Food and Agriculture Organization of the United Nations

SOME CASE STUDIES OF APPLICATIONS OF AGRICULTURAL BIOTECHNOLOGIES IN ASIA-PACIFIC

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IN THE CROP SECTOR

Improving banana production in Sri Lanka using tissue culture and mutation induction

Banana is the fourth most important food crop in the world, in terms of total value of production, and provides food for hundreds of millions of people in the tropics and sub-tropics as well as being used medicinally and in industry. In Sri Lanka, banana farming is increasing and there are 55 local cultivated varieties of banana, but many are susceptible to disease.

The Department of Botany of the University of Colombo has been involved with various projects in collaboration with FAO and International Atomic Energy Agency (IAEA), for example using irradiation to generate mutant lines of banana in order to increase genetic variation and produce new varieties. Biotechnology was used for detecting disease in the new varieties. In addition, tissue culture techniques have been used to help farmers increase banana production and reduce the instance of disease of banana in Sri Lanka. Through this project, virus-free mutant banana plants are being produced for rural farmers in Sri Lanka.

For more information:
Use of Tissue Culture and Mutation Induction to Improve Banana Production for Smallholders in Sri Lanka. By P.J.L. Lagoda. In: FAO. 2013. Biotechnologies at work for smallholders: Case studies from developing countries in crops, livestock and fish, Pages 8-17 (with photos). Available at http://www.fao.org/docrep/018/i3403e/i3403e00.htm

Using marker-assisted selection to improve pearl millet in India

Pearl millet is grown in hot dry climates, but yields are affected by drought and by downy mildew, a disease which can cause yield losses of up to 80 percent. The International Crops Research Institute for the Semi-Arid Tropics (ICRISAT) collaborated with several UK research institutions to develop genetic maps of pearl millet in order to breed pearl millet varieties with improved drought tolerance and disease resistance.

These genetic maps were based on molecular markers, which enable scientists to associate particular plant traits with the genes which encode those traits. By tracking these genes, the process of breeding for desired traits can be greatly accelerated. A higher yielding, more downy mildew resistant variety was released, which matures early and so has lower vulnerability to end-of-season drought. This variety is now widely used in India and has increased farmers' income as well as providing employment for people carrying out seed multiplication. Additionally, the higher yields have enabled farmers to increase cultivation of cash crops since less land is needed for pearl millet production.

For more information:
Successful Marker-Assisted Selection for Disease Resistance and Drought Tolerance in Pearl Millet in India. By R. Yadav, C.T. Hash, C. Howarth, J.R. Witcombe and I.S. Khairwal. In: FAO. 2013. Biotechnologies at work for smallholders: Case studies from developing countries in crops, livestock and fish, Pages 18-26 (with photos). Available at http://www.fao.org/docrep/018/i3403e/i3403e00.htm

Using marker-assisted selection to breed flood-tolerant rice in India

In India, over 10 percent of the land used for growing rice is prone to submergence, which leads to low rice yields and sometimes complete loss of the crop.

Submergence-tolerant varieties of rice have been bred from local varieties which are tolerant to submergence, but these varieties also have undesirable traits making them unpopular with farmers.

Using molecular markers, which enable genes to be associated with the traits they encode, researchers were able to identify the gene responsible for submergence tolerance. This meant that, using marker-

assisted breeding techniques, the gene for submergence tolerance could be bred into popular rice varieties, generating new submergence-tolerant rice which still retains desirable characteristics such as good grain qualities and high yield. For example, a new variety called Swarna-Sub 1 (containing the gene for submergence tolerance) developed by the International Rice Research Institute (IRRI) greatly outperforms the existing popular variety Swarna when fields are submerged, and has a similar yield to Swarna under non-flooded conditions. The Swarna-Sub 1 variety has now reached millions of farmers in India.

For more information:
- Transforming Rice Production in Flood-Affected Areas: Development of the Swarna-Sub1 Variety Using Marker-Assisted Backcrossing and its Deployment in India. By U.S. Singh, M.H. Dar, S. Singh and A.M. Ismail. In: FAO. 2013. Biotechnologies at work for smallholders: Case studies from developing countries in crops, livestock and fish, Pages 63-70 (with photos). Available at http://www.fao.org/docrep/018/i3403e/i3403e00.htm
- Abdelbagi. M. Ismail, U. Singh, D. Platten, E. Septiningsih, R. K. Singh, A. Kumar and D.J. Mackill. 2016. Developing rice varieties with enhanced adaptation to lowland farming systems: Case studies from South Asia. Pages 69-70. Proceedings of the FAO international symposium on the Role of Agricultural Biotechnologies in Sustainable Food Systems and Nutrition", 15-17 February 2016, Rome. http://www.fao.org/documents/card/en/c/66e9a36c-19b2-407a-83c9-5b767e233417/

Producing new crop varieties using mutation breeding

Mutagenesis – changing the genetic material of an organism, for example by using radiation – can be used to produce new crop varieties, and this technique is especially used by and for developing countries. By 2010, over 2 700 mutation-bred crop varieties had been released across the world, with particularly high rates of cultivation in Asia. Mutation-bred varieties of rice in Thailand and Myanmar and pearl millet in India are widely cultivated. Using mutation breeding, three varieties of rice with improved food quality and salt tolerance have been released in the Mekong Delta region of Viet Nam, increasing annual smallholder incomes by 350 USD per farmer.

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 35. Available at http://www.fao.org/docrep/014/i2300e/i2300e00.htm

Controlling migratory locusts in Timor-Leste using biopesticides

Biopesticides can provide an environmentally friendly alternative to chemical pesticides, and are appropriate for use when the environment is particularly sensitive or if crops are not under immediate threat from pests (because biopesticides act more slowly than conventional chemical pesticides). One such biopesticide is formulated from fungal spores and acts against migratory locusts.

In Timor-Leste, this fungal biopesticide was used successfully to combat swarms of migratory locusts which were putting maize and rice crops under threat in 2007, through a combination of aerial and ground spraying.

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 38-39. Available at http://www.fao.org/docrep/014/i2300e/i2300e00.htm
- FAO. 2016. Biopesticides for Locust Control. https://www.youtube.com/watch?v=zySjdXI1Nc0&feature=youtu.be

Using fermentation technology to produce soy sauce in Thailand

The production of soy sauce requires a two-step process of fermentation, using different cultures of micro-organisms. By using defined started cultures and an improved fermentation process, the production of soy sauce in Thailand has become both more technological and more efficient. For example, using a specific variety of starter micro-organism has improved the safety and uniformity of the product, whilst using pressure cookers has reduced the first phase of fermentation – which otherwise takes a minimum of 40 hours – by 14.5 hours. The development of fermentation chambers with controlled temperature and humidity has further shortened the time required for fermentation, whilst having increased the soluble protein content of the soy sauce. These innovations have increased the quality and safety of the product, alongside economic benefits.

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 262-263. Available at http://www.fao.org/docrep/014/i2300e/i2300e00.htm
- Soy sauce production: From a craft- to a science-based system. Presentation by R. Valyasevi and R. Rolle during the FAO international technical conference on Agricultural Biotechnologies in Developing Countries (ABDC-10), Guadalajara, Mexico, 1-4 April 2010. http://www.fao.org/fileadmin/templates/abdc/documents/soysauce.pdf (470 KB).

IN THE LIVESTOCK SECTOR

Breeding for increased sheep productivity in India using a DNA test for high fertility

Sheep-rearing is an important source of income in drought-prone rural areas of India. On the Deccan plateau in Maharashtra, keepers of Deccani sheep rely heavily on the sale of lambs for their livelihood.

In a project carried out by the Nimbkar Agricultural Research Institute (NARI), a gene which increases the fertility of ewes was introduced by crossing Deccani sheep with animals of the prolific Garole sheep breed in India, leading to more productive ewes which still have the desirable traits of Deccani sheep such as larger body size and hardiness.

DNA testing using the polymerase chain reaction (PCR) was used to detect the presence of the high-fertility gene during the breeding programme, making it both easy and fast to determine whether or not a lamb carries the favourable form of the gene, thereby increasing the speed at which the new, productive ewes could be selected.

This breeding programme has increased the average productivity of these sheep by up to 50 percent by increasing the average number of lambs per lambing and the new sheep have been successfully introduced into local flocks, thereby increasing the income of local farmers.

For more information:
- Sustainable Improvement in Sheep Productivity in India Using the *Fecb* (Booroola) Mutation. By C. Nimbkar. In: FAO. 2013. Biotechnologies at work for smallholders: Case studies from developing countries in crops, livestock and fish, Pages 72-81 (with photos). Available at http://www.fao.org/docrep/018/i3403e/i3403e00.htm
- Use of biotechnology for sustainable intensification of sheep rearing on the Deccan plateau in India. Presentation by Chanda Nimbkar during the FAO international technical conference on Agricultural Biotechnologies in Developing Countries (ABDC-10), Guadalajara, Mexico, 1-4 April 2010. http://www.fao.org/fileadmin/templates/abdc/documents/chanda.pdf (740 KB).

Facilitating artificial insemination to improve production of dairy cattle in Bangladesh

Before the 1990s, cattle in Bangladesh were used primarily for draught power, whereas now they are mostly raised for meat and milk, resulting in a need for high milk production to meet demand from the population.

Researchers from the Bangladesh Agricultural University have worked with local stakeholders to set up a foundation which increases access to veterinary services for smallholder cattle farmers using commission from milk sales – a system known as a "productive veterinary service".

The work of the productive veterinary service increases the effectiveness of artificial insemination by improving cattle health, management and other factors, thereby facilitating compliance of the farmers with the requirements of artificial insemination service providers. The productive veterinary service also improves detection of the times when female cows are fertile, which increases the effectiveness of artificial insemination.

The productive veterinary service therefore increases the benefit of artificial insemination services, and coupled with artificial insemination it has led to significant increases in milk production in Bangladesh.

For more information:
- Use of Artificial Insemination in a Community-Based Approach to Deliver Cattle Production-Related Veterinary Services in Four Dairy-Producing Areas of Bangladesh. By M.M.U. Bhuiyan, M.T. Islam and M. Shamsuddin. In: FAO. 2013. Biotechnologies at work for smallholders: Case studies from developing countries in crops, livestock and fish, Pages 98-108 (with photos). Available at http://www.fao.org/docrep/018/i3403e/i3403e00.htm
- Community-based artificial insemination, veterinary and milk marketing services in Bangladesh. Presentation during the FAO international technical conference on Agricultural Biotechnologies in Developing Countries (ABDC-10), Guadalajara, Mexico, 1-4 April 2010. http://www.fao.org/fileadmin/templates/abdc/documents/bangla.pdf (50 KB).

Safe starter cultures for production of a fermented pork sausage (nham) in Thailand

Nham is a fermented pork sausage produced in Southeast Asia, usually produced *via* uncontrolled fermentation, resulting in a product which is considered by the Thai health authorities to pose a high health risk. By developing a starter culture of micro-organisms for nham production, a safer and more consistent product has been developed by a nham manufacturer in collaboration with scientists from the Thai Ministry of Science, and incorporating local yeast extracts into the starter culture has significantly reduced the cost.

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 263-265. Available at http://www.fao.org/docrep/014/i2300e/i2300e00.htm

IN THE FISHERIES/AQUACULTURE SECTOR

Using probiotics to improve shrimp production in China

Production of marine shrimp is an important economic activity in the fisheries sector in China, with over 1.3 million tonnes of shrimp produced in 2010. However, due to the intensity of commercial shrimp aquaculture, there have been problems with water pollution, exacerbated by the use of antibiotics.

Probiotic bacteria may be used as an environmentally friendly alternative to antibiotics for aquatic disease management. These bacteria can serve various functions in shrimp production, including increasing the rates of growth and survival, preventing disease, and improving water quality. They can be provided as a powder, liquid or additive to pellet feed.

Probiotics outcompete harmful bacteria, stimulate the shrimp immune system, and improve digestion and heath of the shrimp. Various species may be used, such as *Bacillus*, *Vibrio* and *Pseudomonas*, depending on the shrimp species. It is estimated that the use of these probiotics in China has led to increases in the growth rate, survival rate, and size of shrimp, leading to higher yields, alongside improved water quality.

For more information:
Application of Probiotics as an Environmental Treatment and Feed Additive in the Production of Farmed Marine Shrimp in China. By Y. Xinhua. In: FAO. 2013. Biotechnologies at work for smallholders: Case studies from developing countries in crops, livestock and fish, Pages 134-139 (with photos). Available at http://www.fao.org/docrep/018/i3403e/i3403e00.htm

Breeding hybrid catfish in Thailand using artificial insemination

Breeding two species together can result in a hybrid which performs better than the average of the parental species – a phenomenon known as 'hybrid vigour'.

In Thailand, the broad-head catfish is a favourite food fish due to its favourable colour and texture, but is slow growing and susceptible to diseases making it difficult to culture on a commercial scale. The African sharp-tooth catfish, in contrast, has a high growth rate and low susceptibility to diseases, but is not palatable to people in Thailand. Breeding the two catfish species together has resulted in a hybrid which is both palatable and fast growing, making it ideal for aquaculture in Thailand. To produce the hybrids, the parent catfish are injected with hormones; the eggs and sperm are then harvested and mixed together to create fertilized eggs.

This biotechnology has created a huge expansion of aquaculture and related industries in Thailand and provides greater access to food and high-quality protein for poor rural people. Between 1990 and 2010, the production of hybrid catfish increased from 17 900 metric tonnes to approximately 120 000 metric tonnes, with a peak in production in 2004 of over 150 000 metric tonnes.

For more information:
Inter-Specific Hybrid Catfish in Thailand. By U. Na-Nakorn. In: FAO. 2013. Biotechnologies at work for smallholders: Case studies from developing countries in crops, livestock and fish, Pages 149-155 (with photos). Available at http://www.fao.org/docrep/018/i3403e/i3403e00.htm

Improving carp in China using gynogenesis

In order to improve the quality and production of fish, two different varieties of the same species can be bred together to produce a hybrid variety which can be of higher quality than the parents – known as 'hybrid vigour'. For example, in China, the Heyuan carp is one such hybrid and has several desirable characteristics including high growth rate and good body shape. However, if the hybrid Heyuan carp are bred together using random mating, the offspring will not retain the same combination of desirable traits.

Using a technology called gynogenesis (where fish eggs are fertilized by sperm which do not contribute genetic material to the resulting offspring), together with selection of the best individuals within families, it has been possible to breed Heyuan carp and still retain a high proportion of offspring with desirable traits, resulting in a new variety known as Jian carp. The Jian carp can be mated together easily and still retain the desirable traits, and have a specific yield which is 30 per cent higher than that of other varieties of common carp.

For more information:
Use of Within-Family Selection and Gynogenesis to Develop the Jian Carp (*Cyprinus carpio* var. *jian*) in China. By Z. Dong. In: FAO. 2013. Biotechnologies at work for smallholders: Case studies from developing countries in crops, livestock and fish, Pages 156-160 (with photos). Available at http://www.fao.org/docrep/018/i3403e/i3403e00.htm

Cryopreservation in Malaysian aquaculture

Cryopreservation enables indefinite storage of fish semen, which is useful for aquaculture breeding programmes as well as for facilitating conservation of fisheries genetic resources. In a five-year project for conservation of inland fisheries resources, workable species-specific protocols for semen cryopreservation were developed. Whilst having lower motility than before freezing, thawed sperm samples were motile and were able to fertilise eggs. Fertilisation and hatching rates were both lower when thawed sperm was used rather than fresh sperm, but the survival rates of the resulting fish fry were similar.

For more information:
Application of innovative biotechnologies regarding aquaculture and fisheries sector in Malaysia: Cryopreservation programme. Presentation by Poh Chiang Chew, Zulkafli Abd. Rashid and Rosly Hassan 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/cryofish.pdf (1.35 MB)

Rapid detection of viral diseases in shrimp in India

Techniques that allow for the rapid detection of viral diseases have had a major impact on the cutting of losses in shrimp farming. The use of DNA-based diagnostic methods comes from the principle that each species of pathogen carries unique DNA or RNA sequences that differentiate it from other organisms thus offering high sensitivity and specificity for rapid screening for the presence of pathogen DNA.

Very small quantities of the viral DNA can be multiplied through the use of the polymerase chain reaction (PCR) – a tool to make more DNA – until there is a sufficient amount of the viral DNA to be detected in the laboratory. These methods have been adopted rapidly and used in diagnosis and for detection of many economically important viral pathogens of cultured finfish and penaeid shrimp. However, there are some limitations regarding their use, including "false negatives" caused by, for example, the selection of inappropriate host tissue sources, incorrect choice of DNA extraction methods, or low pathogen prevalence in the population being sampled – a situation that may erroneously affect the analysis and interpretation of test results.

The use of PCR has been introduced in India where shrimp aquaculture is mainly carried out by small- and medium-scale farmers located in remote villages - this included providing farmers with kits for collecting and preserving DNA. Since 2002, efforts to support shrimp farmers in disease control and coastal management have led to significant improvements in income and reduced shrimp disease risks.

An FAO–assisted project has supported local farmers form self-help groups or “clusters” to share experiences and implement better management practices. An economic analysis of 15 farmer groups in Andhra Pradesh showed that farmers adopting better management practices including using postlarvae (immature shrimp) for their shrimp stocks that had been screened in the laboratory for the presence of DNA from specific pathogens had higher profitability, lower production costs and were able to produce quality and traceable shrimp without using any banned chemicals.

The project has been highly successful in forming a self-help movement of farmers – from a mere five farmers who first adopted the cluster-farm approach in 2002, the programme swelled to more than 1 000 farmers in 30 aquaculture societies in five Indian coastal states by 2007.

For more information:
- PCR-based Pathogen Detection in Shrimp Aquaculture in India. By P.C. Thakur, A.P. Padiyar, A.K. Sahoo, G. SubbaRao and D. Ramraj. In: FAO. 2013. Biotechnologies at work for smallholders: Case studies from developing countries in crops, livestock and fish, Pages 140-148 (with photos). Available at http://www.fao.org/docrep/018/i3403e/i3403e00.htm
- 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 223-224. Available at http://www.fao.org/docrep/014/i2300e/i2300e00.htm

IN THE FORESTRY SECTOR

Development of a biopesticide against a serious insect pest of teak in India

The teak defoliator is a serious insect pest of teak. By isolating a virus from the larvae of the teak defoliator insect, researchers at the Kerala Forest Research Institute were able to develop an effective biological control method: regular spraying of teak with this virus, which attacks the teak defoliator insect, leads to an increase in timber volume. However, the technology has not yet been accepted by forestry professionals and remains in the laboratory. The case study demonstrates that research in forest biotechnology has a much better chance of producing results when conceived, developed and implemented in a broader framework that involves not only scientists and technologists but also at every stage the forestry professionals who work at the field level and, at some level, policy-makers who eventually have to give their approval.

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 108-109. Available at http://www.fao.org/docrep/014/i2300e/i2300e00.htm

Use of tissue culture in Malaysia for successful propagation of teak planting stock

Teak (Tectona grandis) is a valuable tropical hardwood widely planted in Asia, South and Central America and Africa. However, in many countries, the supply of teak planting stock cannot meet the demand. Teak has low seed yield per tree even in seed orchards as well as low and sporadic seed germination. This creates a problem for making teak germplasm available for smallholders and other tree planters, and for improving the quality of teak planting stock.

In Malaysia, the Sabah Foundation Group has been testing the mass propagation of high-quality teak clones using efficient nursery and micropropagation techniques since the early 1990s. This work has been carried out in collaboration with the Centre de Coopération Internationale en Recherche Agronomique pour le Developpement (CIRAD, France). Micropropagation – growing plant tissue cultures in laboratory conditions – is used to clone superior teak trees with desirable traits, such as fast growth, straight bole (trunk), minimal branching and high heartwood to sapwood ratio.

Successful application of these techniques from the laboratory to the ex-vitro acclimatization of plants to the field-ready stage has led to the increased availability of high-quality teak planting stock in Malaysia and worldwide exportation of teak plants to many tropical and sub-tropical countries. The technologies allow the mass production of clones from any outstanding teak tree regardless of its age.

The increased availability of high-quality teak planting stock has contributed to further development of intercropping systems based on teak and other cash crops such as rubbers, coffee, cocoa or even annuals such as legumes with nitrogen-fixing ability. These intercropping systems are of great interest

to smallholders who are eager to not only maximize financial returns on their investments but also to increase the sustainability and diversity of their production systems.

For more information:
Tissue culture production of clonal teak for large-scaled plantation establishments. Presentation by Doreen Goh during the FAO international technical conference on Agricultural Biotechnologies in Developing Countries (ABDC-10), Guadalajara, Mexico, 1-4 April 2010.
http://www.fao.org/fileadmin/templates/abdc/documents/teak.pdf (4 MB)