



## Eastern and Central Africa Programme for Agricultural Policy Analysis

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#### NEWS

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#### THE ROLE OF NON-GM BIOTECHNOLOGY IN DEVELOPING WORLD AGRICULTURE

*Discussions about the role of agricultural science in boosting food production tend to be dominated by controversy over the characteristics of genetically modified (GM) crops and the implications of their use. This has tended to overshadow consideration of the many other contributions that cutting-edge research can make to increasing crop productivity. This briefing paper by Zephaniah Dhlamini, a former consultant with the International Atomic Energy Agency, summarizes the main ways in which these non-GM techniques are helping plant breeders to develop and propagate new crop varieties.*

#### Introduction

IN the intense debates around the applications of modern biological research to agriculture and food production, genetic modification (GM techniques)—and the novel crops that result from their application—tends to attract the lion's share of public attention. This is despite the fact that such research offers a range of other tools and techniques that do not involve genetic modification, and yet can still make major contributions to agriculture.

One result of the disproportionate focus on GM crops is that policymakers in the developing world often lack adequate information on the nature and potential use of non-GM biotechnologies. This briefing seeks to help fill this information gap by summarizing the characteristics of the most common non-GM biotechnologies that are being developed and applied to crop improvement in the developing world. It focuses on four types of non-GM biotechnology: tissue culture, molecular markers, diagnostic techniques and microbial products.

## 1. Tissue culture technologies

One technology that deserves greater attention from both the public and policymakers is the use of tissue culture, the most widely used application of which involves creating copies of plants through a process known as micro-propagation. In essence, micro-propagation involves taking tissue (known as an 'explant') from a plant and growing it on sterile media containing substances essential for growth. Once it is growing well, samples of this culture can be taken and used to grow entire plants under laboratory conditions. The technique is currently used mainly with perennial crops that can reproduce vegetatively, producing new stems directly from the existing ones rather than needing to be pollinated and produce seeds.

It can be used to create millions of new 'clones' from a single plant, each genetically-identical to the parent plant. The method can be used to produce large quantities of high-quality plant lines, to eliminate pathogens from infected planting materials, or to produce 'true-to-type' material from desirable plant lines.

Micro-propagation has been developed over many decades, and can now be considered a 'mature' plant biotechnology. It is already widely used in developing countries, especially Asia—in particular as a result of the immense market in China for plants generated in this way. It is relatively cheap, and has been shown in general to increase productivity (especially of root and tuber crops, such as sweet potatoes and potatoes). Its most common application in developing countries involves producing virus-free plantlets by heat-treating the explant to kill any viruses present and then culturing cells from its 'meristem', the plant's actively growing tissue. Because micro-propagation cannot, however, guarantee that plants will be virus-free access to a virus diagnostic facility is essential.

### *Micro-propagation in developing countries: some examples*

In China's Shandong Province, a micro-propagation project that created and distributed virus-free sweet potatoes led to an increase in yields of up to 30 per cent. By 1998, productivity increases were valued at US \$ 145 million annually, raising the agricultural income of the province's seven million sweet potato growers by three to four per cent in one season. Government subsidies helped to encourage adoption of the technology and keep the cost of the planting material low.

In Kenya, the commercial micro-propagation of disease-free bananas is currently being carried out. The initiative has been shown to offer significantly higher financial returns than traditional growing practices. In Vietnam, introducing improved, high-yielding potato cultivars able to resist the late-blight disease has seen yields double, from 10 to 20 tonnes per hectare. The farmers are themselves multiplying their plantlets through micro-propagation, making the seed more affordable.

### *"Anther culture" and embryo rescue*

Another widely used tissue culture technique, 'anther culture', uses the immature pollen-producing organs of a plant to generate fertile 'haploid' plants, which have half the full set of genetic material. These plants can later be crossed to produce pure homozygous 'diploid' plants, with identical copies of each gene, thus eliminating undesirable variation in key traits. The technique is popular

among breeders as an alternative to the numerous cycles of inbreeding or 'back-crossing' usually needed to obtain pure lines.

*In vitro* anther culture is now used routinely for improving vegetables, such as asparagus, sweet pepper, eggplant, watermelon and *Brassica* vegetables. It is also used, though to a lesser extent, for cereal crops such as rice, barley and wheat. A further refinement of the technique is the 'microspore culture.' This involved isolating and culturing the cells from which pollen grains develop, and can yield up to ten times as many haploid embryos as anther culture.

A further tissue culture technique, known as 'embryo rescue' (or sometimes 'embryo culture') involves crossing species that are not normally sexually compatible. In nature, embryos that result from such 'wide crosses' usually fail to develop, but in the laboratory, wide crosses can be used to transfer genetic traits from wild relatives of crops, (that is to say, secondary and tertiary gene pools) into cultivated crop plants (primary gene pools). An example is triticale, a relatively new hybrid variety that is the result of a cross between rye and wheat.

#### *New Rice for Africa: A tale of two techniques*

Both embryo rescue and anther culture have recently been used extensively in the successful development of the so-called New Rice for Africa (NERICA). Breeders at the Africa Rice Center (WARDA) in Benin, for example, have used both techniques to cross *Oryza sativa* (Asian rice) with *Oryza glaberrima* (African cultivated rice). Farmers have selected new rice varieties from the resulting germplasm, with qualities such as higher yields, shorter growing seasons, resistance to local stresses, and higher protein content than traditional African varieties. The new varieties have been released in Cote d'Ivoire, Nigeria and Uganda, and are being evaluated in Benin, Burkina Faso, Ethiopia, The Gambia, Malawi, Mali, Mozambique, Sierra Leone, Tanzania and Togo. WARDA researchers suggest that some 200,000 hectares will soon be under NERICA cultivation, producing about 750,000 tonnes of rice per year, and leading to an annual saving on rice imports of nearly US \$ 90 million.

## **2. Molecular marker techniques**

A second set of non-GM biotechnologies that are having a growing impact in crop development are a range of techniques that use 'molecular markers.' These are relatively short and easily-identifiable strips of DNA whose location can indicate the presence in a plant's genome of a gene with desired characteristics. The physical proximity on the genome between the marker and the gene responsible for a particular trait means that scientists can select for the marker, rather than the gene itself. The value of 'molecular markers' to plant breeders is therefore that they allow plant species to be investigated at the level of their DNA, and for the knowledge generated in this way to be used to manage genetic variation and diversity in plants.

The first generation of molecular markers, known as restriction fragment length polymorphisms (RFLP), required slow and expensive ways of reproducing lengths of DNA through a process known as DNA-DNA hybridization. However the invention of the technique known as polymerase chain reaction (PCR), which amplifies short segments of DNA and thus makes them easier to identify, gave rise to a second generation of faster and less expensive molecular markers. The

most common of these are randomly amplified polymorphic DNA (RAPD), amplified restriction fragment length polymorphisms (AFLP), and simple sequence repeat (SSR).

Cost-effective techniques based on molecular markers have many applications in plant breeding, and the ability to detect the presence of a gene (or genes) controlling a particular desired trait has given rise to what is called 'marker-assisted selection' (MAS). This approach makes it possible to speed up the selection process. For example, a desired trait may only be observable in the mature plant, but MAS allows scientists to screen for the trait at the much earlier plantlet stage.

Other advantages of techniques based on molecular markers are that they make it possible to select simultaneously for more than one characteristic in a plant. They can also be used to identify individual plants with a particular resistance gene without exposing the plant to the pest or pathogen in question. However, the current cost of applying these techniques is high, which means that for many breeding programmes—particularly in the developing world—they may be unaffordable.

Furthermore, there are relatively few useful molecular markers for traits that are important to plant breeders, such as those leading to increased yield. As a result, only a handful of crop varieties in farmers' fields have so far been developed through MAS. However the relative cost-effectiveness of conventional breeding methods compared to using MAS depends on the circumstances. Where the characteristics of new, experimental crops can be examined in the field, conventional breeding methods can be very cost-effective. But where this is not possible, or is particularly costly or difficult, the use of molecular markers can be significantly cheaper. This is the case, for example, with breeding projects that involve multiple genes, recessive genes, the late expression of the trait of interest, or seasonal and geographical constraints.

Molecular markers can also be used to characterize germplasm in situations in which a detailed database of the genetic material of different varieties of a particular plant species has been built up. Indeed DNA-based genetic markers are often more useful for studies of genetic diversity than morphological and protein markers because their expression is not affected by environmental factors. Molecular markers are already being widely used for characterizing and managing germplasm in many developing countries.

### **3. DNA and immuno-diagnostic techniques**

In addition to seeking ways of breeding better, stronger or higher-yielding crops, much agricultural research and development focuses on ways of fighting plant diseases. This is a key area of research as many crop diseases are difficult to diagnose, especially at the earliest stages of infection. Successful diagnosis can also be made harder by the fact that a number of different viral diseases exhibit similar symptoms. In such circumstances, diagnostic efforts can be assisted by molecular assays—such as enzyme-linked immuno-sorbent assay (ELISA)—that can precisely identify viruses, bacteria and other disease-causing agents.

ELISA has become an established tool in disease management in many farming systems. Indeed it is now the most widely used commercial diagnostic technique in all regions of the developing world.

In addition, diagnostic assays have been developed that identify a wide range of other organisms, chemicals—including undesirable by-products such as aflatoxin and impurities that affect food quality.

A relatively new but increasingly powerful technique for identifying pathogens and other organisms in agriculture is known as DNA diagnostics. This works by identifying a suspected pathogen from details of its DNA. Most DNA diagnostics are now based on the PCR. Until recently, this was problematic because the effectiveness of PCR was based on the heat-resisting properties of the enzyme *Taq polymerase*, which is heavily protected by patents. More recently, however, *Taq polymerase* has come to be treated as a 'generic' biochemical reagent, substantially reducing the cost of PCR applications in research and commerce.

#### **4. Microbial products for agriculture**

Pest control and soil enrichment are as important to agriculture as accurate disease diagnosis. Products based on micro-organisms play an increasing role in both processes, and include bio-control agents (or 'bio-pesticides'), 'bio-fertilizers' and products that aid fermentation and food processing. In Africa and much of Asia, research in bio-control and bio-fertilization is still at the early stages. But countries such as China, India and the Philippines, as well as several in Latin America, are already routinely using advanced techniques. Some of their results are already being tested.

##### *Bio-pesticides*

Although conventional chemical pesticides are still widely used across the developing world, some countries are shifting to the use of newer types of pesticide that are more selective and less toxic to humans and the environment, as well as remaining effective at lower rates of application. A small but growing proportion of these are bio-pesticides, based on naturally occurring organisms or substances. These include microbial pesticides such as *Bacillus thuringiensis* (Bt), *Trichoderma*, *Verticillium*, *Bauveria* and *Bacillus subtilis*; plant extracts; and nematode worms or viruses such as the nucleo-poly-hedrosis virus (NPV) that are 'entomopathogenic,' (attack insects).

Other bio-control agents include pheromones, growth regulators and hormones. Many of these agents are increasingly used in integrated pest management (IPM), which uses a variety of methods—from monitoring pests to planting pest-resistant crops, to minimize the use of pesticides.

##### *Bio-fertilizers*

Recent progress on bio-fertilizers has been equally impressive. For example, there has been much research on biological nitrogen fixation (BNF), the process by which micro-organisms in the soil 'fix' atmospheric nitrogen, mostly within subsoil plant nodules, and make it available for assimilation by plants. The most studied and important nitrogen-fixing bacteria are *Rhizobia*. But a number of endophytic (growing within a plant) bacteria are now also known to do the job. Using such bacteria to fix atmospheric nitrogen is an environmentally-friendly alternative to applying chemically generated fertilizers.

Other micro-organisms, such as *Mycorrhiza*, can establish a symbiotic relationship with both cultivated plants and forest trees, facilitating the uptake of phosphorus and water uptake. Inoculating plants with these fungi is an efficient substitute (or complement) to phosphorus-based chemical fertilization.

Research on bio-fertilizers, mainly *Rhizobium*, is currently being carried out in many developing countries. For example, the UNESCO Microbiological Resources Centre (MIRCEN) project at the University of Nairobi, Kenya, has developed a *Rhizobium* inoculant, known as *BIOFIX* that is currently the main inoculant available on the local market. A hectare of crops can be treated by 100 grams of *BIOFIX* costing about US \$ 1.25, and has a comparable effect to 90 kilograms of chemical nitrogen costing about 10 times as much.

## **Conclusion**

Policy makers and research managers need to focus more attention on the full range of promising tools and techniques offered by modern biological research—not only those that involve genetic modification. As this brief review shows, there are already many promising non-GM biotechnologies in the public domain that could make significant contributions to crop improvement and agricultural management. Each has both advantages and disadvantages, each of which needs to be carefully assessed.

For most developing countries, however, the main challenge is not to develop new agricultural technologies (such as plant breeding techniques or disease diagnostics) but to design and implement the capacity building programmes and regulatory systems needed to facilitate the sustainable transfer of these technologies to the relevant farming systems. Furthermore if the full potential of these non-GM biotechnologies is to be realized, they must not be adopted as stand-alone interventions. Rather they should be treated as tools that need to be fully integrated with other proven agricultural research and farming practices.

*This policy brief is available on [www.scidev.net/dossiers/index.cfm](http://www.scidev.net/dossiers/index.cfm)*

## **COMMUNICATION**

### *FAO to boost bio-technology research*

The United Nations' Food and Agriculture Organization will launch an online network this month to boost biotechnology research and policy development in Africa. The Agricultural Biotechnology Network for Africa (ABNET) will encourage researchers, policymakers, farmers and the media to share information and discuss how biotechnology can improve agriculture. The network will gather relevant information and host electronic discussions on its website. A key aim is to promote dialogue on policy issues such as bio-safety and the conservation of genetic resources. ABNET will be launched in Nairobi, Kenya on 21 March. It will organize regional meetings, training courses and workshops to promote agricultural biotechnology, and improve farmers' access to new technologies. The African Biotechnology Stakeholders Forum, an association with members in seven African nations, will manage the network.

### *Research Fellowship*

The Consultative Group on International Agricultural Research (CGIAR) System-wide Program on Collective Action and Property Rights (CAPRI) invites participating CGIAR centers to apply for a Research Fellowship, in collaboration with PhD students who wish to undertake field research in a CGIAR project. Research fellowships funded through this request for proposals (RFP) will seek to contribute to policies and practices that alleviate rural poverty by analyzing and disseminating knowledge on the ways that Collective Action and Property Rights institutions influence the livelihood of the rural poor as well as the efficiency, equity and sustainability of natural resource use. The following are the priority research themes: Accommodating multiple uses and users of natural resources; Changing market relations; Feminization of agriculture and demographic change; Genetic resources; Environmental risk; Structuring devolution and; Technology adoption. For details, contact, Ruth Meinzen-Dick, e-mail, [r.meinzen-dick@cgiar.org](mailto:r.meinzen-dick@cgiar.org) or Stephen Dohrn, [s.dohrn@cgiar.org](mailto:s.dohrn@cgiar.org) or visit <http://www.capri.cgiar.org/themes.asp>

### *Vacancy announcements*

1. The International Food Policy Research Institute (IFPRI) is seeking a **Senior Research Assistant** to work with the Consultative Group on International Agricultural Research (CGIAR) System-Wide Program on Collective Action and Property Rights (CAPRI). This partnership fosters research and promotes collaboration on institutional aspects of poverty reduction and natural resource management between CGIAR Centers and National Agricultural Research Institutes. Applicants should have a minimum of Masters Degree or equivalent in agricultural/ development/ environmental/ institutional economics, political science, sociology, anthropology or related disciplines. This position is based in Washington, DC and is for a one-year, fixed-term renewable appointment. For details, contact IFPRI, HRS, Position #06-113, 2033 K Street, NW, Washington, DC 20006 or e-mail, [ifpri-hrlocal@cgiar.org](mailto:ifpri-hrlocal@cgiar.org)
2. The World Conservation Union (IUCN) invites applications from qualified candidates for a position of **Co-ordinator, IUCN South Africa Country Programme**, based in Pretoria, South Africa. The overall goal of this position is to implement and deliver an effective IUCN Programme in South Africa (IUCN-SA), creating linkages between conservation science and development policy processes in South and southern Africa and ensuring engagement with key IUCN constituencies in South Africa. To apply, send resume and cover letter no later than **17 March 2006** to: Finance and Administration Manager, e-mail: [vacancies@iucnrosa.org.zw](mailto:vacancies@iucnrosa.org.zw) or IUCN – ROSA, 6 Lanark Road, Belgravia , P.O. Box 745, Harare, Zimbabwe. **Please note that this position has been re-advertised and those who applied need not re-apply.**

*ECAPAPA received this information from Dr. Luis Navarro, IDRC, Kenya. He is gratefully acknowledged.*

*Grants for food security and nutrition studies*

The regional Network for Equity Health in east and southern Africa (AQUINET) and the Health Systems Research Unit of Medical Research Council (MRC), South Africa invite interested individuals or groups to apply for grants to prepare commissioned country case studies on existing food security and nutrition programmes in the region that demonstrate good practice in health systems promotion of food sovereignty and equity. Case studies may be drawn in areas such as; response to acute food shortage; nutrition supplementation programmes; other health and nutrition interventions, including breast milk substitutes, HIV and nutrition; response to over-nutrition. The closing date is **3 April 2006**. For details, contact EQUINET Secretariat, [admin@equinetafrica.org](mailto:admin@equinetafrica.org) or MRC, [Sylvia.louw@mrc.ac.za](mailto:Sylvia.louw@mrc.ac.za)

*ECAPAPA received this information from Peter Ewell, USAID. He is gratefully acknowledged.*

*Training opportunity*

The International Institute of Rural Reconstruction and the Environmental Alert Uganda are organizing a two-week course on **Participatory Innovation Development (PID)** to be held in Kampala, from **26 June to 11 July 2006**. The course is intended for practitioners from PROLINNOVA (Promoting Local Innovation), a global learning network that promotes local innovation in ecologically oriented agriculture and natural resource management, as well as from organizations and networks. For details, contact, the International Institute of Rural Reconstruction, Y.C James Yen Center, Silang, Cavite 4118, Philippines, Telefax: 6346-414-2417, e-mail [education&training@iirr.org](mailto:education&training@iirr.org) or contact Environment Alert, via e-mail [rlutalo@envalert.org](mailto:rlutalo@envalert.org)

*ECAPAPA welcomes your comments, suggestions and encourages article submissions.*

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