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), Guadalajara, Mexico, 1 – 4 March 2010

APAARI Issue Paper: Harnessing biotechnologies for food security in the Asia-Pacific region.

Jawahir L. Karihaloo & Oswin Perera[1]

The developing countries of Asia-Pacific[2] contribute significantly to the world agrarian economy. With 53.1% of its 3.6 billion people engaged in agriculture, the region produces 46.2% of the world's cereals, 37.2% of tubers and root crops, 44.5% of pulses, 50% of vegetable oils, 44% of fruits, 68% of vegetables, 40% of milk, 37% of meat and 64% of inland capture fish[3]. Several countries of the region have in the past made remarkable progress in food and agricultural production through adoption of improved strains of crops and animals along with high input production technologies, due to which hunger and poverty were contained despite burgeoning population. However, the last few years have seen decline in crop productivity growth leading to alarmingly low grain reserves and spiralling food prices. Today, nearly two thirds of the world's undernourished live in the Asia-Pacific region and a number of these countries are placed at "serious" or "alarming" severity levels in the 2009 Global Hunger Index[4]. With the projected 15-50% loss in agricultural productivity by 2080 due to climate change[5], the region faces severe threat of food insufficiency and hunger. While several measures are required to reverse the trend and make agriculture an effective instrument of development in the region[6], improving agriculture productivity and nutritional quality of food in an environmentally sustainable manner through application of appropriate technologies is an important solution.

The Convention of Biological Diversity (CBD) defines biotechnology as "any technological application that uses biological systems, living organisms, or derivatives thereof to make or modify products or processes for specific uses." The biotechnological techniques and processes that have found application in agriculture include genetic modification (GM), chromosome number manipulation, biotechnology based diagnostics and vaccines, animal

---

[1] This paper was produced for the FAO international technical conference on Agricultural Biotechnologies in Developing Countries (ABDC-10), held in Guadalajara, Mexico 1-4 March 2010. The views expressed in this information product are those of the author(s) and do not necessarily reflect the views of the Food and Agriculture Organization of the United Nations.

[2] The Asia-Pacific region comprises three developed countries, Australia, Japan and New Zealand, and 38 developing countries of five subregion: Southeast Asia (Cambodia, Indonesia, Lao PDR, Malaysia, Myanmar, Philippines, Thailand, Timor-Leste and Vietnam); South and Southwest Asia (Afghanistan, Bangladesh, Bhutan, India, Iran, Maldives, Nepal, Pakistan, Sri Lanka); Central Asia (Kazakhstan, Uzbekistan); East Asia (China, DPR Korea, Mangolia, Republic of Korea) and Pacific Islands (Cook Islands, Fiji Islands, Kiribati, Marshall Islands, Fed. States of Micronesia, Nauru, Niue, Palau, Papua New Guinea, Samoa, Solamon Islands, Tonga, Tuvalu, Vanuatu)[2].

[3] FAO-RAP (2009) Selected Indicators of Food and Agricultural Development in the Asia-Pacific Region 1998-2008. Food and Agriculture Organization of the United Nations, Regional Office for Asia and the Pacific, Bangkok.

[4] von Grebmer, K., Nestorova, B., Quisumbing, A., Fertilizers, R., Fritschel, H., Pandiya-Lorch, R., Yohannes, Y. (2009) 2009 Global Hunger Index. Wet hunger hilfe, Bonn; IFPRI, Washington D. C.; Concern Worldwide, Bonn.

[5] Nellemann, C., Mac Devette, M., Manders, T., Eickhout, B, Svihus, B., Prinis, A.G., Kaltenborn, B. P. (Eds.) (2009) The Environmental Food Crisis-The Environments' Role in Averting Future Food Crisis. A UNEP rapid response assessment. United Nations Environment Programme, GRID-Arendal.

[6] FAO. 2009. How to feed the world in 2050. Paper presented at the High Level Expert Forum, Rome 12-13 October 2009. Available at: http://www.fao.org/wsfs/forum2050/wsfs-background-documents/hlef-issues-briefs/en/

reproductive biotechnologies, micropropagation, *in vitro* hybridization, *in vitro* conservation and cryopreservation, mutagenesis, fermentation, and biopesticides and biofertilizers[7]. The objective is to create new genetic variation, identify and utilize genetic variation more efficiently, and improve production and management systems.

Biotechnology for agriculture in Asia-Pacific – Status: The potential of biotechnology in improving agricultural productivity, including that of smallholder farming systems, is well recognized[8]. Several developing countries of the Asia-Pacific support biotechnology based agricultural improvement programs and some have even made policy statements asserting biotechnology as being integral to priority planning for agricultural development. Perusal of the FAO database on Biotechnology in Developing Countries[9] reveals that 17 countries of the region have one or more ministries responsible for biotechnology research in agriculture, and 11 have ongoing programs on application of biotechnology in agriculture. Twenty-one countries are party to or have ratified the Cartagena Protocol on Biosafety of the CBD. The biotechnology programs operating in the 11 countries cover practically all the important food, agriculture and forestry crops and involve application of techniques like micropropagation, somaclonal variation, protoplast fusion, somatic hybridization, anther culture, embryo rescue, molecular markers, marker aided selection, in vitro and cryopreservation based germplasm conservation, and biofertilizers and biopesticides. More than 50 crops and forestry trees are being targeted for genetic modification for diverse traits, most prominent among which are resistance to diseases and pests, and abiotic stress tolerance[10]. Most of these researches are in laboratory or greenhouse phase while some are in advanced field trial phase.

Some of the achievements in application of biotechnology in agriculture that have brought tangible benefits in terms of improved strains or better management practices are summarised below.

Production of low-cost quality planting material of economically important as well as food security crops on a large scale has been successful in a number of crops and countries. Farmers in Vietnam have been growing potato from tissue culture plantlets due to which potato yields are estimated to have doubled from 10 to 20 tonnes per hectare[11]. In China, tissue culture propagation and ELISA testing methods were used to develop disease-free mother plants of sweet potato which led to at least 30 percent yield increase with little or no change in the use of other inputs[12]. In India, integration of micropropagation, disease

---

[7] FAO (2010) 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). Current status and options for crop biotechnologies in developing countries. Document ABDC-10/3.1.

[8] FAO (2004) The State of Food and Agriculture 2003-2004. Agricultural Biotechnology: Meeting the Needs of Poor? Food and Agricultural Organisation, Rome. P. 208.

[9] FAO-BioDec (2007) Biotechnologies in developing countries. (available at: *http://www.fao.org/biotech/ inventory_admin/dep/default.asp;*

[10] Gupta, K.; Karihaloo, J.L. and Khetarpal, R.K. (2008) Biosafety Regulations Asia-Pacific Countries. Asia-Pacific Association of Agricultural Research Institutions, Bangk Asia-Pacific Consortium on Agricultural Biotechnology, New Delhi and Food and Agriculti Organization of the United Nations, Rome, P. 96

[11] Yuen, N.V., Ho, T.V.,Tung, P.X., Vander Zaag, P., Walker, T.S. (1996). Economic impact of the rapid multiplication of high-yielding, late-blight-resistant varieties in Dalat, Vietnam, in: Walker, T., Crissman, C. Case studies of the economic impact of CIP-related technology, International Potato Center (CIP), p. 127-138.

[12] Fuglie, K.O., Zhang, L., Salazar, L.F., Walker, T.S. (1999) Economic Impact of Virus-Free Sweet Potato Planting Material in Shandong Province, China, International Potato Center, Lima/Peru, 27.

detection and elimination, and conventional propagation in potato and sugarcane has led to substantial improvements in seedling quality and health and economic returns[13,14].

GM crops are under commercial cultivation in China, India and the Philippines. In addition, China, Korea, the Philippines and Thailand have approved some GM crops for food and livestock feed. In China, Bt cotton cultivation had expanded to 3.8 mha in 2007, while in India the area under Bt cotton reached 7.6 million hectares in 2008-09, which constitutes nearly 81% of the total cotton area of the country. The Indian cotton production reached 4.9 million tonnes in 2008-09, from 2.3 million tonnes in 2002-03 when the first Bt hybrids were introduced. Several studies in India and China have established that adoption of GM crops has led to substantial increase in harvested produce, reduced pesticide applications and environmental impact, and increased net incomes of the farmers, though there have been some negative reports as well[15,16,17].

Marker aided selection has been used to develop a downy mildew resistant pearl millet hybrid 'HHB 67-Improved'[18]. It is estimated that the value of potential pearl millet grain yield losses in one year of a major downy mildew epidemic in some states of India exceeds the total research funding utilized during the period 1990 through 2005 for developing 'HHB 67-Improved'. Bacterial blight resistant varieties of rice have been developed in China and India[19,20]. In the Philippines, rice variety IR64-Sub1 developed through marker aided selection from the popular IR64 has tolerance to submergence [21].

Induced mutagenesis has been widely used to breed improved food and industrial crops. FAO/IAEA database of mutant varieties and genetic stocks lists 1,858 varieties including 1,336 food crop varieties having been developed through mutation in Asia http://mvgs.iaea.org/Search.aspx. In Vietnam, three new mutant rice varieties having tolerance to salinity and good food quality have been released to farmers due to which farmers' incomes have increased by US $350 million per year[22]. Doubled haploid and interspecific hybrid rice varieties are being grown in China and Vietnam[23].

---

[13] Naik, P.S. and Karihaloo, J.L. (2007) Micropropagation for Production of Quality Potato Seed in Asia-Pacific. Asia-Pacific Consortium on Agricultural Biotechnology, New Delhi, India. 54 P.

[14] Jalaja, N.C., Neelamathi, D. and Sreenivasan, T.V. (2008) Micropropagation for Quality Seed Production in Sugarcane in Asia and the Pacific. Food and Agriculture Organization of the United Nations, Rome; Asia–Pacific Consortium on Agricultural Biotechnology, New Delhi; Asia-Pacific Association of Agricultural Research Institutions, Bangkok, p. i-x + 46.

[15] Dong, H., Li, W., Tang, W. and Zhang, D. (2004) Development of hybrid *Bt* cotton in China – A successful integration of transgenic technology and conventional techniques. *Current Science.* 86: 778-782.

[16] Brookes, G. and Barfoot, P. 2006. Global impact of biotech crops: Socio-economic and environmental effects in the first ten years of commercial use. *AgBioForum* 9: 139-151.

[17] Karihaloo, J. L. and Kumar, P. A. (2009) Bt cotton in India - A status report (Second Edition). Asia-Pacific Consortium on Agricultural Biotechnology (APCoAB), New Delhi, India. p. 56.

[18] Khairwal, I. S. and Hash, C. T. (2007) 'HHB 67-Improved' - The first product of marker-assisted crop breeding in India. Asia-Pacific Consortium on Agricultural Biotechnology e-News.

[19] Zhai, W., Li, X., Tian, W., Zhou, Y., Pan, X., Cao, S., Zhao, Y., Zhao, B., Zhang, Q. & Zhu, L. (2000) Introduction of a blight-resistance gene, *Xa21*, into five Chinese rice varieties through an *Agrobacterium*-mediated system. *Sci. China, Series, C.* 43, 361–368.

[20] India Notifies Evolved Basmati Variety For Export Basmati-1. Available at: http://oryza.com/Global-Rice/Basmati-Rice/Basmati-India/5647.html

[21] Mackill, D. J., Collard, B. C. Y., Neeraja, C. N., Maghirang-Rodriquez, R., Heuer, S. & Ismail, A. M. (2006) QTLs in rice breeding: examples for abiotic stresses. In Fifth Int. Rice Genetics Symp., Manila, Philippines. Los Ban˜os, The Philippines: International Rice Research Institute

[22] FAO & IAEA. 2008. Atoms for Food: a global partnership. Contributions to Global Food Security by the Joint Division of the Food and Agriculture Organization and the International Atomic Energy

Among the successful applications of biotechnology in forestry, are the large-scale micropropagation of some forestry tree species in India, Indonesia, Malaysia, Thailand and Vietnam, and environmental release of insect resistant GM poplar in China[24]. While a large number of reports on the use of molecular markers for diversity analysis in tree species are available, few of these are based on wide area coverage and address issues of genetic resources management.

Biotechnological tools are being used for conservation, characterization, evaluation and enhancement of crop and forestry genetic resources. Genebanks and other institutions in China, India, Indonesia, Malaysia, Pakistan and the Philippines apply *in vitro* and cryopreservation techniques for *ex situ* conservation of vegetatively propagated and recalcitrant species[25]. In China, *two in vitro* banks have 1,787 collections while in India, seven *in vitro* and cryopreservation facilities hold 7,922 and 1,904 accessions, respectively. There are also plans for developing DNA-based genomic resources facilities.

Use of biofertilizer and biopesticides in agriculture and forestry is being made in India, the Philippines, Korea and Vietnam[26]. In India, about 2.5% of the total pesticide market is commanded by biopesticides whereas the use intensity of biofertilizers to chemical fertilizers (N+P+K) is 0.04:90 kg per ha. In the Philippines, use of bioagents for pest control crop is and is being encouraged as a part of organic movement. Several facilities in the country produce biofertilizer containing nitrogen fixing bacteria.

Among the animal biotechnologies, the most widely used ones in the region are the application of assisted reproductive biotechnologies such as artificial insemination (AI), oestrous synchronization and embryo transfer (ET)[27]. In animal health, molecular based serological techniques using monoclonal antibodies and recombinant antigens as well as PCR-based methods are being used for diagnosis of diseases and epidemiological studies in most countries, together with conventional and recombinant vaccines for controlling diseases. Molecular markers for genetic diversity studies are also used widely, but marker assisted selection for genetic improvement is only being used in a few of the more developed countries. Biotechnologies to improve animal nutrition through feed additives such as amino acids and enzymes are widely applied, especially in monogastric livestock, whereas use of other additives such as prebiotics and probiotics is less common. Advanced technologies such as cloning and transgenesis are hardly used in most countries of the region, as they currently have limitations in success rates and cost-effectiveness, as well as ethical, religious and animal welfare concerns. The species of animals on which these biotechnologies are used in the region include cattle, buffalo, sheep, goats, pigs, horses, camels, deer, chicken, ducks, quails, guinea fowl and fish.

Agency. Report to the IAEA General Conference September 2008. Available at: www.iaea.or.at/Publications/Booklets/Fao/fao1008.pdf.

[23] Footnote 6

[24] FAO (2010) 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). Current status and options for forest biotechnologies in developing countries Document ABDC-10/4.1.

[25] The State of the World's Plant Genetic Resources for Food and Agriculture http://www.fao.org/agriculture/crops/core-themes/theme/seeds-pgr/sow/en/

[26] APCoAB (2010) Proceedings of the Expert Consultation on Biopesticides and Biofetilizers for Sustainable Agriculture. Taichung, 27-29 October 2009. Asia-Pacific Consortium on Agricultural Biotechnology (APCoAB), New Delhi (in press).

[27] FAO (2010) 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). Current status and options for livestock biotechnologies in developing countries. Document ABDC-10/5.1

Issues and the way ahead:

From the above detailed progress, it would be apparent that Asia-Pacific countries vary greatly with respect to policy support to biotechnology, investment, institutional and human capacity, and public perceptions and participation in decision making. In general, while the experiences so far have been encouraging, the achievements have fallen short of the expectations. Some of the delay can be ascribed to the inevitable lag period between technology acquisition or development and the results of its implementation. However, specific issues that impact adoption of biotechnology comprise those listed above as well as regulatory and intellectual property issues. Several options have been proposed to address these at the national and international levels[28]. A number of high level policy meetings and expert consultations organized by the Asia-Pacific Association of Agricultural Research Institutions (APAARI) in collaboration with national agricultural research systems of the region have recommended following priority actions to accelerate the adoption of biotechnology for meetings food security needs in Asia-Pacific:

(i) Strengthening biotechnology for food security and profitability of farmers

- Extend policy support by recognizing biotechnology as an integral part of strategy to achieve food security and Millennium Development Goals.
- Increase funding support to R&D in biotechnology commensurate with the needs to achieve farm level adoption of products.
- Adopt appropriate biotechnological tools (GM technology, marker-aided-selection, genomics, micropropagation, diagnostics) to address specific scientific issues related to agricultural improvement and diversification. The objective should be to increase productivity in conventional crops and animals as also help in agricultural diversification.
- Emphasis to be placed on improving nutritional quality of food, being an important component of food security.
- There is a need for policy changes and programs that improve farming profitability, reduce risks faced by farmers, preserve biodiversity, and educate and orient consumers.
- Biotechnology provides opportunities to develop alternatives to food crops for biofuel production. Non-food crops like cellulosic grasses and microalgae need biotechnological interventions to render their use for biofuel production economically viable.

(ii) Facilitating regulatory management

- Build confidence in GM technology which will facilitate a more open and acceptable regulatory system.
- Simplify regulatory norms for GM food crops and traits of apparently limited environmental and human risk.
- Facilitate transboundary movement of GM food crops through bilateral or regional agreements on biosafety information requirement and acceptance.

(iii) Strengthen linkages

South-South linkages

- South-South linkages will help in promoting agricultural biotechnology among developing countries and bridge regional and interregional gaps. There is a need to exchange information, germplasm and technologies through South-South collaborations. This can be done through:
  - Conducting workshops and defining the available resources and needs, followed by mutually agreed action plans.
  - The existing fora such as APAARI, FARA, AARINENA and other networks already functional within these platforms can play a major role in facilitating South-South interaction.

North-South linkages

[28] Foot note 6

- Countries of the South have abundant genetic resources while the tools and technologies are available in North. North-South linkages for germplasm, technology, products and information exchange will be of mutual benefit and help the developing countries to accelerate the pace of biotechnology adoption.

Public-Private linkages

- The strengths of public and private sectors are mutually complementary. There is a need for the two to work together with mutual trust and commitment to create a dynamic and result oriented working environment.

(iv) Creating awareness by improving communication

- Train young scientists as communicators, not just in the field of biotechnology but also on issues of agriculture, food security and environmental safety.
- Arrange discussions between scientist, CSOs, farmer organizations and consumer groups to foster understanding and cooperation between all stakeholders.
- Develop farmer-scientist linkages and cooperation through conducting field visits, seminars etc.
- Set up scientific academia and communication units at the national level to assist in awareness creation.

(v) Creating awareness through education

- Include biotechnology in school syllabi providing factual information about its usefulness and safety aspects.
- Develop educational tools including websites on GM technology, safety of GM crops, IP and regulatory systems.

(vi) Capacity building

- Need to strengthen capacity in developing countries especially in the area of advanced biotechnology tools, scientific risk assessment and management, and safety and intellectual property issues.
- Collaborate in regional and interregional capacity building through support of NARS, CG centers and fora like APAARI, FARA and AARINENA.