
How Might NGOs Handle Genetically Modified Seeds for Small Farmers in Africa?

TOM REMINGTON

*Catholic Relief Services
Nairobi, Kenya*

PAULA BRAMEL

*International Institute of Tropical Agriculture
Nairobi, Kenya*

Catholic Relief Services (CRS) works through partners throughout the developing world to help farm families recover from disaster and increase incomes and resilience, and collaborates with international and national research institutions to facilitate farmer access to seeds of new and promising varieties. It supports farmer evaluation of new materials, the multiplication of farmer-selected varieties and their subsequent promotion and dissemination. CRS expects that genetically modified (GM) varieties will soon be available, and is articulating guidance for Country Program and Partners on how to handle these materials in our technology-transfer work with farm communities.

AGRICULTURE IN DEVELOPING COUNTRIES

A report by the United Nations Food and Agriculture Organization recently discussed the potential benefits of biotechnology for resource-poor farm families in developing countries (FAO, 2004). It surveyed the current state of agricultural biotechnology, its potential use by smallholder farmers in the developing world, possible risks, and the status of biosafety regulation. The report stated that agriculture is faced with many difficult challenges as the world population expands and agricultural production falls behind consumption for the fourth year in a row. There will be an additional two billion customers for agricultural products within 30 years. At present, 384 million people are chronically food insecure, most resid-

Although the global need for food aid has declined in the past 15 years, the need continues in Africa, where thirty-eight of the forty-three countries were found to be in need of assistance in 2003. Seven of the eight countries in the CRS East Africa region were declared food emergencies in 2004.

ing in rural areas of the least developed countries. Many more suffer from nutritional deficiencies due to poor food quality and lack of diet diversity. Although the global need for food aid has declined in the past 15 years, the need continues in Africa, where thirty-eight of the forty-three countries were found to be in need of assistance in 2003. Seven of the eight countries in the CRS East Africa region were declared food emergencies in 2004.

COMPARING AND CONTRASTING THE GREEN AND THE “GENE” REVOLUTIONS

The contribution of technological innovation to sustained growth in food production and to reduced poverty and hunger in developing countries was also recently reviewed (FAO, 2004). The Green Revolution was compared and contrasted with the “gene” revolution since both are encapsulated in the seeds of new improved varieties. The successful dissemination and exploitation of the Green Revolution varieties was dependent on the availability of international public goods and sufficient national agricultural research capacity to adapt new varieties to local conditions. The majority of this research was done by public institutions and was freely transferred. The Green Revolution initiated a major international plant-breeding effort and the development of germplasm-exchange mechanisms which are still important for the crops grown by smallholder farmers in Africa. It established a model for public international cooperation in plant breeding, germplasm evaluation and variety testing still present in conventional crop improvement today. While the approach to agricultural development initiated with the Green Revolution has made substantial improvements in productivity in Asia, its impact on resource-poor farmers in Africa remains disappointing.

The “gene revolution,” with its reliance on products of biotechnology such as GM plants, has a different approach. The majority of the research products are being developed by the private sector for commercial purposes. The focus has been on traits that are of value to farmers in developed country, such as herbicide tolerance and insect resistance. Because this research has not been done in the public sector, there is no easy spillover of the technology to crops and traits of

This restricted access, and the increased cost of regulation, will impact the ability of NGOs to promote GM crops as part of the development package for smallholder farmers in Africa.

greater value to developing-country farmers. The private cost of biotechnology research, development, and the approval processes is much greater than with the conventional approach. Consequently, the products of biotechnology are held under restricted access with patents and exclusive licenses. This restricted access, and the increased cost of regulation, will impact the ability of NGOs to promote GM crops as part of the development package for smallholder farmers in Africa.

HIGH COST OF BIOSAFETY REGULATION

The development of biosafety regulations and the approval and release of specific GM products has taken more than a decade in the United States and Canada (CBI, 2004). These regulatory processes are elaborate, complex and expensive, involving a number of regulatory agencies and procedures at various stages of the approval process. The cost of regulation can be in the range of \$50–300 million and require 6 to 12 years. It is a high-risk venture with only a 0.4% probability of any gene or trait making it to the market. In developed countries, the development and commercialization of a GM variety is recovered in the price and volume of its seed sales. In developing countries, who will pay the cost of this technology? Smallholder farmers are not likely to bear the high cost of seed or purchase the required volumes. The exception in Africa is cotton, a vertically integrated cash crop.

The majority of developing countries do not have a regulatory system for GM plants. Tawanda Zidenga (2003), reporting on the status of biosafety regulation in Africa, identified four issues where African countries differ from developed countries:

- the prevalence of farmer seed saving,
- the importance of informal seed exchange to variety dispersal,
- the introduction of GM products as food aid, and
- weak scientific and technical capacity.

Despite these constraints, there has been progress in biosafety. Two countries, South Africa and Zimbabwe, have GM legislation and a functioning biosafety framework. Seven other countries are formulating legislation, while forty-three countries are in the UN Environment Programme-Global Environment Facility (UNEP-GEF) biosafety development process. In South Africa, GM plants are being grown under a general release permit.

Two countries, South Africa and Zimbabwe, have GM legislation and a functioning biosafety framework. Seven other countries are formulating legislation, while forty-three countries are in the UN Environment Programme-Global Environment Facility (UNEP-GEF) biosafety development process. In South Africa, GM plants are being grown under a general release permit.

It is clear that delivery of GM products to smallholder farmers in Africa will be expensive. For example, it is estimated that the regulatory costs alone will be \$10 million for each new transgenic product.

CURRENT SUPPORT FOR AGRICULTURE IN AFRICA

The trend in donor assistance for agriculture continues downward. This decline has been most severe in Africa where assistance per agricultural worker is now only 25% of the peak 1982 level. Compounding this reduction in support is evidence that the assistance is not reaching the countries most in need. External assistance is significantly higher in countries where undernourishment is the lowest (over \$25/worker in countries with <5% undernourishment, but less than \$10/worker in countries with >35% undernourishment).

Clearly, in the competition for declining funding, the poor are neglected. FAO (2004), recognizing the role that NGOs play in advocating for the poor, suggested that they should advocate for increased funding for agriculture research, both conventional and biotechnological. They went further, recommending that specific advocacy groups be developed to lobby for public biotechnology research funding for the poor, and that this should include purchasing the right to use private-sector technology on behalf of the poor. This should raise the alarm that increased funding for biotechnology will come at the expense of conventional research technology transfer and that the benefits will be captured by more advanced developing countries and by larger and richer farmers.

CURRENT SUPPORT FOR GM CROPS IN AFRICA

Currently, a number of institutions in Africa are focused on developing and promoting biotechnology for farmers (CBI, 2003). A search of the Internet presents a plethora of Web-sites dedicated to biotechnology for Africa. Foundations, international organizations (including NGOs), and national governments are promoting the potential benefits of biotechnology in addressing the critical need to increase food production in Africa. Several research networks have been established to

Several research networks have been established to promote biotechnology research in crops such as cassava, sweet potato, and cowpea that can benefit the poorest farmers in Africa.

promote biotechnology research in crops such as cassava, sweet potato, and cowpea that can benefit the poorest farmers in Africa. Donor initiatives are promoting research and development of biotechnology products with public/private-sector partnerships, and donor and international organization initiatives will strengthen biosafety-regulation and technical expertise in developing countries to enhance the application of biotechnology products. The United States and Germany are funding projects to enhance biosafety research, policy, and the scientific/technical capacity for African countries in biosafety and to help countries develop laws and regulatory structures to ensure that GM crops pose no threat to human or environmental health. Currently, one regional body in southern Africa and eight countries are involved in regulation of GM food (especially food aid) and seeds (Organic Consumers Association, 2003).

PERCEIVED BENEFITS OF BIOTECHNOLOGY FOR RESOURCE-POOR FARMERS

The FAO (2004) survey concluded that biotechnology has potential benefits, but only if the technologies are appropriate for poor farmers in poor countries and there is access on sustained and profitable terms. This means that research and development of biotechnology products needs to be part of a well funded comprehensive program, with public and private sector investment. Regulation should be strong and rationalized with transparent, predictable, and science-based evidence. While the FAO report provided a comprehensive review of the role of research and development in the application of biotechnology, technology transfer and dissemination aspects were assumed to be of secondary importance. However, the report (page 87) apparently contradicted this in stating that “the paradigm for research and technology delivery that made the Green Revolution possible has broken down.” Technology transfer is critical, complex and expensive. To the extent that it continues to function, NGOs have assumed a lead role. Effective biotechnology transfer will require increased commitment, capacity and donor support for NGOs. These should not be assumed.

While African countries are open to the potential benefits of biotechnologies for their farmers, there is consensus that improving food security and agriculture will require more than technology. Rosset (2000) concluded that it is not a lack of technology that limits productivity and keeps farmers in poverty. Rather, the persistent injustices and inequalities in access to resources, such as land, credit,

markets, and anti-poor policy biases are responsible. Therefore, farmers do need greater resources targeted to research, development, and dissemination of pro-poor technologies in order to overcome diseconomies of scale, such as agroecology and farmer organization. In addition, an agro-enterprise approach is needed that enables farmers to access and benefit from market opportunities.

ROLE OF NGOS IN TECHNOLOGY TRANSFER

NGOs, such as CRS, have a long history of transferring new technologies to poor farmers. Agricultural recovery from disaster programs have typically included the delivery of “seed and tools” packages. When available, this has been of commercial seed of new varieties. These same packages have been promoted in development contexts, often combined with training programs on new farming methods such as row planting, animal traction, and other “improved farming system options.” The main objective of these programs has been increased productivity and production. They have been supported by technical assistance from international and national research programs. A range of approaches has been used, including farmer-evaluation plots, demonstration plots, and more recently, mother-baby trials and farmer field schools.

The strength of these partnerships with NGOs has been their established presence in the community and their logistical capacity to deliver the seeds and conduct the trials.

These activities are important opportunities to transfer new technologies to smallholder farmers to contribute to reducing poverty. Similar programs will enhance the adoption of GM products. The strength of these partnerships with NGOs has been their established presence in the community and their logistical capacity to deliver the seeds and conduct the trials. However, NGOs have significant weaknesses including:

- lack of capacity to conduct scientifically sound testing programs,
- rapid staff turnover,
- short-term nature of programming and funding, and
- diverse social and cultural objectives contributing to low priority assigned to agricultural development.

Although NGO-based technical transfer is feasible, it requires effective research support for training, activity design, implementation, data collection, analysis, reporting and follow up. These requirements are needed even more for the testing and delivery of GM varieties with which there are biosafety concerns.

ASSESSING AND ACCEPTING GM-CROP-ASSOCIATED RISK

CRS supports farmer evaluation of a wide range of crops including maize, pearl millet, sorghum, chickpea, pigeon pea, cassava, bean, sweet potato, rice, sesame and groundnut. All of the available varieties come from public institutions, either directly from the International Agricultural Research Centers (IARCs) or through national agricultural research system (NARS) programs and have been tested over a period of years in regional or international trials. These tests are done as part of larger research programs, and potential productivity and stability of specific traits are determined prior to decisions to proceed with farmer evaluations. This process has resulted in high probability of farmer acceptance. Risk is rarely explicitly assessed in the technology-transfer process. Rather, it is assumed that it will be considered by farmers themselves prior to adoption. Risks—nutritional, human health, environmental, agronomic, marketability, *etc.*—are inherent in all breeding programs. However, there is increased risk with GM crops because of:

- possible transmission of transgenes to other varieties or to wild relatives,
- possible health implications,
- social and ethical acceptability, and
- market acceptability due to these same concerns on the part of the consumer.

The questions for CRS and other NGOs will be who should assess and who should accept the risk: the developer of the technology, the international and national research programs, the NGOs, or the farmers?

The questions for CRS and other NGOs will be who should assess and who should accept the risk: the developer of the technology, the international and national research programs, the NGOs, or the farmers? These questions, not asked in traditional technology transfer, must be addressed in GM-crop programs.

The FAO (2004) report reviewed the status of risk to human and environmental health from GM crops and raised these key questions:

- Who bears the risk and who stands to benefit?
- Who evaluates the harm?
- Who decides what risks are acceptable?

Risk is a product of the hazard, its probability, and its consequence. There are a number of direct and indirect food-safety concerns with GM crops, the assessment of which is based on the precautionary principles of risk assessment, risk management, and risk communication. The principles of risk assessment state that the food derived from GM plants should be compared with its conventional

counterpart. It states that the risk-management measures should be proportional to the risk. Risk communications are based on the ideal that they are effective and transparent. Participatory process should be used to communicate at all phases of the risk analysis. The risk analysis of GM crops for farmers in Africa needs to be carefully considered on a case-by-case basis depending upon the particular species, trait, and agro-ecosystem.

The assessment of risk can be based on various sources of data and on various assumed uses. In addition, assessment of traditional food-use risk will need to be addressed, including home-use preference as well as human-health concerns. The marketability of GM commodities will also need to be assessed within local markets for local food uses. The overall impact of the introduction of the GM crop to the complex agroecology of traditional farming systems will need to be assessed, especially as it relates to the intercropping systems used by farmers. These assessments will be needed prior to the introduction of a GM crop to farmers or there is a risk that the trials will be used as local seed sources, as was the case for *Bt* cotton in Gujarat, India. As with evaluation of conventional varieties, farmers will grow and save seed prior to official release. This would be a significant risk for NGOs when testing GM varieties that are still in the development stage. Formal approval and release will be needed, therefore, before initiation of testing and promotional programs in conjunction with farmers.

The increased risk and cost involved in the development and release of GM varieties, and the need for a mechanism and institutions to insure that farmers have long-term sustained access to these products, will impede their distribution to poorer farmers. In order to ensure that these increased costs and regulations are worthwhile, economic studies will be needed to measure the value of these varieties to farmers versus the cost, including the cost of risk. The process of release and promotion needs to address environmental concerns, health concerns, cultural concerns, economic concerns, and long-term sustainability concerns. The cultural concerns include questions of who will access the technology, how will they access it, how will seed be exchanged and how will seed be regulated. Economic concerns include the cost:benefit aspects of the technology in comparison with alternative options, impact of the adoption of the technology on trade or market potential and the impact of the adoption on credit burden. The long-term sustainability issues include predictable access to seed and to markets and impact on crop and variety diversity.

Risk has been addressed through international conventions and agreements. The Convention on Biological Diversity deals with the management of risk to biodiversity from the introduction of GM crops. It protects and promotes the conservation of the local biodiversity, and led to the Biosafety Protocol. The crops currently grown by poor farmers in Africa are covered by this Convention, which obligates signatory countries to develop legislation to protect and conserve biodiversity. These same countries have agreed to follow general rules laid out in the Biosafety Protocol for development of regulations within their countries for

the introduction, testing and release of the products of biotechnology. To date, these regulations have been established in very few of the least-developed countries of the world.

The Biosafety Protocol, ratified in September 2003, is an agreement on rules that govern international trade in GM organisms. It allows developing countries to control the importation of GM crops and their products. A number of issues impact the promotion and dissemination of GM crops by NGOs (Christian Aid, 2004). One of the main issues is that social and economic concerns should be explicitly included in risk analysis, in particular the impact on the livelihoods and food security of smallholder farmers. A second issue is that only GM seed is covered by the Protocol and not their products, for advanced informed consent. This is a concern because GM products could be used for seed as well as for food and/or feed. There is a third issue of liability for damages and labeling. These regulations are necessary to ensure that any risk to environmental and human health is avoided or minimized. Strategies to manage risk can be developed, but these need to be adhered to and considered prior to product release. All of this requires research and testing. Adherence requires enforcement of government regulations. The absence of enforcement of regulations increases risk and compromises farmer recourse. It is possible that farmers would find themselves assuming all the risk and NGOs would find themselves assuming responsibility for enforcing regulations post-release; the developer of the research products, research institutions and government would bear little of the risk.

THE COST OF TECHNOLOGY TRANSFER

The products of conventional breeding programs are the result of a process that begins with early-generation testing, usually on-station. In the final years of testing, the varieties' overall productivity, adaptation and stability are evaluated at multiple locations, including farmers' fields, often with NGO assistance. The final stage of testing occurs when the value of the variety has been determined, but its acceptability to farmers and the market is not yet certain. The cost of most of this process is borne by the IARCs and national programs. This testing, which can be expensive, results in the identification of recommendation domains.

The testing of a GM variety has additional steps due to concerns over risk to environmental and human health.

The testing of a GM variety has additional steps due to concerns over risk to environmental and human health. This includes stricter field-testing protocols, more extensive testing for human-health issues, and assessment of risk of transfer of the transgene(s) to other varieties, wild relatives, or other organisms in the environment. This results in greater cost and time to make the GM products avail-

able for testing by farmers. The cost of this testing will have to be borne by the developer since it requires greater control and stricter guidelines, regardless if the developer is a private company, IARC, or a national program. The broader testing and promotion that occurs with the partnership of the NGOs cannot be undertaken until environmental and human health risks have been assessed and determined to be minimal and manageable. Post-release strategies to manage risk will need to be considered in partnership with the NGOs to ensure that they can be adhered to by resource-poor farmers. This may include consumer-acceptability and market analyses. Clearly, one of the major constraints to the release of GM crops to farmers by NGOs is the increased costs involved. Thus, benefits from these new varieties will need to significantly outweigh their increased cost and risk.

Commercial seed companies are compelled to apply measures to prevent or discourage seed-saving by farmers.

SEED ISSUES

The private-sector profit on investment in conventional and GM varietal development comes from recurrent seed sales. This is not a significant issue with hybrids, with which farmer seed saving comes at a cost of reduced performance. However, this is not the case for other crops in Africa, most of which are either self-pollinated or vegetatively propagated. For these crops, commercial seed companies are compelled to apply measures to prevent or discourage seed-saving by farmers. These include use of a terminator gene, a patent and legal injunction, and misinformation (e.g. an unsubstantiated claim of loss of performance with seed saving). Based on the Catholic Social Teaching principle of the universal destination of good, CRS opposes these three measures (Warner, 2001). Terminator genes are harmful to smallholder farmers in Africa. Punitive legal injunctions are difficult and costly to apply. Misinforming growers results not so much in farmer decisions to purchase seed annually as in loss of credibility for NGOs and other information brokers. In addition, CRS opposes the appropriation of the responsibility for seed production by commercial seed companies, when farmer seed production is both effective and efficient. This is counter to the Catholic Social Teaching principle of subsidiarity.

Farmers continually experiment with new varieties, obtained from relatives, neighbors, the local market or from development projects. They adopt a new variety when they have determined it is of value to the household. Adoption does not always imply abandonment; they may grow new varieties and continue to plant their own landrace varieties, because of different uses in the home or in the cropping system. Once obtained, farmers in traditional cropping systems in Africa depend on home-saved seed for future needs.

In many cases, lack of access to seed of new varieties is a constraint to technology adoption in the remote, rural areas of Africa. It is a concern of many agricultural recovery programs implemented by NGOs. Continuous movement of seed into and out of the home is referred to as seed flow. Production of own seed can result in the transfer of genes from other varieties of the crops grown by the household with cross-pollination. The pollen from the farmers' variety can also cross with wild relatives in the field or adjacent areas. This is referred to as gene flow. This practice can result in the incorporation of new genes from other varieties, including new improved GM varieties. The consequences of traditional seed saving and seed exchange are an additional risk with GM varieties and will need to be considered in the release and promotion of GM seeds to smallholder farmers.

The responsibility for regulating the use of GM seed by farmers and the need to meet their need for affordable seed will have to be clarified before NGOs consider the promotion of these varieties.

Seed flow in the farmer-seed system is very informal and can be used to disseminate new varieties where formal seed systems do not exist. This is the case for most of the crops (maize is an exception) grown by poor farmers in Africa. Although discouraged for the new publicly available varieties, farmers have not found affordable reliable options for access to these varieties while being able to retain their traditional approaches. The release and promotion of new varieties with legal protection will add a new complication to this issue. Farmers might be restricted from saving seed and told to obtain new seed each year. This restriction on seed saving will be compounded by the higher cost of GM seed. The responsibility for regulating the use of GM seed by farmers and the need to meet their need for affordable seed will have to be clarified before NGOs consider the promotion of these varieties.

ISSUES FOR CRS

The promotion of the products of biotechnology is an opportunity to introduce and assist farmers to grow crops that will contribute to poverty alleviation through enhanced agricultural development in Africa. The GM plant is a technological innovation that carries new challenges in introduction, evaluation, adoption, and sustained use. The potential benefits of this new technology are great, but so also are the costs and risks. NGOs must confront the following opportunities, risks and challenges to ensure that smallholder farmers, benefit.

Farmer and NGO Participation in Decision-Making

Farmers and NGOs need to be involved in policy and donor-fund allocation discussions that affect them. The tendency to first make a decision to invest in biotechnology and to allocate funding and then bring in farmer and NGO stakeholders needs to be reversed. The costs of investing in biotechnology need to be compared with costs of investing in alternative means of agricultural development.

Biosafety

National and international regulations to ensure environmental and human health, and to address cultural, economic, and sustainability issues need to be in place before technologies are recommended to farmers. Varieties made available to NGOs must have all the necessary assessments to ensure their safe use by farmers. The need for risk management of these GM crops, such as refuges, will need to be developed and training programs for farmers developed and implemented.

Benefits from GM Crops for Resource-Poor Farmers

There is a need for clear evidence that the improvements offered in these biotechnology products outweigh the risk of their introduction and use. There needs to be a clear, transparent assessment of the risk, including factors that are unique to traditional tropical cropping systems. Farmers need to have redress options for any damage to environmental or human health or their economic well-being caused by GM crops.

Freedom to Save and Exchange Seed

The issues of long-term access to affordable seed and planting material need to be addressed. The farmer seed system is of vital importance to African agriculture. As is the case with the products of formal breeding, farmers must have the right to save and multiply seed for further planting. Furthermore, research must support NGOs and farmers to improve the effectiveness of seed saving.

The focus of the IARCs on the science of the problem and the focus of CRS on the delivery of the solution can lead to conflicts and disappointments. Transparent partnerships are required that place value on both research and development. Partnerships with the private sector will be new and require new mechanisms of interaction and funding.

Partnerships and Capacity Strengthening

NGOs will need strong partnerships to effectively deliver this biotechnology to farmers. They need access to technical expertise from the national programs, IARCs, and the private sector on biosafety concerns, intellectual property and license agreements, and risk management. CRS currently has partnerships with IARCs and national programs to deliver new varieties and other improvements. These partnerships have constraints, such as the need to claim success to attract donor funds, which result in conflicts on equitable sharing of credit and costs. The focus of the IARCs on the science of the problem and the focus of CRS on the delivery of the solution can lead to conflicts and disappointments. Transparent partnerships are required that place value on both research and development. Partnerships with the private sector will be new and require new mechanisms of interaction and funding.

REFERENCES

- Christian Aid/World Development Movement (2004) The Biosafety Protocol—Controlling trader in GMO's. Policy Brief/Position Paper. <http://www.christian-aid.org.uk/indepth/003bios/biosafet.htm>.
- Food and Agriculture Organization (FAO) (2004) Agricultural biotechnology. Meeting the needs of the poor? In: *The State of Food and Agriculture 2003–2004*. Rome: FAO.
- Council for Biotechnology Information (CBI) (2003) Biotechnology transfer: Sharing innovation with the developing world. <http://www.whybiotech.com/index.asp?id=3650>.
- Council for Biotechnology Information (CBI) (2004) Regulation of Biotech Crops and Foods in the United States and Canada. <http://www.whybiotech.com/index.asp?id=3993>.
- Organic Consumers Association (2003) Africa Developing Biosafety Regulations for GMO's. <http://www.organicconsumers.org/ge/africa102703.cfm>.
- Rosset P (2000) Genetic engineering of food crops for the third world: An appropriate response to poverty, hunger, and lagging productivity? In: *Proceedings of the International Conference on Sustainable Agriculture in the New Millennium—The Impact of Modern Biotechnology on Developing Countries*. Brussels: Friends of the Earth Europe. <http://www.foodfirst.org/progs/global/biotech/Belgium-gmo.html>.
- Warner KD (2001) Are life patents ethical? Conflict between Catholic Social Teaching and agricultural biotechnology's patent regime. *Journal of Agricultural and Environmental Ethics* 14 301–319.
- Zidenga T (2003) The Status of Biosafety in Africa. ISB News Report July.

TOM REMINGTON grew up in Madison, WI, and received BS and MS degrees in horticulture from the University of Wisconsin. He has worked in Africa for over twenty-five years, beginning as a Peace Corps volunteer in Mali in 1977. He received his PhD from the University of Wisconsin in 1990 in agronomy for work with women rice farmers in western Gambia.



Dr. Remington has served as agriculture advisor with Catholic Relief Services (CRS) since 1994. Currently he is responsible for Eritrea, Ethiopia, Sudan, Uganda, Tanzania, Kenya, Rwanda, and Burundi. He has helped CRS articulate a comprehensive agriculture strategy consisting of innovative means of recovery from disaster; increasing farm-family income and resilience; facilitating farmer access to new technologies through linkage with national and international research institutions; integrating domestic and productive uses of water; and improving nutrition through biofortification.

He collaborates with international research centers on farmer evaluation of new crop varieties, including the International Potato Center (Peru, sweet potato), the International Institute of Tropical Agriculture (Nigeria, cassava), the International Center for Crop Research in the Semi-Arid Tropics (India, chickpea, groundnut, and pigeon pea), the International Center for Tropical Agriculture (Colombia, common bean), the International Maize and Wheat Improvement Center (Mexico, maize) and the Africa Rice Center (Ivory Coast, rice).