SOME CASE STUDIES OF APPLICATIONS OF AGRICULTURAL BIOTECHNOLOGIES IN SUB-SAHARAN AFRICA

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IN THE CROP SECTOR

Producing clean planting materials to improve sweet potato, plantain and banana in Ghana

Crops such as plantain and banana which are propagated vegetatively – meaning that offspring are clones of the parent plant rather than originating from seeds – are at high risk of passing diseases from parent to offspring. For plantain and banana, this transmission of disease can reduce crop yields by 40 percent in the first year of production.

Tissue culture techniques can be used to produce clean planting materials, avoiding transmission of disease from the parent plant. By isolating infection-free cells from the shoot tip of a plant and growing them in sterile conditions, and then multiplying the material using micropropagation techniques, researchers from the Council for Scientific and Industrial Research – Crops Research Institute (CSIR-CRI) in Ghana created disease-free planting materials for sweet potato, plantain and banana, which led to significant increases in the vigour and yield of these crops.

For more information:
Clean Planting Materials Produced *in vitro* to Improve Performance of Sweet Potato, Plantain and Banans in Ghana. By M. D. Quain and B. M. Dzomeku. In: FAO. 2013. Biotechnologies at work for smallholders: Case studies from developing countries in crops, livestock and fish, Pages 27-36 (with photos). Available at http://www.fao.org/docrep/018/i3403e/i3403e00.htm

Improving African rice by breeding with Asian rice

Rice is an important subsistence crop in West Africa, in addition to being a cash crop for small and medium scale farmers in East and Southern Africa. Whilst African rice is able to thrive in difficult environmental conditions including infertile soils, fluctuating water depths and harsh climates, it tends to disperse its seed which makes harvesting more difficult and results in a low yield. In contrast, Asian rice generally retains its seed, giving higher yields, and has high genetic diversity which is useful for breeding new varieties. However, Asian rice is not suitable for growth in many parts of sub-Saharan Africa, since unlike African rice it is not adapted to a wide range of environmental conditions.

By breeding African and Asian rice species together, researchers at the Africa Rice Center have generated high-yielding ‘NERICA’ (New Rice for Africa) varieties which are now widely distributed across Africa. These new varieties are well adapted to African growing conditions whilst having the higher yield associated with Asian rice. For example, the new varieties can have over five times the number of grains on each head of rice, in addition to having a greater protein content than either African or Asian rice.

The African and Asian rice species do not interbreed naturally, so biotechnological tools were used to facilitate the breeding programme. These tools included embryo rescue, which enables weak embryos to reach maturity rather than being aborted in the seed, so that the new hybrid rice would reach maturity and could be used in the breeding programme.

For more information:
- FAO. 2011. Biotechnologies for Agricultural Development: Proceedings of the FAO international technical conference on “Agricultural biotechnologies in developing countries: options and opportunities in crops, forestry, livestock, fisheries and agro-industry to face the challenges of food insecurity and climate change” (ABDC-10). Pages 32-33. Available at http://www.fao.org/docrep/014/i2300e/i2300e00.htm
- Using science to fight hunger, disease and poverty in Africa: The case of NERICA. Presentation by Sidi Sanyang during the FAO international technical conference on Agricultural Biotechnologies in Developing Countries (ABDC-10), Guadlajara, Mexico, 1-4 April 2010. http://www.fao.org/fileadmin/templates/abdc/documents/nerica.pdf (2.5 MB)

Improving soil in Kenya

Leguminous crops, such as beans, peas, cowpeas and soybeans, form associations with specialized bacteria which sequester nitrogen from the atmosphere. This provides the plant with a good supply of nitrogen, which is an essential component of protein – vital for healthy plant growth and for producing a nutritious crop for human consumption. The University of Nairobi has developed Biofix, a culture of the specialized bacteria which provide legumes with nitrogen. Applying this culture to legume seeds before planting can boost plant nitrogen uptake and therefore improve growth. In the Nyeri district of Kenya, Biofix has been welcomed by farmers, but in other regions, Biofix has not been used extensively. Clear information about the product, good distribution systems and sufficient agricultural extension services are important for helping farmers to adopt biotechnologies.

For more information:
FAO. 2011. Biotechnologies for Agricultural Development: Proceedings of the FAO international technical conference on "Agricultural biotechnologies in developing countries: options and opportunities in crops, forestry, livestock, fisheries and agro-industry to face the challenges of food insecurity and climate change" (ABDC-10). Page 34. Available at
http://www.fao.org/docrep/014/i2300e/i2300e00.htm

Generating resilient sorghum in Africa

Sorghum is a very important crop in Africa, but its yields are threatened by the parasitic plant Striga, which affects 40 percent of arable savannah land. Hybrid varieties of sorghum have been instrumental for increasing yield by increasing resistance to Striga. Researchers have used a combination of molecular genetics, biochemistry and agronomy to identify genes conferring resistance to Striga. These have been bred into locally adapted and more modern sorghum varieties, creating Striga-resistant hybrids suitable for use in different farming systems and ecological zones in Africa. These new lines of sorghum are now grown from Sudan to Zimbabwe.

For more information:
FAO. 2011. Biotechnologies for Agricultural Development: Proceedings of the FAO international technical conference on "Agricultural biotechnologies in developing countries: options and opportunities in crops, forestry, livestock, fisheries and agro-industry to face the challenges of food insecurity and climate change" (ABDC-10). Pages 39-40. Available at
http://www.fao.org/docrep/014/i2300e/i2300e00.htm

Boosting cassava yields in Africa using molecular markers and tissue culture

Though native to South America, cassava (*Manihot esculenta* Crantz) is one of the most important food staples in sub-Saharan Africa. It is a very reliable source of dietary calories for smallholder farmers and their households because it can be cultivated relatively easily, without the need for costly inputs such as fertilizers. It is also gaining importance as a cash crop and offers immense potential for enhancing income and improving the livelihoods of these small-scale subsistence farmers.

However, to realize this potential, cassava crop yields in sub-Saharan Africa need to be boosted. For instance, the average yield of fresh roots per hectare is 10.2 tons in Africa, 12.5 tons in South America and 17.3 in Asia while worldwide it is 12.4.

Efforts to develop superior varieties of the crop in Africa benefit from increasing the genetic diversity of the breeding materials. There is a rich pool of cassava diversity, including its wild relatives in South America.

But the intercontinental transfer of cassava germplasm (living genetic resources), through seeds or stem cuttings, faces numerous constraints. For example, using seeds for this process has proven too difficult, time-consuming and expensive. The characteristics of the parents are difficult to reproduce in the offspring from seeds. Stem cuttings, on the other hand, pose a high risk because their transport can spread pests and diseases across regions. Cassava germplasm from South America is also susceptible to a myriad of virulent pests and diseases found in Africa, in particular cassava mosaic disease (CMD).

To address these constraints, the National Root Crop Research Institute in Nigeria in 2004 pioneered the use of cell biology and molecular markers to introduce desirable traits of South American germplasm to cassava in Africa while at the same time increasing resistance to CMD. Thousands of plantlets - miniature plants grown on sterile media in test tubes or flasks in the laboratory - were obtained from one of the world's largest repositories of cassava germplasm, the International Center for Tropical Agriculture in Colombia. These aseptically grown plantlets have minimal risk of spreading diseases and pests and are thus not subject to the stringent quarantine conditions applied to the transport of other cassava germplasm. Through the use of molecular markers – analyzing and identifying fragments of cassava DNA linked to the traits of interest – scientists were able to rapidly combine into a new cassava variety the resistance to CMD obtained from a Nigerian variety and the high-yield, drought-tolerant traits contained in the South American types.

It is estimated that the improved cassava varieties, the fruit of these biotechnologies, could enhance the crop's yield in Nigeria from the average 14 tonnes per hectare to 25 tonnes per hectare with an estimated additional revenue of 1.48 billion dollars for the cassava sector.

For more information:
Molecular Markers and Tissue Culture: Technologies Transcending Continental Barriers to Add Value and Improve Productivity of Cassava in Africa. By E. Okogbenin, C. Egesi and M. Fregene. In: FAO. 2013. Biotechnologies at work for smallholders: Case studies from developing countries in crops, livestock and fish, Pages 37-46 (with photos). Available at
http://www.fao.org/docrep/018/i3403e/i3403e00.htm

IN THE LIVESTOCK SECTOR

Protecting Namaqua Afrikaner sheep in South Africa using genetic characterization

Many indigenous cattle, sheep and goat breeds in South Africa are well adapted to the harsh and arid local conditions. This makes them a valuable genetic resource, since they have traits which are useful for breeding animals which are adapted to challenging environments. However, various factors are threatening such breeds with extinction. The characterization of genetic traits is vital for the conservation of these breeds.

Namaqua Afrikaner sheep are robust, long-lived, and perform well under extreme conditions, yet populations of these sheep in South Africa have been dwindling. Using microsatellite markers – stretches of DNA containing repetitions of short DNA sequences known as motifs – characterization of genetic traits was carried out for Namaqua Afrikaner sheep, in a programme implemented by the National Department of Agriculture: Directorate Grootfontein Agricultural Development Institute (GADI) in South Africa. This characterization will prevent harmful inbreeding, and is already being used to increase the genetic diversity of the flocks.

For more information:
Saving the Endangered Namaqua Afrikaner Sheep Breed in South Africa Through Conservation and Utilization. By E. van Marle-Koster, C. Visser, S. O. Qwabe and G. Snyman. In: FAO. 2013. Biotechnologies at work for smallholders: Case studies from developing countries in crops, livestock and fish, Pages 82-89 (with photos). Available at
http://www.fao.org/docrep/018/i3403e/i3403e00.htm

Early diagnosis of peste des petits ruminants in Cameroon

The viral disease peste des petits ruminants (PPR) affects small ruminants such as sheep and goats throughout sub-Saharan Africa. PPR is highly contagious and has a mortality rate close to 100 percent, meaning that outbreaks can be devastating for smallholders.

Diagnosis of PPR has previously involved expensive and time-consuming laboratory work requiring careful control of temperature during the tests. These methods cannot be used in the field, and cannot provide an instant diagnosis of the disease. Researchers at the FAO/IAEA Programme for Nuclear Techniques in Food and Agriculture in Vienna worked with a range of laboratories to develop and test a 'mobile laboratory' method for diagnosing PPR, using biotechnology to detect the genetic material of the virus. They developed a mixture of compounds which can be added directly to biological samples at room temperature. The PPR pathogen can then be detected using a specialized scanner which can operate from a car battery. This system can be used in the field and is both fast and cost-effective, and has been used in Cameroon to rapidly diagnose PPR when an outbreak occurs. This enables early detection of PPR outbreaks so that appropriate vaccination can be carried out to protect neighbouring herds, reducing the spread of the disease.

For more information:
Taking the Laboratory to the Field: Rapid Diagnosis of Peste des Petits Ruminants (PPR) in Cameroon. By A. Wade and A. Souley. In: FAO. 2013. Biotechnologies at work for smallholders: Case studies from developing countries in crops, livestock and fish, Pages 117-124 (with photos). Available at http://www.fao.org/docrep/018/i3403e/i3403e00.htm

Eradicating tsetse flies in Zanzibar using the sterile insect technique

In Africa, tsetse flies transmit parasites which cause trypanosomosis, a disease which is deadly for humans and livestock. It is estimated that tsetse flies and trypanosomosis cause over US$1 billion in losses of livestock and US$4-5 billion in lost potential (when animals are weakened by the disease) every year.

Drugs and insecticides are of limited success in preventing trypanosomosis in livestock, since drug resistance is increasing and these chemicals are costly. The sterile insect technique (SIT) is a biotechnological tool which has been used with success to combat tsetse flies in Zanzibar. This technique involves producing sterile male insects – usually by irradiation – and introducing them into the environment. The large numbers of sterile males outcompete wild males and mate with wild females who consequently do not produce offspring. Molecular genetics approaches can be used to study the degree of movement of genes between pest insect populations to determine whether or not the populations are isolated. This enables better planning of interventions, since SIT is much more effective in eradicating isolated populations of insects.

On the Unguja Island of Zanzibar, SIT was used successfully to eradicate tsetse flies in the 1990s. 110 000 sterile males were released each week at the peak of the campaign, which eradicated the tsetse flies in less than three years, and has increased agricultural productivity significantly due to the increased availability of livestock. For example, from 1999 to 2002, there was a 30 percent increase in the average monthly income of farming households, strongly correlated with milk yields and the use of animal power.

For more information:
Application of the Sterile Insect Technique in Zanzibar to Eradicate Tsetse Flies, the Vectors of Trypanosomosis. By U. Feldmann, F. Mramba, A. G. Parker, K. M. Saleh, V. A. Dyck and M. J. B. Vreysen. In: FAO. 2013. Biotechnologies at work for smallholders: Case studies from developing countries in crops, livestock and fish, Pages 125-132 (with photos). Available at http://www.fao.org/docrep/018/i3403e/i3403e00.htm

The global rinderpest eradication campaign

Global freedom from rinderpest (cattle plague) was declared in 2011 and marked only the second time in history that a disease has been eradicated worldwide, the first being smallpox. This achievement was the result of a combination of advances in the production of vaccines and strong cooperation among the international animal-health community, individual national veterinary services and local small-scale farming and pastoralist communities.

An infectious viral disease of cattle, buffalo, yak and numerous wildlife species, rinderpest caused devastating effects throughout history, including massive famines in regions where the disease spread unabated. Major waves of rinderpest outbreaks lasted for years and would result in mortality rates that could approach 90 percent in unprotected herds. This posed a massive risk to the food security and livelihoods of millions of large and small-scale farmers, including pastoralists. It is estimated that major outbreaks of rinderpest would destroy more than 70 million (or 14 million per year) of the 220 million cattle in Africa.

The first important step in the elimination of rinderpest was the development of a rinderpest virus capable of growing in cell culture and from it, the production of a quality-assured vaccine. Additional advances included technologies that allowed for this vaccine to be freeze-dried and stably stored for years. However, the vaccine would lose its effectiveness when exposed to heat. Subsequently a vaccine more resistant to higher temperatures was developed, guaranteeing further effectiveness in remote areas.

An additional technological advancement was the development of diagnostic assays (tests) that could be carried out on the national herd of countries to establish, in a rapid and cost effective way, the vaccine coverage or to identify where the virus was circulating.

While samples of the virus that causes rinderpest are still stored in multiple laboratories in a few dozen countries, the disease no longer exists in nature. The last outbreak of rinderpest occurred in Meru National Park, Kenya, in 2001.

For more information:
FAO. 2011. Biotechnologies for Agricultural Development: Proceedings of the FAO international technical conference on “Agricultural biotechnologies in developing countries: options and opportunities in crops, forestry, livestock, fisheries and agro-industry to face the challenges of food insecurity and climate change” (ABDC-10). Pages 166-168. Available at http://www.fao.org/docrep/014/i2300e/i2300e00.htm

IN THE FISHERIES/AQUACULTURE SECTOR

Processing fish using fermentation in West Africa

The fermentation of fish involves degradation by enzymes or micro-organisms, sometimes aided by the addition of salt. The growth of beneficial bacteria is encouraged; these bacteria increase the acidity of the fish and therefore prevent the growth of detrimental bacteria such as those which cause spoilage or food poisoning. When carried out safely, fermentation results in a fish product which is easier to digest, lasts for longer and can increase food security in the region.

Fermented fish products are popular in Chad, Côte d’Ivoire, Gambia, Ghana, Mali, Nigeria, Sierra Leone, Sudan and Uganda. In Gambia, 50 percent of fish produced annually are processed into salted, partially fermented and dried products, whilst in Mali 75 percent of annual fish production is processed into smoked, grilled and dried fermented products.

Different micro-organisms are involved in the fermentation of different fish. The use of starter cultures, composed of appropriate micro-organisms, could improve the process of fermentation by reducing the fermentation time, suppressing pathogens, and creating a longer-lasting product with improved texture and taste.

For more information:
Small-Scale Fish Fermentation and Processing in West Africa. By G. R. Akande. In: FAO. 2013. Biotechnologies at work for smallholders: Case studies from developing countries in crops, livestock and fish, Pages 161-172 (with photos). Available at
http://www.fao.org/docrep/018/i3403e/i3403e00.htm

IN THE FORESTRY SECTOR

Using DNA markers to conserve forest trees in Gabon

In addition to climate change, human interventions such as logging, urbanization and agricultural activities can have negative effects on forests. Genetic approaches can be useful for forest conservation and management. For example, microsatellite markers are stretches of DNA containing repetitions of short DNA sequences known as motifs, and are useful for assessing genetic diversity within populations.

The moabi tree is an important species in tropical rainforests of the Congolese basin, but is under threat from logging. In Gabon, researchers have studied the degree of genetic diversity in this species using microsatellite markers, and have used the information to make recommendations for the conservation and management of the moabi tree. For example, knowledge of the degree of genetic diversity of moabi trees enables researchers to determine an appropriate level of seed collection from forest trees in order to preserve diversity in seedbanks and therefore reduce inbreeding of this valuable species in the future.

For more information: Applications for microsatellite markers in the management and conservation of forest trees: Illustration with *Baillonella toxisperma* and *Milicia excelsa*. Presentation by Ndiade Bourobou D. during the FAO international technical conference on Agricultural Biotechnologies in Developing Countries (ABDC-10), Guadlajara, Mexico, 1-4 April 2010.
http://www.fao.org/fileadmin/templates/abdc/documents/cafrica.pdf (2.6 MB)