA): Among the challenges that you had in bringing *Bt* maize to Africa you didn't mention the strong resistance that Africa is presenting. Why is the *Bt* approach not valued and where is that recalcitrance coming from?

Hoisington: Are you specifically speaking to resistance to technologies in Africa?

Ganey: Yes.

Hoisington: I'll let Chris answer that because he's more up to date on some of those issues.

Ngichabe: Drawing from yesterday's presentation about the NewLeaf™ potato, it's all about awareness creation. The resistance we have experienced in the southern part of Africa was certainly because of awareness creation and also a top-down directive that we feel did not go properly through the consultation process with scientists at that time. Also, there was a visit to the United States quite recently of a team from that direction and they met with various regulatory agencies and they now understand that a number of measures could be taken to avoid the kind of situation that occurred in South Africa. Now they agree that GM crops, or the GM-food aid should enter the countries, maybe after milling for example, so that the flour can go across the countries. We are now very actively involved in developing a policy, a transit policy, so that a similar situation does not occur again. So one, it was a learning process, and two, it simply underscores the importance of awareness creation in this particular area.

Cathleen Kneen (The Ram's Horn, Sorrento, BC): Just a very quick comment and maybe a caution: my experience with working with community organizations and with the public is that the more people know about genetic technology the more skeptical they are of it, not the less.

Ngichabe: Well, it appears to be the opposite in Africa, but we all are free to have our opinions on this.