Food and Agriculture Organization of the United Nations


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Realizing the potential of agricultural biotechnology in the Asia-Pacific region

Our global population is burgeoning: estimates put the world population at nine billion by 2030. Achieving global food security, and reaching Sustainable Development Goal 2 of Zero Hunger by 2030 requires more than just feeding people. It is not simply a question of higher production but of providing nutritious, safe and affordable food produced by farmers living within secure and equitable livelihoods. Though most of the world's 570 farmers are small scale family farmers, agriculture is a complex and multifaceted sector affected by environmental, social and economic factors. Climate change is negatively impacting agricultural production as rainfall cycles and temperature patterns diminish yields. Economic and civil crises result in rural-to-urban migration. Changing demographics is resulting in an ageing profile for the average farmer. Agricultural biotechnologies can respond to these complicated issues with flexible, responsive and appropriate solutions.

Agricultural biotechnologies are a diverse collection of appropriate technologies, ranging from low-to very-high-level systems, applications, tools or techniques. This report summarizes and presents the key results of a recent study commissioned by the Food and Agriculture Organization of the United Nations (FAO, 2018), *The status of application, capacities and the enabling environment for agricultural biotechnologies in the Asia-Pacific region: Regional background study*. It explains and describes different kinds of available biotechnologies and their application to a range of beneficiaries. It compares the success of biotechnologies between the crop, forestry and fisheries & aquaculture sectors, identifies the challenges to and existing gaps in implementing biotechnologies and concludes with recommendations for moving forward in increased integration of biotechnologies in the Asia-Pacific region.

Biotechnology saves rice crops from devastation by flood (FAO, 2017)

A flood can wipe out the work of an entire season, destroying a rice crop and fodder for animals. Floods are common and the impact is always devastating – 10 or 15 days under water destroys rice and other crops. Trilochan Parida, 52, is a rice farmer in Turianbando village of Orissa, India, who spent 27 years of his life on paddy fields and he has just such first-hand experience of experience of losing his crop, his work and his livelihood to floods. With a family, children to educate and financial obligations for building a new home, a flood almost destroyed the farm Parida had worked so hard to build over his lifetime. In Orissa, every two or three years a flood would destroy the paddies and the lives of the local farmers was becoming increasing austere. Farmers had to ask for assistance from relatives, friends and money lenders, hoping to pay back from next harvest, provided floods did not hit again.

Parida still remembers the day he met a stranger who brought a new rice variety, which the man claimed would survive submergence. Parida was skeptical.

Dr J.K. Roy, a rice researcher at the Central Rice Research Institute, Orissa, India, was in Orissa promoting Swarna-Sub 1 submergence resistant rice. This rice was hybridized using Marker-assisted selection (MAS). MAS is a medium-level agricultural biotechnology used to develop stress

tolerated rice varieties. MAS is a process to select a trait of interest based on a marker (morphological, biochemical or DNA/RNA variation) pertinent to a trait of interest such as productivity, disease resistance, abiotic stress tolerance and/or quality, without necessarily looking at entire trait itself. Introgressing Sub 1 gene into Swarna, a popular rice variety in Eastern India, is how submergence tolerant Swarna-Sub 1 variety was created, which can survive full submergence for up to 14 days (STRASA, 2013). Central Rice Research Institute, in collaboration of International Rice Research Institute used MAS to create a new Swarna-Sub 1 submergence tolerant variety and released it in 2009.

Dr Roy recognized the need in Parida's farming zone of Orissa for submergence tolerant rice. He recalls that "what we found was a Turianbando village in Orissa, India that was a typical and chronically flood-prone area. Non-traditional rice variety which can withstand submergence or flood is something that farmers in this area desperately needed. Otherwise, flash floods and submergence keep affecting their rice crops, or even wipe out entire rice varieties they plant if the severity of this long and baffling natural phenomenon is too high. I thought if we try in this area to help farmers get good crop notwithstanding arrant crop killing weather phenomena that would be a real boon to these flood ridden Orissa farmers" says Dr J.K. Roy.

He approached Parida to try planting the new variety, but Parida was hesitant to commit too much land to what he perceived as an uncertain experiment. He accepted only 5 kg of rice seed to plant on small patch. As expected, the floods came. When the water receded, everyone including Parida, who was the only farmer in the region who had accepted Roy's proposal was astounded with what they saw, the Swarna-Sub 1 Rice variety grown from Roy's seed was still standing and rigorous unlike all other varieties on other farmers' paddies, and yielded as if it has never been struck by floods. Other varieties were all gone or severely affected. Not only farmers from the same village, but many others from distant villages came to see Parida's miraculous rice and wanted to have his seeds of "magic" variety. Parida left some for his own planting needs, and shared the rest with others. Ever since, the journey of this flood tolerant variety that can survive 15 days of submergence.

Now, says Parida, "If the scientist comes to our village, we will welcome them in our traditional way, using the same rituals we offer for God, because he is no less than a God, because he is no less than a God for us who has shown us food security."

Pramila Mohapatra, a local woman farmer shares Parida's positive experience and echoes his appreciation. "Since we started planting Swarna-Sub 1, we are getting better results from this field. Now we are able to provide sufficient food to our family. The extra paddy we can sell in the market and use that money to buy vegetables and new clothes. This was only possible after we started cultivating this rice".

Building on the success Swarna-Sub 1 and the confidence farmers now have in innovative rice cultivars, scientists are now working to reach more farmers and develop more stress tolerant varieties. The next goal is for varieties resistant to both submergence and drought.

What are agricultural biotechnologies?

The term 'agricultural biotechnology' tends to bring to mind genetically modified crops, with all the controversial connotations that may go with them in the public mind. However, there are numerous examples of non-controversial agricultural biotechnologies that are of direct and immediate benefit to smallholder farmers, livestock keepers and aquaculturists, such as:

- Traditional biofertilizers and biopesticides that are common components of organic agricultural systems
- Breeding tools such as marker-assisted selection in crops, livestock and fish
- Clonal propagation in trees and increasingly in livestock
- Use of artificial insemination and embryo transfer to increase productivity of local or international breeds of livestock
- Disease diagnostics and vaccines, especially in livestock and aquaculture
- Use of genome mapping and associated techniques in characterizing and conserving plant, livestock, forest and aquatic genetic resources

Many of these are directly applicable and beneficial to small-scale farmers, foresters and aquaculturists. Others, such as new breeding technologies like gene editing and cisgenesis – transfer of genes from closely related organisms – offer the prospect of speeding up development of new varieties of crop plants, trees and animals, including fish. Such tools are particularly valuable for breeders working with trees and livestock, which have long generation intervals, which means that conventional breeding can be too slow to deal with rapidly changing circumstances, such as climate change and changes in disease patterns linked to it. Cisgenesis and techniques such as embryo rescue are invaluable in breeding bananas, for example, which are largely infertile and hence difficult to improve using traditional crossbreeding approaches. Development of all-male lines of farmed fish would greatly increase the productivity of fish farms and simplify production systems.

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Untapped potential

Agricultural biotechnologies – ranging from simple, traditional applications like biofertilizers and biopesticides to the latest-generation tools like gene editing – have the potential to dramatically boost agricultural production in the Asia-Pacific region. The recent *Study*, found that a wide range of these are currently being used in the crop, forestry, livestock and fishery/aquaculture sectors in the region, although most countries are employing only low- and medium-level technologies. Many countries have weak policy and enabling environments, do not have adequate strategies for their application and lack the capacities to develop and implement such biotechnologies, including lack of trained people and lack of investment. Lack of policy incentives, combined with market constraints, limit engagement of the private sector, leaving the public sector as the principal actor in the development and delivery of agricultural biotechnologies.

The study found that, in particular, small island states and many least developed and developing countries, such as Afghanistan and Mongolia, are yet to benefit appreciably from the biotechnology revolution. In contrast, several larger and emerging economies, such as China, India and the Republic of Korea, are using biotechnology extensively in all four sectors, while Australia, New Zealand and Japan are at the forefront of development and application of agricultural biotechnologies in many areas.

Examples of low-, medium- and high-level agricultural biotechnologies covered in the survey

Sector	Low-level technologies	Medium-level technologies	High-level technologies
Crops	Biofertilizers Biopesticides	Tissue culture Marker-assisted selection	Genetic modification Gene-editing techniques
Livestock	Artificial insemination Pregnancy diagnosis Probiotics	Embryo transfer *In vitro* fertilization	Cloning Gene-editing techniques
Forestry	Biofertilizers Biopesticides	Tissue culture Marker-assisted selection	Genetic modification Gene-editing techniques
Fisheries/aquaculture	Polyploidy Probiotics	Marker-assisted selection Sex reversal	Genetic modification

Application of biotechnologies strongest in crops, weakest in forestry and fisheries/aquaculture

Several countries in the region have invested extensively in development and implementation of agricultural biotechnologies across agricultural sectors, including China, India and the Republic of Korea. These regional powerhouses offer lessons for other countries in the region as they develop their biotechnology sectors.

A wide range of biotechnology tools are already in use in the crop sector across the region, ranging from low-level technologies such as biofertilizers and biopesticides to high-end applications such as gene editing. Tissue culture and marker-assisted selection are widely used and has benefitted smallholder farmers extensively, especially in the horticulture sector in India and in Sri Lanka. In the livestock sector, molecular tools have been widely deployed in genetic characterization and conservation and in breeding for increased productivity and disease resistance in cattle, chicken, pigs and other species. Diagnostic tools and vaccines developed using biotechnologies are extensively used, although only about eight countries in the region have the capacity to develop them. Several countries in the region are conducting fundamental research in animal biotechnology, including Australia, China, India, Iran (Islamic Republic of), Japan, New Zealand and the Republic of Korea.

Few countries are employing biotechnologies in their forestry sector, and then only low-level technologies such as biopesticides and tissue culture. Genetic modification of trees is largely restricted to research; only China has approved cultivation of a GM tree (*Populus* species).

Biotechnologies have huge potential in the fisheries/aquaculture sector, but remain largely unused.

An overview of the regional situation

Key gaps in the application of agricultural biotechnologies:

- Uneven adoption of technologies across countries and across sectors. This is a cause for concern as this indicates that the technologies might not have been adopted by those who need them most.
- Underutilization of the potential in some technologies such as tissue culture and marker-assisted selection indicates that issues such as technical difficulties, lack of extension and lack of capacity have to be addressed. In livestock, fisheries and aquaculture a major gap is lack of capacity to adopt medium- and high-level technologies. An important issue is whether the public sector and extension services are well-enough equipped to harness the potential of technologies.
- Lack of policy measures to promote biotechnology in different sectors.
- Lack of sector-specific strategies.
- Lack of collaborations and issues in technology absorption appear to be important gaps, although these aspects were not studied in detail.

Key capacity gaps

- Lack of institutional capacity and lack of human resources in terms of both numbers and expertise and skills are the major gaps that constrain overall capacity in biotechnologies in the region.

  Reliance on collaborations to compensate for lack of internal capacities. Although there are international collaborative programmes, detailed in the *Study*, in the region, they alone are not sufficient to address all weaknesses in capacity in the region and have to be expanded in scope and coverage.
- Capacity is lacking in both the public sector and the private sector. Public-sector capacity has to be enhanced through public investment, while development of the private sector's capacity can be encouraged through policy interventions.

Realizing the potential of agricultural biotechnologies

Realizing the potential of biotechnologies to support sustainable food systems and nutrition and to achieve Zero Hunger in the Asia-Pacific region will require concerted efforts at many levels.

Governments will have to develop and implement policies and strategies that promote development and uptake of these applications within both the public and the private sector. Many countries already have strong enabling environments, and much can be done to share knowledge and experience with those countries that do not yet have this in place.

Much has already been achieved through collaborative programmes among countries within the region and with regional and international partners, but countries need to do more to ensure that they have the home-grown talent needed to take full advantage of advances in agricultural biotechnologies. The public sector will need to invest more in development of human resources capable of contributing to the development and adoption of agricultural biotechnologies and in the institutions and infrastructure needed to support this. Public-private partnerships will be crucial to the success of these efforts.

Many of the smaller countries in the region do not have the resources to pursue such approaches on their own, and existing regional mechanisms for collaboration and technology transfer will need to be strengthened. International organizations like FAO and the International Fund for Agricultural Development will be important partners in these efforts.

Recommendations

- Create a knowledge platform on agricultural biotechnologies and associated policies and strategies to improve communication and networking, increase knowledge exchange and strengthen partnerships on agricultural biotechnologies.
- Focus on development of biotechnologies that address specific needs and practical problems facing smallholder farmers, foresters and aquaculturists to ensure applications are demand-based and applicable within existing production systems.
- Increase public-sector investment in the development and delivery of agricultural biotechnologies, particularly in education, training and extension.
- Promote public-private partnerships and south-south cooperation for agricultural biotechnologies to help developing countries to move a step closer to exploiting the benefits of agricultural biotechnologies for their needs.
- Promote technology transfer to and/or among Pacific countries to help overcome the constraints of geographic isolation and small market size in these countries.

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