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Chapter 5

Parallel sessions: People, policies, institutions and communities

5.1 Report of outcomes from the three parallel sessions dedicated to the theme of people, policies, institutions and communities

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As part of this theme, three parallel sessions were organized. The first parallel session was entitled "Social and economic impacts of agricultural biotechnologies for smallholders: Taking stock of the evidence and prioritizing future assessments."

The session looked at the impact of biotechnologies on agricultural productivity, environmental sustainability and socio-economic well-being. It also considered the role of evidence in policy-making. Nineteen case studies were discussed in consideration of applying non-GMO biotechnologies for smallholders, which could eventually assist policy-makers when deciding on potential interventions involving biotechnologies for smallholders in developing countries. Specific case studies and experiences from China and India were also discussed, with reference to both GMOs and non-GMO biotechnologies.

Through those case studies, five key lessons were learned:
1) Political commitment by national/local/state governments is critical for improving the productivity of smallholder enterprises and the livelihoods of smallholder farmers.
2) Financial support from donors and international agencies is indispensable for supplementing efforts.
3) Partnerships are vital for achieving results, particularly for translating research outputs into field outcomes and impacts.
4) Long-term national investments in both human capital and infrastructure for science and technology are critical.
5) Biotechnologies do not work in a vacuum, but are introduced into the fields of both researchers and farmers through integration of traditional knowledge and science-based considerations of applying innovative methodologies.

Despite the complexities of smallholder farmer production and farming systems, agricultural biotechnologies can represent powerful tools to benefit smallholder farmers given the appropriate conditions and enabling environment.

Continued investment in assessing the impact of biotechnologies on smallholders is needed to gauge their productivity, sustainability and welfare outcomes.

Participants recognized the importance of learning from the past and looking to the future through well-structured *ex ante* and *ex post* socio-economic assessments, and evidence-based analyses, long-term studies and credible counterfactuals that assess the cost of non-adoption of agricultural biotechnologies.

Participants also recognized the importance of taking an integrated and interdisciplinary approach to impact assessment, linking traditional knowledge to the process of impact assessment, and careful consideration of different perspectives towards biotechnologies and their applications.

Impact assessment will also be aided by active and global sharing of the scientific data and long-term financial support by donors and international organizations.

Finally, participants recognized that technology alone cannot solve the problems that small-scale farmers are facing, and that there is a strong need for strengthening rural education so that small-scale farmers can make informed choices.

The session concluded with the statement that the contribution of agricultural biotechnologies to effective and sustainable food systems and nutrition will require continued accumulation of evidence on their sustainability, productivity and welfare impacts based on well-designed social, economic and environmental assessments.

The second parallel session was entitled "Public policies, strategies and regulations on agricultural biotechnologies".

The session looked into public policies, strategies and regulations around agricultural biotechnologies, including GMOs. The five speakers discussed institutional structure, governance issues, health and food safety, environmental risks and issues around intellectual property rights (IPR) from the perspectives of the private sector, public sector, civil society and research institutes.

The session also considered the challenges faced by developing countries in developing national policies and strategies for biotechnologies and the importance of ensuring that the needs and capacities of smallholders are taken into account.

In many instances, it is not IPR *per se* that impede diffusion of agricultural biotechnologies in developing countries but rather lack of appropriate institutional frameworks. IPR are legal tools to arrange a licensing agreement; there are legal tools available to handle conflicts raised within IPR (for example, competition law and policies) which should be activated whenever needed.

The participants acknowledged that most developing countries needed to strengthen their institutional, regulatory and legal frameworks on the use of biotechnologies. At the same time, it was realized that many elements around such frameworks are actually common for conventional agriculture and breeding. Regulating the process and use of biotechnology is a challenge when compared with setting up end product based regulation schemes.

Furthermore, the following key points emerged from the presentations and the discussion on the presentations:

1) There is a clear need for a common understanding on vocabulary and definitions of the terminology used for agriculture biotechnologies (e.g. what is meant by GMO?) for an informed discussion. Presenters devoted time to discussing this need, highlighting that the term “agricultural biotechnologies” is broader than GMOs. Non-GMO biotechnologies have been used successfully in many developing countries.
2) GMO-related policies, however, seem to ignore the historic evolution of genetic engineering, whereas problems in the legal national definition of GMOs are on what is intended, what is unintended, what are the regulatory uncertainties and how to cope with potential risks.
3) The enabling environment for biotechnology is very much related to handling knowledge and so is very closely related to research and development (R&D). It should be acknowledged that the developing environment for agricultural biotechnologies is not the same as the one for conventional agriculture because technology is developing at a quicker pace for the former.
4) Elements of the enabling environment for agricultural biotechnologies should be the convergence of biological with other sciences, the higher investment requirements, more attention to IPR and biosafety issues and the changed role of the private sector in developing and using technologies.
5) Although it is not simple, agricultural research and technological policy should become integral parts of a country’s overall R&D agenda. Furthermore, policies should be decomposed to instruments addressing issues on access to knowledge and technologies and on instruments dealing with the use of technologies in specific production systems. Stakeholder participation in decision-making and in designing the enabling environment was thought to be of crucial importance.

Attention needs to be given to the dissemination of this knowledge and to the delivery systems in place. This issue was highlighted both in the presentations and in the discussion.

Consensus emerged on the lack of dissemination mechanisms so that scientific work reaches the final recipients, who are the farmers. The output of any research should become recognizable, affordable, locally available and readily understood and usable by smallholders, with short- and long-term individual and societal benefits and risks weighted and distributed fairly and transparently.

The third parallel session was entitled “Investing in biotechnology solutions through capacity development and partnerships”.

Partnerships have helped in adoption of new technologies. The establishment of regional bioscience facilities and technology platforms with the partnership of the International Livestock Research Institute and the New Partnership for Africa’s Development, leading to Biosciences eastern and central Africa (BecA) is clear evidence of this in the African region.

Strategies for dynamic policy choices like public–private partnerships (PPPs) are very important. Vigilance of the public sector would be very important along with partnerships between farmers and other stakeholders.

- Bt brinjal in Bangladesh and Embrapa’s partnership with BASF for herbicide tolerant soybean are examples.

- Water efficient maize for Africa (WEMA) is going to be another example for the African region.
- New technological choices with open-source tools combined with gene editing methods like clustered, regularly interspaced, short palindromic repeats (CRISPR), zinc finger nucleases (ZFNs) etc. provide new opportunities. This may be good news for smallholder farmers. It may help in opening new doors at much reduced cost. However, issues related to the precision of these technological choices are yet to be fully addressed.
- Mega-mergers in the agricultural biotechnology sector are a growing trend. With the entry of China's public sector, this trend is further energized.
- The time is ripe for a new generation of innovative PPPs and new agricultural biotechnology paradigms aimed specifically at the needs of small and marginal farmers, meeting food security and nutrition needs of poor and vulnerable groups.
- South–South cooperation is an important opportunity for wider adoption of biotechnology with concerns and modalities being discussed among the leading economies from the South. New dimensions of cooperation between North and South may also be explored. This can be North–South–North or North–North–South. Trilateral cooperation should be explored where it is relevant.

5.2.1 *Report of the parallel session*

Social and economic impacts of agricultural biotechnologies for smallholders: Taking stock of the evidence and prioritizing future assessments[12]

A wide range of biotechnologies have been developed and approved for commercial use in many developing countries. The session confirmed the importance of impact assessment to be the basis of consideration of applying agricultural biotechnologies for smallholders. Assessing the cost of non-adoption of agricultural biotechnologies was also emphasized as a strong need. The session was chaired by Sachin Chaturvedi (India) and co-chaired by Eduardo Trigo (Argentina).

New tools in biotechnology have the potential to increase the availability of, and access to quality foods in developing countries and play an important role in accelerating progress in the agricultural and life sciences. Gathering continuous evidence about biotechnology tools and products is essential for more sound policy design in the global food and agriculture system. It is essential to further explore the costs, benefits and trade-offs of these applications under real-world conditions. Three types of evaluations on the social, environmental, and economic impacts of biotechnologies are needed to concretize the evidence-based policy development: 1) lessons-learned approach of the looking-back evaluation; 2) forward-looking evaluation, with the construction of scenarios that explore the societal, economic and environmental gains and losses associated with particular biotechnologies; and 3) looking deep: gaining insights into the choices that farmers, firms, consumers and governments make with respect to biotechnologies. The science should look not only on the output frontier, but should also provide evidence on sustainability, productivity and welfare. Ultimately, this combination of real-world impact analyses translates into the basic foundation to consider biotechnology applications at the national, regional and global levels and provides key consideration factors for policy-makers to make informed decisions.

Nineteen case studies were discussed in consideration of applying non-GMO biotechnologies for smallholders, which could eventually assist policy-makers when deciding on potential interventions involving biotechnologies for smallholders in developing countries. Through those case studies, five key lessons were learned: 1) political commitment by national/local/state governments is critical for improving the productivity of smallholder enterprises and the livelihoods of smallholder farmers; 2) financial support from donors and international agencies is indispensable for supplementing national efforts; 3) partnerships are vital for achieving results, particularly for translating research outputs into field outcomes and impacts; 4) long-term national investments in both human capital and infrastructure for science and technology are critical; and 5) biotechnologies do not work in a vacuum, but are introduced into the fields of both researchers and farmers through integration

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[12] This report was prepared by Masami Takeuchi, Karin Nichterlein and Aikaterini Kavallari, the FAO rapporteurs for the theme of people, policies, institutions and communities.

of traditional knowledge and science-based consideration of applying innovative methodologies. Despite the complexities of smallholder farmer production systems and farming, the study results revealed that agricultural biotechnologies can represent powerful tools to benefit smallholder farmers given the appropriate conditions and enabling environment.

China has been maintaining more than 100 percent food self-sufficiency for many years. However, the current trend is that imports are exceeding exports and the rate of self-sufficiency has fallen slightly in the last few years. Domestic demand growth is exceeding the production growth and imports of many agricultural commodities continue to rise. Thus biotechnology is one of the major tools for China to meet the demands and to increase agricultural productivity and competitiveness, while reducing chemical uses, and improving farmers' welfare. In China, investment in agricultural biotechnology research has doubled every four years since the mid-2000s. The results have been impressive and China gained significantly from transgenic *Bacillus thuringiensis* (Bt) cotton and it is expected to gain much more from other crops, including maize and rice, derived from biotechnology. In China, biotechnologies will play ever-more important roles to feed the population. At the same time, there is a trend that more Chinese consumers are mindful of the topic of food safety; therefore the Government of China is actively conducting safety assessment of foods derived from biotechnology. Recent policy to facilitate commercialization of genetically modified (GM) maize in China has been a big step forward and will also have important implications for global biotechnology development.

In India, application of biotechnology in agriculture gained prominence with the cultivation of Bt cotton in 2002. Subsequently, 11 GM crops have been approved for ongoing trials. However, in spite of phenomenal progress in GMO production, the general public has been hesitant in introducing other GM crops, mainly due to failure to exhibit resistance against all pests, low crop yield, high cost of seeds, heavy dependence on seed companies, lack of a governmental mechanism to monitor safety measures and assess potential risks, inadequate biosafety studies, monopoly of a few multinationals and lack of transparency. Resolving such issues is important in India to achieve food security. Tissue culture is another important technology that is popular and commercially viable in India. Use of biofertilizers and biopesticides has also become popular during the last two decades. Biotechnologies have been used in genomic studies of Indian cattle and buffaloes to obtain better economic traits and in clonal propagation. Studies of microbes are active as these may help in recycling bio-waste and production of efficient vaccines. The agricultural biotechnology sector has gained significance in India through the change in policy to grow GM crops. Biotechnology is expected to have a major role in food security and rural prosperity.

Summary of the open discussion

Participants recognized the importance of learning from the past and looking into the future through well-structured *ex ante* and *ex post* socio-economic assessments, evidence-based analyses and long-term studies. To analyse the impact of biotechnologies on smallholders, social benefits for sustainability and welfare and opportunity costs with productivity and profits are the main elements for constructing the baseline of the assessment framework. Effective modalities for assessing the impact and assisting policy-making include: 1) foresight analysis; 2) linking traditional knowledge to evidence-based data through a global approach; 3) an integrated and interdisciplinary approach to impact assessment, linking traditional knowledge to the process of impact assessment; and 4) careful consideration of different perspectives towards biotechnologies and their applications. Furthermore, there is a strong need to strengthen rural education with the assessment results so that small-scale farmers can make informed choices.

Technology alone cannot solve the problems that small-scale farmers are facing. Long-term data analyses of the impact of biotechnologies in society as a whole, together with active and global sharing of the scientific data and financial support by donors and international organizations through strong partnerships are critical for developing countries to consider applying various agricultural biotechnologies.

The session concluded with the statement that establishing evidence for sustainability, productivity and welfare from assessments of social, economic and environmental impacts in smallholder farming systems is key in considering the role of agricultural biotechnologies in effective and sustainable food systems and nutrition. Credible counterfactuals that assess the cost of non-adoption of agricultural biotechnologies are also needed in such evidence-based studies.

5.2.2 Evidence-based policy-making: The role of impact assessment studies and their implications for agricultural biotechnologies

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Recent decades have seen an exciting increase in new tools and products that could accelerate the application of biotechnology to agriculture in developing countries. From genetic diagnostics, tissue culture, genetic modification and genome editing, to reproductive and vaccine technologies, nanotechnology, and synthetic biology – all of these technologies have the potential to increase the availability of, and access to, quality foods in developing countries and to improve the livelihoods of the rural and urban poor. In fact, scientists, businesses, governments and civil society organizations are already exploring technologies that increase crop and livestock yields, decrease production costs, reduce susceptibility to environmental stresses and improve the nutritional content of food crops.

The agricultural and economic impacts of several technologies in this broad category of biotechnology – for example, GM insect-resistant Bt cotton and maize – have already been the subject of extensive scrutiny at the farm, household and market levels. A large number of rigorous studies of these technologies find significant cost savings, yield improvements and reductions in pesticide exposure for farmers, including many who operate small and poorly-resourced farms.

There is also a range of innovative technologies – for example, tools that improve the efficacy and efficiency of plant breeding, livestock vaccine development or the propagation of planting materials – that have yet to receive much scrutiny. This is partly because these technologies are upstream process innovations that address scientific discovery and product development, rather than downstream product innovations that more immediately affect smallholders' farming practices and rural livelihoods. Nonetheless, we know these technologies play an equally important role in accelerating progress in the agricultural and life sciences.

Looking to the future, it will be important to continuously gather evidence about the full range of biotechnology tools and products in order to better inform policy design by developing-country governments and other actors in the global food and agriculture system. Well-informed, evidence-based policy design relies on rational, systematic decision-making to shape social, economic and scientific choices made by the state. Of course, evidence-based policy design does not occur in a vacuum. Careful attention must be given to the nature of evidence used in policy-making, how it is integrated into the policy-making process and the role of other influences on decision-making.

There is, however, general recognition that the use of rigorous evidence is essential to sound policy-making, particularly when the issues at stake concern agricultural growth, economic development and poverty reduction in developing countries.

Traditionally, published papers from the biophysical sciences have set the standard for credible and rigorous evidence. They evaluate new applications of biotechnology under carefully controlled conditions of a laboratory experiment or field trial. Yet this body of evidence is far from complete, which is why economists and social scientists are also asked to explore the costs, benefits and trade-offs of these applications under real-world conditions – where weather and price risk play a critical role, where individual and household characteristics are essential considerations, and where individual preferences, expectations and beliefs can further shape social and economic impacts. While their findings often support results from the biophysical sciences, they can also add nuance to the picture, or even call into question the best of good laboratory science.

Two types of evidence on the social, environmental and economic impacts of biotechnologies are increasingly needed to strengthen the evidence base around which public policies – laws and legislation, rules and regulations, public investments and expenditures, taxes and subsidies, and trade and investment regimes – are designed. The first is forward-looking evaluation, or the construction of *ex ante* scenarios that explore the societal, economic and environmental gains and losses associated with a particular biotechnology application or policy design relative to appropriate counterfactual scenarios. For example, a forward-looking analysis can be used to identify the varied impacts of a new labour-saving crop technology for large farmers, smallholders and landless labourers. It can also be used to understand the productivity losses associated with regulatory delays and uncertainty that impede the release of new biotechnology research tools to scientists or new biotechnology products to farmers. Rigorous foresight analysis of the impacts of both technologies and policies allows policy-makers to consider their policy options from a more informed position, particularly at high levels of aggregation – global, national or landscape.

The second type of evidence relies on insights into the choices that farmers, firms, consumers and governments make with respect to biotechnology. Here, the science of individual and household decision-making has advanced considerably in recent decades. Economists and social scientists have access to more rigorous experimental designs and long-term panel data that allow them to identify complex causal – not just correlated – relationships between technology or policy interventions on the one hand, and productivity, sustainability and welfare outcomes on the other. Moreover, a growing convergence among disciplines that study the behavioural dimensions of decision-making is increasing our understanding of how individuals make choices about new technologies, how they value competing choices and how they learn about these technologies and choices over time.

These same scholars are applying increasingly sophisticated tools of analysis to the study of how the interactions between firms in the market for innovation in agriculture can influence the availability and price of new biotechnologies for farmers and consumers, and how government interventions in those markets can help or hinder innovation processes around biotechnology.

More rigorous evidence on these micro-level dimensions not only improves the accuracy of our forward-looking analyses, but also helps us to better identify what works under real-world conditions.

Ultimately, this combination of real-world evidence and forward-looking analysis translates into insights about biotechnology applications at the landscape, national or global scale, taking into account both patterns of technological change and social, environmental and economic impacts. When combined with historical perspectives and qualitative insights from stakeholders, these analyses and insights can provide the critical evidence needed for developing countries to improve the policy, regulatory and investment choices that influence the development and introduction of biotechnology applications. Greater commitment to the use of science-based evidence in policy-making can, in turn, help overcome ideology and advance the technological opportunities available to the world's 500 million farmers and seven billion consumers.

5.2.3 Lessons learned from case studies of applying biotechnologies for smallholders

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FAO promoted the study of 19 cases in which biotechnologies were applied to serve the needs of smallholders in developing countries. The case studies, selected after an open call for proposals, were prepared by scientists directly involved in the initiatives who were asked to describe the background, achievements, obstacles/challenges encountered, factors for success (or failure), impacts and lessons learned from their case study. The cases covered different world regions, production systems, species and underlying socio-economic conditions in the crop (seven case studies), livestock (seven) and aquaculture/fisheries (five) sectors. Apart from one on West Africa, the studies focused on a specific initiative within a single country. More details on the different case studies are provided in Ruane et al. (2013).

A wide range of biotechnologies was used in the case studies, including some of the traditional methods such as fermentation and artificial insemination (AI), as well as several advanced techniques involving sophisticated DNA and genetic analyses. GMO applications were not included because of the highly polarized debate they normally engender. By dominating the debate, this has prevented serious consideration to be given to the potential contributions that the many non-GMO biotechnologies can make to sustainable development and food security (Ruane and Sonnino, 2011). Most of the case studies involved application of a single biotechnology in a single crop, livestock or fish species, with the objective of overcoming biological and technological constraints to increase productivity, improve people's livelihoods, tackle diseases and pests, expand market opportunities through diversification and value addition, and to conserve genetic resources.

The case studies yielded many varied and valuable outputs, in terms of the scientific and technical knowledge, capacities and products. While not all cases provided evidence of widespread adoption by farmers, some biotechnologies were adopted on a large scale. For example a new high-yielding and downy mildew resistant hybrid of pearl millet, developed in partnership by the International Crops Research Institute for the Semi-Arid Tropics (ICRISAT), Indian agricultural universities and UK research institutes, was released in 2005. By 2011, cultivation of this variety had spread to almost 900 000 ha in northern India, bringing greater food security to about two million people. In rice,


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the International Rice Research Institute (IRRI) and Indian research institutes released in 2009 the Swarna-Sub1 variety, highly tolerant to submergence and lodging. In flood-affected areas, it was able to produce 1–3 tonnes per hectare more than other previously grown varieties. During the 2012 wet season, Swarna-Sub1 was cultivated by over three million farmers, covering over one million ha.

In aquaculture, the Jian carp, developed in China by within-family genetic selection and gynogenesis (a reproductive technology resulting in all-female carp offspring which have received genetic material only from their mothers), is now grown on about 160 000 farms and is responsible for over 50 percent of the total common carp production in the country.

The rate of adoption indicated in other case studies was less wide but nonetheless meaningful to the farming communities concerned. For example, a community-based foundation provides production-related veterinary services, including AI, to around 3 000 smallholder dairy cattle farmers in Bangladesh. The initiative increased milk production and farmers' income and generated employment.

From all the case studies, ten general and interrelated lessons have been drawn which can be used to inform and assist policy-makers when deciding on potential interventions involving biotechnologies for smallholders in developing countries. These are:

1. Commitment by national and/or state governments was critical for improving the productivity of smallholder enterprises and the livelihoods of smallholder farmers.
2. Financial support from bilateral and multilateral donors and international agencies was indispensable for supplementing national efforts.
3. International and national partnerships were vital for achieving results, particularly for translating

research outputs into field outcomes and impacts. The case studies provided numerous examples of successful partnerships within the public sector, between public and private sector entities, and involving non-governmental organizations (NGOs) and community-based approaches.

4. Long-term national investments in both human capital and infrastructure for science and technology were critical components of the recipe. The case studies involved continuous agricultural research efforts that extended over 15–40 years.
5. Biotechnology approaches did not work in a vacuum, but were introduced into both the research mix and farmers' fields through appropriate integration with other sources of science-based and traditional knowledge.
6. The diffusion of genetic resources, techniques and know-how across national and continental boundaries was an essential ingredient of most case studies.
7. Intellectual property issues did not constrain research or the production or use of biotechnology innovations in the case studies examined here.
8. Products generated through the biotechnologies described did not need to conform to new biosafety or food safety regulations or standards. Without entering into the merits of such regulatory issues, this clearly represents an advantage for the development and use of products from the biotechnologies described in these case studies over those developed using genetic modification.
9. Some case studies demonstrated clearly that development projects involving smallholder farm production systems can be dynamic and risk-prone. Stakeholders need to be aware, and anticipate, that the system may evolve quickly because of issues like changes in plant or animal disease dynamics or changes in farmer and consumer preferences.
10. Planning, monitoring and evaluation of biotechnology applications were weak and should be strengthened. Most of the studies provided no information concerning the costs or benefits (in terms of production, productivity or financial returns) or changes in livelihoods. To improve both the planning and management of future projects, these aspects should be given much higher priority.

These case studies demonstrate that despite the complexities of smallholder farmer production systems, agricultural biotechnologies can indeed represent powerful tools to benefit smallholder farmers given the appropriate conditions and enabling environment.

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5.2.4 Impacts of agricultural biotechnology and policies: China's experience

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Facing enormous constraints in natural resources, China's ability to feed its growing population with rising income is impressive. Per capita water availability is only one-fourth of the world average and arable land accounts for only 8 percent of world total, but China supported over 20 percent of the world's population and had been a net food exporter before the mid-2000s. However, total food demand growth has surpassed production growth thereafter, which resulted in a fall of overall food self-sufficiency to 96 percent in 2014. Most imports have been soybeans and feed grains (e.g. maize and other coarse grain) for livestock production.

China's food imports are expected to rise as demand growth is expected to exceed production growth for many agricultural commodities in the future. In the past, increased food production has been at the expense of sustainable development. Recent rising costs of production due to rising wages have resulted in less competitiveness of China's agriculture in the global market. Under these backgrounds, China has been looking at all potential measures to increase its agricultural production in more sustainable ways.

Among many efforts, biotechnology is considered as one of the major tools by the national leaders to boost China's agricultural productivity and ensure national food security. After China initiated its agricultural biotechnology programmme in the mid-1980s, public investment was doubled every four years between the late 1990s and the mid-2000s. Since 2008, Chinese R&D on GM crops and animals has been further spurred by US$3.8 billion of new funding from the National GM Variety Development Special Programme (GMSP) for the period 2008–2020. By 2010, there were more than 13 000 researchers working on agricultural biotechnology, including GM plants, animals and micro-organisms. By 2015, a number of GM crops have been issued with production safety certificates, though major GM crops have not been approved for commercialization.

Bt cotton is one of the most successful cases of GM technologies in China. After its commercialization in 1997, about 7.1 million small farmers adopted it by 2009, and now Bt cotton accounts for more than 85 percent of the total cotton area in China. Our empirical studies show that the impacts of Bt cotton have been impressive. On average, Bt cotton increased cotton yields by 9.6 percent, reduced pesticide use by 34 kg/ha, reduced labour input by 41 days/ha and, despite higher seed costs, net profit increased by 1 857 yuan (or about US$25) per ha. Our surveys of randomly-selected farm households in the experimental villages show that the households which cultivated Bt rice, when compared with households cultivating non-GM rice, small and poor farm households, also benefitted significantly from GM rice adoption through both higher crop yields and reduced use of pesticides. Moreover, both Bt cotton and Bt rice also contributed to improved health of farmers by reducing the probability of farmers suffering pesticide-related morbidity during the crop growing season.

The model simulations further show that the economic-wide impacts of GM crops are substantial. Annual gains from Bt cotton and Bt rice reached respectively US$1.1 billion and US$4.2 billion, which already exceeds the costs of total investment in agricultural GM R&D in China. Moreover, the commercialization of GM crops will significantly increase China's maize and other food production and therefore raise food and feed self-sufficiency levels in the future.

However, the rising debate on the safety of GM food has largely changed the consumers' attitudes toward GM food in China. Our surveys show that the percentage of urban consumers who perceived such food as unsafe for consumption increased by more than 30 percent in the period 2002–2012. Major shifts have occurred after 2010, one year after China issued the biosafety certificate of production for Bt rice and phytase maize. The public concerns on GM food have obviously affected China's policy on the commercialization of GM technology after the late 2000s. However, given the significant socio-economic impacts of GM technologies, China has re-emphasized the roles of biotechnology in ensuring the nation's food security in recent years. The national leaders have decided to take the three-step development strategy: moving from non-food (e.g. fibre) to indirect food (e.g. feed), and finally to direct food (e.g. rice and wheat). Under this new strategy, China is expected to commercialize its GM maize in the very near future.

The presentation ended with four remarks: 1) China has invested significantly in GM technology, and the progress has been impressive; 2) China has also gained significantly from Bt cotton commercialization, and will gain much more from the commercialization of other major GM crops such as maize and rice; 3) GM technologies will play more important roles in improving agricultural productivity, ensuring food security and improving farmers' welfare; and 4) recent policy to facilitate commercialization of GM maize is encouraging and will also have important implications for global biotechnology development and global trade in the future.

5.2.5 Socio-economic impact of agricultural biotechnologies for smallholders in India

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Biotechnology for improving agricultural production

Application of biotechnology in Indian agriculture gained prominence with the cultivation of transgenic Bt cotton crops in 2002. Since then, India has taken the lead in exploring the potential of biotechnology on various fronts. The biotechnology programme in agriculture includes molecular mapping of genes of important plants, marker genes for selection of quality traits, development of transgenic crops, tissue culture for plant propagation, biofertilizers, biopesticides, vermicomposting, biodegradation of wastes and toxic substances, and mushroom production. With regard to transgenic crops, the objectives of breeding new GM crops were: to increase crop yields, improve product quality, increase nutritional values, reduce biotic stress, improve tolerance to abiotic stress such as drought, frost, heat, salinity, herbicides, and produce plant-based pharmaceuticals.

Genetically modified crops

When the genetically modified Bt hybrid cotton was introduced in 2002, 55 000 farmers cultivated it on 30 000 ha. There was an initial setback because of certain concerns such as low yield, non-resistance to sucking pests and high cost of inputs. With the rectification of these problems, Bt cotton was widely accepted across the country. In 2014, 7.5 million farmers were engaged in cultivation of Bt cotton on 11.6 million ha, covering 96 percent of the total area under cotton production, using 1 100 varieties; more than 50 percent of the farmers were small landholders. Indian cotton production increased from 13 million bales in 2002 to 40 million bales in 2014 enhancing the income of farmers from 300 percent to 400 percent. Since the cultivation of Bt cotton, Bt cotton seed oil and Bt cotton seed cakes have entered the food chain in India. In 2007, the Government of India allowed the import of glyphosate tolerant GM soybean oil and canola oil to meet the growing demand for edible oils. Presently, India ranks fourth among GM crop-producing countries in the world.

However, India has been very hesitant in introducing other GM crops, mainly due to failure to exhibit resistance to all pests, low crop yield, high cost of seeds, heavy dependence on seed companies, lack of a mechanism to monitor safety measures and assess risk, inadequate biosafety studies, monopoly of a few multinational corporations and lack of transparency. However, with the change in the government in 2014, 11 new crops have been approved for field trials. These include corn, rice, mustard, wheat, sugarcane, groundnut, brinjal, okra, cabbage, cauliflower and tomato. A large number of public and private research institutions have taken up studies on identification of marker-assisted genes and the development of new transgenic crops and varieties.

Tissue culture

Presently, India is producing over 1 900 million plantlets every year particularly for cultivating horticultural, aromatic, medicinal and forestry crops. Tissue cultured plants are very well accepted by small farmers due to assured quality and timely guidance to adopt good production practices.

Biofertilizers and biopesticides

During 2012–13, over 0.5 million tonnes of biofertilizers were produced while the potential is 2.5 million tonnes/year. Presently, the biofertilizers under commercial production are *Rhizobium, Azotobacter, Azospirillum, Herbspirillum, Azolla* and blue green algae species, *Pseudomonas* and *Bacillus* species, *Frateuria* species and vesicular arbuscular mycorrhizae (VAM).

Commercial production of biopesticides such as biofungicides, bactericides, bioinsecticides and bionematicides has also been undertaken by the private sector for crop protection. These products have been very well accepted by farmers due to their low cost, easy availability, safety and effective control.

Biotechnology for animal husbandry

Use of frozen semen for breeding cattle and buffaloes since mid-1970s has already created a white revolution in India. Indeed, BAIF was the leader in taking this technology to small farmers across the country. India has been successful in clonal propagation of buffaloes. However, the major research focus is on genomic studies of Indian cattle and buffaloes to identify genes for economic traits and marker-assisted selection for productivity enhancement. Use of embryos for bull production, karyotyping for screening of cattle against genetic disorders, and use of sexed semen for producing female milk animals are the other initiatives which are likely to make significant impacts on the earnings of small farmers. Selection of thermostable microbial strains for production of efficient diagnostics and vaccines is another area of priority. Technologies have been developed for efficient recycling of dung and biowaste through vermicomposting and biogas production using efficient microbes, which benefit small farmers who represent 87 percent of landholders in India.

Studies on identification and introduction of bacteria which can suppress methane production in the rumen to improve feed efficiency while reducing the emission of greenhouse gases, need greater attention.

Conclusion

The biotechnology sector in India is generating an annual income of US$4 billion with agricultural biotechnology having a share of 14 percent. With the change in the policy to grow GM crops, agricultural biotechnology is bound to have a major role in food security and rural prosperity in India. Development of critical infrastructure to facilitate backward and forward linkages, and building the capacity of farmers to access appropriate technology and market information systems are critical factors for success.

5.3.1 *Report of the parallel session* Public policies, strategies and regulations on agricultural biotechnologies[13]

The session, chaired by Vimlendra Sharan (Embassy of India, Italy), looked into public policies, strategies and regulations around agricultural biotechnologies including GMOs. The five speakers discussed institutional structure, governance issues, health and food safety, environmental risks and issues around intellectual property rights (IPR) from the perspective of the private sector, public sector, civil society and research institutes. The session also considered the challenges faced by developing countries in developing national policies and strategies for biotechnologies and the importance of ensuring that the needs and capacities of smallholders are taken into account.

IPR were defined as the right to control the commercial exploitation of the projected subject matter for a specific period. Different forms of IPR exist, such as copyrights or patents, each having different requirements. It was noted that minimum standards for protecting IPR are set by the WTO Agreement on Trade-Related Aspects of Intellectual Property Rights (TRIPS) for signatory countries. The use of IPR in agricultural biotechnology has been controversial, especially in developing countries, and have been criticized for a variety of reasons including conflicts with farmers' traditional practices to reuse seed; excessively broad patent claims; patentability of genetic material and plant varieties; uncertainty regarding the scope of research use; high transaction costs; pricing of improved varieties (high because it has to cover costs of licensing of IPR); and appropriation of traditional knowledge and sovereign genetic resources. In many instances, it is not IPR *per se* that impede diffusion of agricultural biotechnologies in developing countries but other confounding issues are involved. IPR are legal tools to arrange a licensing agreement; there are other legal tools available to handle conflicts raised within IPR (e.g. consumer protection legislation), which should be activated whenever needed.

The participants acknowledged that most developing countries needed to strengthen their institutional, regulatory and legal frameworks on the use of biotechnologies. At the same time, it was realized that many elements around such frameworks are actually common for conventional agriculture and breeding. Regulating the process and use of biotechnology is a challenge when compared with setting up end product based regulation schemes.

Some key points which emerged from the presentations and discussion on the presentations were as follows:

There is a clear need for a common understanding on vocabulary and definitions of the terminology used for agriculture biotechnologies (e.g. what is meant by genetic modification, genetic engineering or a GMO?) for an informed discussion. Presenters devoted time to discussing this need, highlighting that the term "agricultural biotechnologies" is broader than GMOs.

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[13] This report was prepared with input from Masami Takeuchi, Karin Nichterlein and Aikaterini Kavallari, the FAO rapporteurs for the theme of people, policies, institutions and communities.

The regulatory approaches should take into account the historic evolution of genetic engineering but should also keep in pace with the more recent changes in technologies.

The enabling environment for biotechnology is very much related to handling knowledge and so is very closely related to R&D. We are living through a “knowledge revolution” and it should be acknowledged that the latest globalized environment for agricultural biotechnologies is different from the previous one for conventional agricultural research due to the pace of the development.

Elements of the enabling environment for agricultural biotechnologies should be the convergence of biological with other sciences, the higher investment requirements, the higher profile of IPR and biosafety issues and the changed role of the private sector in developing and using technologies.

Although not simple, agricultural research and technological policies should become integral parts of a country’s overall science and technology policy. As a result, such policies will be the effective foundation in developing practical instruments to facilitate access to knowledge and technologies. An effective consultation process to allow stakeholder participation in decision-making and in designing the enabling environment was thought to be of crucial importance.

Regarding GMOs, some stakeholders expressed concerns about their possible adverse effects on human health and the environment; their economic impacts for smallholder farmers; and the implications of IPR and the role of multinational biotechnology companies. Biotechnology policies need to encompass aspects related not only to the safety of biotechnology products but also to their ownership.

To ensure adequate and effective policies are developed and communicated, the stakeholders who are likely to be affected (positively or negatively) by the relevant biotechnologies should be consulted. Key questions should be addressed during this process, such as whether the biotechnologies will be used directly by the farmer or by a specialist acting on his/her behalf; what practices are needed for the introduction of the new technologies?; what do people know and what inputs can they access?; what skills are required and how can they gain them?; if a redistribution of power, income etc. is involved, who will benefit and how can the losers be compensated?

Special attention needs to be given to the dissemination of technologies and knowledge and to the development of efficient delivery mechanisms and seed systems. There was consensus regarding the importance of having a functional delivery system for biotechnology so that the outputs of scientific work do not remain on the shelf but actually reach the final recipients, i.e. the farmers. It was noted that the importance of delivery systems was often underestimated. The central role that the private sector can play in delivery systems was underlined, including through stewardship to ensure that a GM product contains the relevant trait in successive generations. The outputs of any research should become recognizable, affordable, locally available and readily understood and usable by farmers including smallholders, with short- and long-term individual and societal benefits and risks weighted and distributed fairly and transparently.

International standards and agreements relevant to policy-making and regulation of biotechnology are important. For example, a representative of the Secretariat of the International Plant Protection

Convention (IPPC) informed participants that international standards are developed, negotiated and agreed by 182 countries under the IPPC framework, and that one of the standards specifically provides guidance for assessing the potential risks of living modified organisms that could affect plants and their ecosystems.

The session closed with the Chair noting that: "Biotechnology, like any other technology, gives us the power. But it does not and cannot tell us how to use that power". Designing appropriate policies can be facilitated, but at the end it is the responsibility of the governments themselves to put them in place and to ensure they work for the benefit of its citizens.

5.3.2 The role of intellectual property rights in enabling or impeding the application of agricultural biotechnologies in a developing country context

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International legal framework for intellectual property rights (IPR)

IPR bestow on the owner the right to control commercial exploitation of the projected subject matter for a specified period of time. Different forms of IPR exist such as copyright, patents, trademarks and plant variety protection (PVPs), with each having different requirements. The exclusionary rights conferred by IPR are typically justified in economic and policy terms as being essential to reward innovation which would otherwise not occur in the absence of such rights.

The WTO Agreement on Trade-Related Aspect of Intellectual Property Rights (TRIPS) sets down minimum standards for protecting IPR which signatory countries are required to implement through national legislation. With 162 signatories, TRIPS-driven harmonization facilitates global trade across industries in which IPR operate as the common bedrock across industries, driving innovation and diffusion of technologies in developed and developing countries alike. Patents and PVPs in particular are considered to be key drivers of innovations in agricultural biotechnology as they allow recoupment of the substantial investment in research required to develop novel inventions and plant varieties.

IPR impeding the diffusion of agricultural biotechnologies

The use of IPR in an agricultural biotechnology context is not without controversy, particularly in a developing country context. Critics claim that far from facilitating access and diffusion, the increasing fragmentation of IP ownership from upstream agricultural research inputs and production technologies to downstream improved plant varieties and agricultural inputs for use in cropping systems collectively raise barriers to access and impede dissemination. This proliferation of IPR also increases the threat of infringement such that in a developing country context IPRs are often accused of favouring the market-expansion interests of corporations at the expense of farmers and consumers. Criticisms concerning IPR-related issues are also broad and include, for example, conflicts with farmers' traditional practices of reusing seed, excessively broad patent claims, patentability of genetic materials and plant varieties, uncertainty regarding the scope of research use, high transaction costs, pricing of improved varieties as a result of licensing of IPR, and appropriation of traditional knowledge and sovereign genetic resources.

IPR in agricultural biotechnology create a complex landscape to navigate and while there is certainly substance in many of the critiques raised, in many instances it is not IPR *per se* that impede diffusion of agricultural biotechnologies in developing countries. Often confounding issues are involved such as institutional familiarity with IPR, increased transactions costs, and regulatory/stewardship challenges. The presentation will draw examples from the CGIAR to contrast the role of IPR with these confounding factors as an impediment to diffusion.

IPR enabling the diffusion of agricultural biotechnologies

Global harmonization and strengthening of IP protection in recent decades has been credited with attracting an increase in private sector investment in agriculture-related research and development, and a surge in innovation leading to improved plant varieties, agricultural chemicals and production technologies. Agricultural biotechnologies have transformative potential in a developing country context and an effective IPR framework not only encourages home-grown innovation, it also provides a framework for catalysing technology transfer. Permissive licensing of IPR plays an important role in the local adaptation and diffusion of agricultural biotechnologies and the presentation will draw examples from the CGIAR to highlight IPRs as an enabler for diffusion.

Developments concerning IPR-related issues and diffusion of agricultural biotechnologies

Future developments concerning a number of IPR-related issues and trends have the potential to effect the diffusion of agricultural biotechnologies. These include the following and will be covered in the presentation if time permits:

- Humanitarian licensing and the rise of "open-access" frameworks;
- Increased patent activity and the potential for patent thickets/pools;
- The expiration of patents for GM traits and the potential for a generics market;
- Prior Informed Consent and Mutually Agreed Terms associated with access and use of genetic resources under the Nagoya Protocol (potential for reach through for commercialization);
- Differentiated regulatory approach for transgenic and cisgenic technologies;
- Increasing concentration of the agricultural biotechnology market.

5.3.3 Biotech policy: The need for historical perspective and context

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Introduction: A bit of essential history

Modern biotechnology is a collection of technologies, or tools, that are based on the use of cells and biological molecules. All are rooted in and derived from earlier biology-based tools that allowed humans to use and modify living organisms, both multicellular and single-celled, for centuries. At first, our manipulations of organisms were hit-and-miss ventures. However, as scientific knowledge of living organisms grew, our use and modification of them became more directed and precise because we better understood the biological bases of the processes we wanted to control and the changes we hoped to make. As the reductionist approach to biology led to an understanding of biochemical mechanisms, the evolution of our science-based use of organisms reached a point where we understood our manipulations at the molecular and cellular levels. This has allowed us to capitalize on unique properties of life at the molecular and cellular levels: its extraordinary specificity and its "oneness."

The evolutionary transition from poorly-informed use of whole organisms to directed and predictable manipulation is seen most easily in the evolution of crop plants. Until approximately 8500 BC, all of the plant material people used came from wild, gathered plants. Around that time, they began to save seeds and intentionally plant them rather than relying on the plant's mechanisms of random seed dispersal. Thus the first technological revolution – agriculture – was born. Once they recognized plant offspring resemble their parents, they began to save seeds from certain plants with traits they valued. As soon as humans started planting certain seeds and not others, they unknowingly began to alter the genetic make-up of the wild plants they had been gathering. Our ancestors genetically transformed wild gathered plants to domesticated crops by trial and error, relying only on the minimal understanding they had amassed through experience. Humans were stuck in the "artisan seed selection" stage for thousands of years because they understood nothing about the biological processes they were relying on: seed production and trait inheritance. They were limited to selecting the best seeds from whatever nature provided. Reaching the next level of crop improvement meant exerting control over the type of seeds produced. Scientists learned how plants reproduce in the 1600s, and soon thereafter, farmers began incorporating desirable traits into crops by intentionally cross-pollinating certain plants by hand. Hand-pollination, which limited seed production to the best plants, along with selection of certain offspring for next year's planting greatly accelerated crop genetic improvement. Yields increased as farmers developed crop varieties specifically adapted to local conditions. Taking control of plant reproduction also allowed them to create crops that would never have occurred in nature, because they began overriding some of nature's restrictions on cross-pollination.

The next stage in science-based plant breeding was made possible by Mendel's elucidation of the laws of trait inheritance. Armed with a fundamental understanding of genetic mechanisms provided by Mendel's work, farmers and plant breeders now knew they could cross well-adapted cultivars to another plant with a desirable trait, no matter how inferior or poorly adapted, without fear of losing the genes in the superior, well-adapted line and replacing them with the inferior's gene. After creating a hybrid plant whose genetic make-up consisted of half superior and half inferior genes, they could cross the hybrid to the superior line for a number of generations. Plant breeders began to look for desirable traits in cultivars from all over the world and in the ancestral, wild plant of the crop in question and its relatives. They developed a number of laboratory techniques that allowed them to hybridize crops and plants that would never have been able to interbreed in nature. Many of these "wide crosses" involved plants belonging to different species. In some cases the amount of genetic difference between the crop and other plant was even greater, because breeders began crossing plants in different genera. For example, bread wheat contains genes from at least ten different species in six different genera.

Plant breeding and regulatory policy

The long history of genetic modification of plants has not received the attention it deserves in policy discussions surrounding "GMOs" an ill-defined term that means different things to different people.

By neglecting the long history of genetic modification through interspecific and intergeneric breeding, as well as mutagenesis, many definitions of "GMOs" drafted by governmental bodies inadvertently capture thousands of varieties of crops that were in the food supply many decades before the development of genetic engineering in the 1980s. Others capture processes that occur regularly in nature. The governments opt to either ignore the crops genetically modified by other means, even though they are captured by the definitional scope of the regulation, or they are forced to add on a list of exemptions. It goes without saying that neither approach is based on risk, leading to regulatory systems all over the globe in which the risk of the product is uncoupled from the degree of regulation.

Plant breeding and intellectual property (IP) protection

The history of plant breeding has not been ignored in the development of IP protection. In the United States of America, laws passed in 1930 and 1970 grant IPR to various categories of plants developed by plant breeders. And later a judicial decision granted even broader protection to new plant varieties. Although many people associate IPR issues with "GMOs", in many countries IPR for plants preceded the development of recombinant DNA techniques. In addition, although people assume that only the private sector in the United States of America protects IPR in its background germplasm and biotechnology traits, public sector institutions also seek patents or plant variety protection certificates for new varieties that they develop. In addition, public institutions in the United States of America also seek compensation through the courts if their IPR are not respected.

The *act* of patenting is not unethical. It is what the patent holder does with the patent that raises concerns about ethics and values. A public institution can pursue a patent or plant variety protection for a new crop cultivar and then provide access, free of charge, to any entity it chooses.

Summary

The issues most people consider to be problems of "GMOs" are not unique to agricultural biotechnology but, instead, are inseparable from all forms of agricultural production. Whether the issues are socio-economic, legal or biological, if modern biotechnology and "GMOs" disappeared from the agricultural landscape today, the issues and problems would remain. This presentation focused on one of those persistent issues: intellectual property protection for plants in the United States of America.

A unique issue associated with agricultural biotechnology is the pre-market regulatory approval of genetically engineered crops. In the United States of America this form of regulation is added to the post-market regulatory oversight that covers all new plant varieties. A pre-market regulatory approval process has significant impacts on the types of crops that are developed and limits the entities that develop the crops to only those with sufficient resources. The opportunity costs associated with NOT developing certain crops will vary from one country to the next.

5.3.4 FAO must support peasants' selection and condemn the seizure of cropped biodiversity by patented genes

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To deal with biotechnologies, it is legitimate for FAO to call upon those using them in research and industry. It is, however, not legitimate at all that FAO almost exclusively relies on those protagonists when it comes to discussions on public policies and food policies, considering that a great number of farmers and civil society organisations opposed to the uncontrolled use of those technologies are not invited to make presentations, or marginally through the invitation I received. I suggest you do take into consideration the public position those organizations have released.

Transgenic plants have not met expectations. Most of them have been modified to tolerate herbicides. It has led to resistant weeds emerging, an exponential use of herbicides being more and more toxic with sanitary and environmental impacts of which farmers, their families and rural people are the first victims. Other transgenic plants produce insecticide molecules which also lead to resistant insects emerging and an already known agronomic failure. First victims are once again farmers having lost their harvests, often despite an additional use of chemical toxic insecticides. Genetic technologies used to produce those plants have generated many unintentional and unintended effects the industry is desperately trying to hide. The most obvious ones have been loss of crops or of product quality. The cotton sector in Burkina Faso has lost its rank in the market after having conquered it with much effort thanks to the quality of its fibre, a quality which has suddenly disappeared after GMO adoption: what's the point to increase yields if harvests can't be sold? Once again, small farmers are the first victims when the industries, even though they are accountable for such disasters, simply claim they cannot explain what occurred.

Transgenic seeds will keep on being of no interest for food security. Their cost, as the one of the required inputs, makes them suitable for the sole market of industrial crops for rich countries' need of feed and fuel, and for the emerging economy of biomass which confiscates the agricultural lands for non-food uses. Industry shows no interest in subsistence crops which provide three-quarters of food available on earth. Small farmers producing this food do not have the funds to buy GMOs and the required inputs for cropping them. GMOs only aim at taking over their lands to replace them by industrial monocultures for export.

Every time they are authorized, transgenic plants replace the huge cropped biodiversity coming from centuries of farmers' selection by a few patented varieties. Patented genes are moving from one field to another because of the wind, insects and agricultural tools which carry pollen and grains. They

contaminate peasants' seeds which then become counterfeit of industries' patents. In less than 20 years, 89 percent of maize and 94 percent of soybeans in the United States of America have become patented GMOs. This violation of farmers' rights forbidding them to use seeds coming from their harvests also prevents them from adapting their crops to climate changes. Those changes are not linear. At the time of seedling, no one knows what the weather will be like. It is useless to have a gene for drought resistance during tornados or exceptional flooding years. And vice versa. Resilience of crops facing worsening violence of climate shocks depends in the first place on their genetic diversity and local adaptation, not on one new gene or another patented in a laboratory. Only the peasants' selection in the fields working with seeds coming from local harvests, contribute to this adaptation. No solution can exist without them. Patents present in all GMOs are an inappropriate solution because they forbid peasants' selection.

Facing consumers' rejection of GMOs, industry has come up with new techniques of genetic modification and is now willing to have them escape GMO regulations. Those genetic engineering techniques aim at modifying *in vitro* the genes of cropped plants' cells. They undoubtedly produce living modified organisms as defined by the Cartagena Protocol on Biosafety. Under the pretext that some of those techniques leave no trace of the genetic material introduced in the cells to modify their genome, the industry is willing to have those plants not qualified as GMOs in order to escape the international rules of the Cartagena Protocol and the mandatory labelling, risk assessment and follow-up as imposed by many national regulations. It therefore tries to modify the GMO definition in order to reduce it to the insertion of recombinant DNA found in the final product. It is totally unacceptable that FAO endorses in its own publications this obvious violation of the only accepted international definition of GMOs given by the Cartagena Protocol.

This new move from industry is all the more perverse by allowing it to patent genes without distinguishing them from naturally occurring genes in peasants' seeds and in seeds stored in gene banks. The entire cropped biodiversity available is this way being brought under the control of a few multinationals owning the biggest patent portfolios. Peasants and small breeders cannot know if seeds they are using contain patented genes or not in order to protect themselves from those. This legal uncertainty speeds up, on the one hand, the extreme concentration of seed industry allowing three multinational companies to control more than half of the international seeds trade and, on the other hand, the disappearance of the huge diversity of peasants' seeds preserved and renewed each year by peasants in their fields. By making free the access to the information of genetic sequences of the entire phytogenetic resources of the Multilateral System of the International Treaty on Plant Genetic Resources for Food and Agriculture (ITPGRFA), the DivSeek programme violates the mandatory requirement for prior consent and sharing of benefits, supporting this new bio-piracy. ITPGRFA's complicity by collaborating with this programme is an unacceptable betrayal of the millions of peasants' trust who provided their seeds.

Via Campesina and civil society organisations supporting it expect FAO to immediately put an end to this new bio-piracy and to any kind of support of genetic modification technologies which only aim at allowing a few multinationals to patent and take over existing cropped biodiversity. On the contrary, FAO must support peasant organizations and researchers which are involved in collaborative peasants' selection programmes for food sovereignty and peasants' agroecology.

5.3.5 The challenges of developing national policies and regulations for agricultural biotechnologies: Reflections from cumulative experiences

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Biotechnology is transforming the processes and the products of agricultural research, as well as the institutional and economic environment of agricultural technology development and innovation systems. Advances in the biological sciences are producing quantum leaps in our knowledge about the way plants and animals grow and synthesize useful products, as well as the scientists' ability to transform them. In response to this, many developing countries have moved to design and implement promotional policies aimed at promoting the use of the new concepts both as research tools and at the level of specific production situations. Countries as diverse as Brazil, Colombia, the Dominican Republic, Jamaica, Mexico, Nicaragua and Paraguay in Latin America and the Caribbean; Namibia, South Africa and Zambia in Africa; and India, Malaysia and Sri Lanka in Asia, among others, have defined strategies and component policies to promote biotechnology-based activities and moved to create specific regulatory mechanisms, particularly concerning biosafety. Biotechnology has also been the base of many international cooperation initiatives linking developed and developing countries, as well as involving different kinds of South–South cooperation approaches.

Looking in retrospect, these efforts do not seem to have been very successful. Even though it is true that developing countries make up most of the list of the top ten performers in terms of the adoption of GM crops – the best known of the products of biotechnology – the fact is that biotechnology is not a widely-used tool within the toolkit of agricultural research. Consequently, great opportunities are being lost in terms of capturing the potential benefits of the new technologies for sustainable development, improving nutrition, and addressing the challenges of climate change among other issues. Explaining poor performance is not an easy task. In part, the issue is wider than biotechnology, and many of the same aspects can be pointed out in reference to conventional agricultural research as well as science & technology policies in general. However, it is important to highlight that biotechnology approaches evolve in an institutional environment that is very different than that of conventional agricultural research, and many of the shortcomings identified could be linked to a poor recognition of what this environment looks like, and the consequent failure to effectively reflect in the policies designed.

The increased convergence between biological and other sciences, higher investment requirements, the higher profile of intellectual property and biosafety issues, the changed role of the private sector both in the development of the technologies and the technology delivery systems, are all aspects that should be clearly present in an effective policy development process. Clearly, there are no recipes to follow for effective policy-making but given the characteristics of the present processes and their limitations, developing countries have to address a few comments that can contribute to more effective policy development in the future. A first issue is the need to make agricultural research and technological policy an integral part of the country's general science & technology policy, and discuss biotechnology-related issues within that framework. A second aspect – more related to a better recognition of biotechnology-based research, technology and innovation (RTI) processes – would be moving to decomposing the policy space in policies and instruments addressing issues dealing with access to knowledge and technologies, and instruments dealing with the utilization of the technologies in specific production systems could be a good way to improve existing approaches.

5.3.6 Ensuring that policies, strategies and regulations on agricultural biotechnologies benefit smallholders

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Why consider the impacts of biotechnology on small-scale farmers? Isn't small-scale farming a relic of the past? Some policy-makers and academics argue that small-scale farmers need either to take a "step up" in their farming operations – intensify, enlarge, commercialize and become more productive – or "step out" of farming altogether. According to this view, the major policy challenge in relation to smallholder farming is to find pathways out of agriculture for most of its practitioners, and pathways to large-scale agriculture for the few.

This is a debatable point. What is certain is that, today, many millions of rural people still depend heavily on agriculture for their livelihoods and food security. Agriculture can be a motor of economic growth and development in the wider economy. Moreover, times have changed since the days when industry was absorbing millions of unskilled workers. In the future there will be concerns not only about food security but about employment.

Meanwhile, many families with roots in rural areas exhibit a strong desire to keep hold of their land as a buffer against economic insecurity and a source of resilience. And farm-based rural livelihoods are diversifying to include off-farm and non-farm sources of income and livelihoods. So small-scale and family farm operations are unlikely to disappear overnight, if at all. So focusing policy on the needs and interests of small-scale farmers remains vital.

There is no structural reason for thinking that small farms cannot absorb or benefit from modern agricultural biotechnologies. Key questions for development policy and strategy include: What types of biotechnologies will be suitable and appropriate for small-scale farms? And how can the benefits for this sector be maximized and the risks minimized?

The first observation is that both the design of the technology and the context of deployment matter. The best policy, strategy or regulation to support the interests of small-scale farmers will be different for different types of technologies and for different communities or circumstances. There should not be a standard prescription for every situation. However, taking this into account I can offer some general suggestions. Most of these would apply equally to all kinds of farming technologies, not just biotechnologies, or transgenic crops and livestock.

A good start is to think about an effective *process* for developing policies, strategies and regulations. In particular, it is advisable to consult groups likely to be affected (beneficially or adversely) by the technologies in question. This is one reason why Article 23 of the Cartagena Protocol on Biosafety stipulates that signatories should take steps to inform and involve the public in decision-making; but it is particularly important to involve those stakeholders who are directly implicated in technological change, such as small-scale farmers.

It is well to ask some key questions, such as:

- Who is expected to deploy or practise this technology? For example, will it be used by an individual farmer him/herself, or by a specialist acting on his/her behalf (such as an extensionist, consultant or field technician)? Or will adoption of this technology require cooperation across a community of farmers? Answers to these questions can help decision-makers to develop impact strategies and design extension programmes.
- What behaviours or practices are envisaged if this technology is introduced, and which might be eliminated or changed? Who might be affected, positively or negatively, by such changes? Answers to these questions will help to identify key intervention points and the stakeholders who need to be involved in decision-making.
- What material inputs, equipment or tools may be needed in order to take full advantage of the technology? For example, does the new biotechnology depend on additional supplies of fertilizer or water? If so, are these resources readily available? Small-scale producers often farm in unfavourable environments where desirable inputs are unavailable or inaccessible.
- What information, knowledge or skills are required to make the most of the new technology? Who will supply the necessary information and how will farmers be supported to acquire new knowledge and skills they may need to benefit from the technology or avoid possible negative impacts?
- In many cases the deployment of new technology implies a redistribution of power, income, employment or other assets. Who are likely to be the winners and losers from this new technology? How might the potential losses be mitigated or how might losers be compensated? Or can policy ensure that the benefits are more evenly distributed?

Policy- and decision-makers can take several concrete steps to support the uptake of beneficial modern biotechnologies by small-scale farmers. Some key priorities should be:

- Ensuring that the extension and marketing of biotechnologies is done in ways that are effective, clear, transparent, accountable and well-targeted towards small-scale producers.
- Ensuring that modern biotechnologies are accessible to small-scale farmers – i.e. affordable (low or moderate prices), locally available (effective distribution and delivery), and readily understood and usable by small-scale farmers (accompanied by clear and useful information).
- Ensuring that short-term and long-term, individual and societal benefits and risks are weighed and distributed fairly and transparently.

Policy-makers can learn from mistakes that have been made in the past. For example, we know now that it is helpful if new technologies are *recognizable* and *trialable*, that is:

- Technologies can be distinguished from other technologies, inputs etc., both on the farm and in the market. This might be due to the technology's effects or because it is properly labelled. It is important to eliminate fraudulent misrepresentation so that farmers can be confident they are using the technology they need.

- Technologies are introduced at a moderate pace, which allows farmers the time necessary to familiarize themselves with the technology, try it out, observe how it works and understand how to get the best from it.
- Technologies are accompanied by clear and usable information, training and other support.

Learning from mistakes does not happen automatically, however. Decision-makers need systems for gathering lessons that can serve to inform improved policies into the future, from implementing agencies, extension services and field technicians and farmers.

These guidelines are especially important in the case of seed technologies (e.g. transgenic seeds or treated seeds) which might not be easily identifiable in the field or in the market.

A more challenging proposition is that genetic material, including transgenics, for example, should be made available to small-scale farmers in forms that are unencumbered by intellectual property restrictions, so that they can be decomposed and reconstructed to suit the farmers' own local requirements. Small-scale farmers have managed genetic material in their seed portfolios for many generations; allowing them to do so in future could be an effective way to ensure that useful traits are incorporated into locally adapted germplasm quickly and effectively.

This might be a controversial proposal because it confronts the interests of intellectual property owners, who wish to control who may use new genetic material, and also because it might create special difficulties for the stewardship and monitoring of genetically modified organisms in the environment. Assessing biosafety risks in advance would be vitally important (including short- and long-term effects on human, animal and plant health, crop and natural biodiversity, impacts on non-target organisms, and so on).

5.4.1 *Report of the parallel session*
Investing in biotechnology solutions through capacity development and partnerships[14]

The session, chaired by Kongming Wu (China), focused on capacity development as well as on the role of partnerships, including public–private partnerships (PPPs) and South–South cooperation (SSC), for agricultural biotechnologies. A key element of the enabling environment for agricultural biotechnologies is that the individuals and institutions involved have the capacities to generate, adapt and apply biotechnologies in crops, forestry, livestock and fisheries.

Biosciences eastern and central Africa – International Livestock Research Institute (BecA–ILRI) is one regional network of the African Union (AU) and the New Partnership for Africa's Development (NEPAD) Africa Bioscience Initiative, established in 2002 to support and mentor African scientists from national and international public sector and private sector in the application of biosciences in food security and agricultural development. Capacity development at the BecA–ILRI Hub includes: 1) the Africa Biosciences Challenge Fund (ABCF) research fellowships (> 100 since 2010) for capacitating individual scientists and national agricultural research systems (NARS) institutions; 2) training workshops; 3) institutional capacity strengthening (laboratory maintenance and management etc.); and 4) mobilizing capacities for joint action for multicountry/multidisciplinary research. It was emphasized that mentorship is a key cross-cutting mechanism in the capacity building process, and that fund-raising from NARS is a challenge. The Hub will expand capacity development of African scientists, and strengthen the technology platforms that are addressing African agricultural issues, as well as fund work on fund raising to maintain the Hub activities.

In the second presentation, three case studies of PPPs related to smallholders were described: Bt brinjal/eggplant in Bangladesh commercialized in 2014; GM crop development by Embrapa in Brazil; and crops in Africa, such as water efficient maize for Africa (WEMA). Major lessons from recent PPP experiences are that success depends on a full commitment by host countries, appropriate regulatory systems (still emerging), and the sustained participation of all partners, especially smallholders, over a long duration. Such lessons are especially important given the recent development of gene editing methods (CRISPR) that will make current GMO methods (and their regulation) obsolete. Gene editing technologies can considerably widen the range of traits, especially smallholder-relevant traits, that can be improved much more rapidly and cheaply than before, which provides a golden opportunity for the emergence of new PPPs aimed specifically at improving smallholder agriculture. FAO should make sure that these new technologies will be available for improving smallholder agriculture.

The third presentation was about the Cornell Alliance for Science, founded in 2014 with a grant from the Bill and Melinda Gates Foundation. It aims to facilitate access to biotechnologies by building an international network of concerned scientists, farmers and humanitarian organizations to facilitate

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[14] This report was prepared by Masami Takeuchi, Karin Nichterlein and Aikaterini Kavallari, the FAO rapporteurs for the theme of people, policies, institutions and communities.

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access by farmers to modern biotechnologies to help them provide safe, stable and environmentally sustainable food supplies. The Global Alliance (> 6 000 members) aims to strengthen the global network through: 1) The 3-month Global Leadership Fellows Program, designed to equip and empower emerging leaders to foster a more enabling environment for the adoption of biotechnology globally; and 2) Short courses held regionally to strengthen the networks of global leadership fellows in strategic communications planning and grassroots organizing; fellows are already making impact on biotechnology dialogues in their countries.

The presentation on North–South/West–East cooperation in agricultural biotechnologies illustrated an applied biotechnology solution related to partnerships between Italy and China and capacity development in the sector of buffalo production to improve milk production in swamp buffalo. The presentation showed that it was essential to find a common language, common interest and complementary goals for the partnership. The sector is of mutual interest to both countries and it is a good example of the use of a set of different complementary biotechnologies, using the joint Sino-Italy buffalo research centre and private partners in China. The five-year project involves using artificial insemination; using genotyping technology to improve milk and meat production traits and to reduce methane emissions from buffalo populations; and establishing nucleus herds of Mediterranean buffalo with a higher production level and optimized management.

SSC is an important mechanism in technology development, transfer and diffusion. Benefitting from the support of the respective governments and due to substantial investments in R&D, many developing nations have developed home-grown technologies in agricultural biotechnology. However, the level of biotechnology development is uneven among countries with many where biotechnology is at an initial stage. The speakers highlighted that it is essential for countries to have functional agricultural innovation systems to enable the effective utilization of agricultural biotechnology and that SCC is important in this context using three cases to illustrate this point. They demonstrated that SSC in agricultural biotechnology should be based on an integrated approach that includes product development along with capacity building, and that countries such as Brazil, Russia, India, China and South Africa (BRICS) can engage in SSC as a group, complementing each other's strengths providing complementary GMO and non-GMO biotechnologies.

Summary of the open discussion

Through the active discussions, moderated by Courtney Paisley from Young Professionals for Agricultural Development (YPARD) in Rome, the participants recognized:

- That capacity development for biotechnologies includes not only technical (hard) skills but also skills that allow scientists and other actors of the agricultural innovation system to communicate efficiently with farmers, government, private sector and the general public to negotiate, engage in political dialogue and raise funds etc.
- That capacity development needs to go beyond training individuals in biotechnologies, because if they go back to their institutions and do not find possibilities in their organization to continue research or if their countries do not provide an enabling environment to make modern technologies accessible to farmers, their training will have no impact and they do not have incentives to continue.
- That South–South and North–South partnerships, as well as partnerships between the public and private sector, based on common understanding and mutual interests, political will of the host government, and smallholder farmer inclusion, are the preconditions for successful partnerships that benefit the farming sector.
- The potential of lower-cost biotechnologies such as gene editing for bringing benefits to smallholders, and potential of creating open-source technologies affordable for developing and emerging countries.
- Potential roles of international organizations like FAO to support capacity development for regulatory systems in countries lacking them, for technical skills, for business incubation, as well as providing a platform for public and private sector institutions to facilitate open-source repositories for the new generation of biotechnologies and guidance on how to develop efficient partnerships.

5.4.2 Biosciences capacity building in Africa: Lessons learned from the Biosciences eastern and central Africa – International Livestock Research Institute (BecA–ILRI) Hub

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Background

The need to harness biosciences-based innovations to capitalize on agriculture's potential underpinned the vision of the African Union/New Partnership for Africa's Development (AU/NEPAD) Africa Biosciences Initiative (ABI). The ABI aimed to create four regional biosciences "centres for excellence" across the continent:

- NABNet (North African Biosciences Network) for northern African countries;
- WABNet (West African Biosciences Network) for Economic Community of West African States (ECOWAS) countries;
- SANBio (Southern African Network for Biosciences) for southern African countries;
- BecA–ILRI Hub for countries in eastern and central Africa – Burundi, Cameroon, Central African Republic, Congo, the Democratic Republic of the Congo, Equatorial Guinea, Eritrea, Ethiopia, Gabon, Kenya, Madagascar, Rwanda, Sao Tome and Principe, Somalia, South Sudan, Sudan, Uganda and United Republic of Tanzania. The BecA–ILRI Hub was established in 2002 when ILRI agreed with NEPAD to host the Hub at its headquarters in Nairobi, Kenya due to its interest in supporting agricultural research in the region through facilitation of access to modern research infrastructure by scientists in Africa.

The need for the BecA–ILRI Hub

- Biosciences are one of the major engines of global growth not just in agriculture but also in human health, environmental conservation and industrial processes.
- Africa lags behind in biosciences due to low human capacity and limited facilities.
- The main driver of the BecA–ILRI Hub is to support and mentor African scientists in the application of biosciences in food security and agricultural development. The platform hosts and supports the work of scientists from African national agricultural research systems (NARS), ILRI, other CGIAR centres and CGIAR Research Programs, international institutions and the private sector.

Key programme pillars

- Biosciences research;
- Regional bioscience platforms (genetics, genomics, bioinformatics, biorepository, nutrition);
- Support to NARS and CGIAR to address capacity gaps and partnerships.

The BecA–ILRI Hub's state-of-the-art suite of shared biosciences platforms avail the best technologies to the African (and international) scientific community to address national, regional and continental priorities. The outputs of research, technologies and capacity building combine to achieve (developmental) impacts at the beneficiary level, e.g. increased productivity or improved food safety. The BecA–ILRI Hub's vision is that by contributing to stronger NARS, the livelihoods of millions of resource-poor people in Africa will be improved through advances in agricultural bioscience.

Capacity building at the BecA–ILRI Hub

- Africa Biosciences Challenge Fund (ABCF) research fellowships, an essential driver of the BecA–ILRI Hub, which seeks to strengthen the capacity of individual scientists and NARS institutions to deliver on their national research mandates:
    - Research projects of 3–12 months;
    - African NARS-affiliated scientists;
    - Fit with BecA–ILRI Hub priority research themes:
        - Crop improvement;
        - Food safety and nutrition;
        - Livestock productivity;
        - Climate change mitigation;
        - Underutilized crop/animal species.
- Training workshops:
    - Introductory molecular biology and bioinformatics;
    - Introductory laboratory management and equipment operations;
    - Advanced genomics and bioinformatics;
    - Scientific research paper writing;
    - Animal quantitative genetics and genomics.
- Institutional capacity strengthening:
    - Technical assistance with laboratory design/management, equipment installation and procurement, training of engineers and laboratory technicians;
    - Support with resource mobilization;
    - Connections to networks, e.g. suppliers of reagents and laboratory equipment;
    - Customized training workshops at NARS institutions;
    - Brokering partnerships for research, training and resource mobilization.
- Mobilizing capacities for joint action:
    - Joint NARS actions for multicountry/multidisciplinary research.

Capacity building achievements

- Increased awareness of BecA–ILRI Hub;
- Regional impact of the ABCF on the NARS;
- > 15 research papers published and > 40 in preparation;
- Informing private sector, policy and local government;
- ABCF contribution to downstream impact;
- Strong endorsement of the ABCF fellowship scheme by stakeholders. Evaluation in 2014 found that 96 percent of stakeholders believe that the BecA–ILRI Hub builds the capacity of individuals and institutions to harness the latest bioscience technologies to improve agriculture in Africa;
- Four Communities of Practice at nascent stages – chicken genetics (four countries); fish genetics (three countries); striga resistance (four countries); taro improvement (four countries).

Challenges

- High demand for fellowships and training courses;
- Diversity of African research and capacity building landscape – some NARS are well resourced and others are less so. This has led to a decision to focus up to 2018 on engaging NARS in what the BecA–ILRI Hub calls "Stage Two" countries (where we have made substantial investments, matched by investments from NARS): Burkina Faso, Cameroon, Ethiopia, Ghana, Kenya, Rwanda, Senegal, Uganda and United Republic of Tanzania;
- Few applications from some countries;
- Few applications from women scientists;
- Limited investment by African governments.

Lessons learned

- Mentorship is a key cross-cutting mechanism in the capacity building process;
- A strictly competitive process for ABCF fellowships may not achieve strategic objectives;
- Need to engage National Councils of Science and Technology to provide return-to-home institution grants;
- Need to encourage NARS to provide increased co-funding of laboratory users and ABCF Fellows;
- Collaboration with other capacity building programmes helps to magnify impacts, e.g. African Women in Agricultural Research and Development (AWARD) and the International Foundation for Science (IFS).

Way forward

The development of an African-led R&D agenda that responds to market drivers and supports the transformation of agriculture as a driver of economic growth is being articulated by the African Union and its partners, including AU/NEPAD, the Forum for Agricultural Research in Africa (FARA) and other Pan African, regional and national bodies. Being aware of and responding to new priorities and new opportunities will keep the BecA–ILRI Hub relevant as well as responsive to the emergence of agriculture as a profitable enterprise in growing African economies.

The BecA–ILRI Hub faculty will be expanded to include as adjunct appointees more senior bioscientists working with African NARS as well as those with advanced and international research institutes. This expanded faculty will enable a broader and deeper range of capacity strengthening programmes to be conducted at the BecA–ILRI Hub and a larger number of young African scientists to be mentored in their research by more experienced African and international scientists.

Ensuring the availability of "state of the art" technology platforms across a wide range of modern biotechnologies is an important part of the BecA–ILRI Hub's role as a shared research platform that is a "centre for excellence" for biosciences in Africa. These technology platforms serve multiple partners and research consortia that are addressing African agricultural issues. As bioscience is a rapidly evolving field, these technology platforms will need to be continually updated to stay relevant.

The BecA–ILRI Hub is accessible, but not always affordable, for scientists working in national research institutes and universities across Africa. Restricted core support from international investors will be needed to underwrite some of the fixed and capital costs. Mobilizing additional financial resources will also be required to fund more ABCF fellowships for African scientists. Affordability can also be increased by forming new partnerships with African governments and regional bodies, such as the Association for Strengthening Agricultural Research in Eastern and Central Africa (ASARECA), the West and Central African Council for Agricultural Research and Development (CORAF/WECARD) and the Regional Universities Forum for Capacity Building in Agriculture (RUFORUM) to support tailored capacity strengthening programs for particular countries/regions.

5.4.3 Case studies of public–private partnerships in agricultural biotechnologies: Lessons learned

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Introduction

Public–private partnerships (PPPs) have played vital roles in much of the progress of modern agriculture, from the creation and dissemination of hybrid maize in the early twentieth century to the green revolution of the 1960s and beyond. However, during most of the twentieth century, much of the leadership in organization and innovation in agricultural systems in industrialized countries was provided by powerful public bodies, such as the USDA and land-grant universities in the United States of America. This public sector dominance was much reduced after the 1980s as many state entities were privatized and/or suffered funding reductions. The process coincided with the growth of a dynamic, increasingly globalized agricultural biotechnology sector, originally based on agrochemical companies that diversified into bio-based areas including crop breeding and livestock management. As we move through the twenty-first century, future innovations and their implementation will require ever-closer partnerships (i.e. PPPs) between public entities (including state organizations, research institutes, universities, extension bodies etc.) and an increasingly diverse private sector that includes multinationals, small and medium-sized enterprises, NGOs, citizen groups, retailers, small farmers etc.

Such PPPs are especially important in enabling smallholders to contribute to the nature and implementation of modern biotechnology-derived crops, most of which have hitherto addressed the needs of larger commercial farmers and agribusiness interests. These PPPs tend to be highly dynamic as the nature of the various partners constantly changes, the technologies advance, and fresh challenges arise, such as climatic change and (possibly related) newly-emerging threats including pests and diseases. Because PPPs involve so many players and can occur at all scales from single farmers to globe-spanning international partnerships, it is difficult to describe them fully in such a brief presentation. Instead, three selected PPP examples relating to smallholders will be described in some detail in order to derive some lessons for future policy-making.

Case studies

a) Brinjal in Bangladesh: Breaking the impasse on GM crop acceptance?

While there have been several examples of widespread smallholder adoption of GM cash crops, most notably Bt cotton, several promising subsistence GM crop candidates have faced lengthy delays.

However, in 2013 Bangladesh approved Bt brinjal/eggplant for planting after a rapid approval process. In 2014, commercialization was initiated via a PPP when a total of 120 farmers planted 12 hectares. This followed strong political support from the government, with leadership from the Ministry of Agriculture, and close collaboration with farmer groups and private sector breeders. This approval by Bangladesh is important in that it has broken the impasse experienced in trying to gain approval for commercialization of Bt brinjal that blocked its introduction in India and the Philippines. It also serves as a possible model for other small poor countries.

Two other developing countries in Asia, Vietnam and Indonesia, also approved cultivation of GM crops in 2014 for commercialization in 2015. Vietnam approved Bt maize and Indonesia approved a drought tolerant sugarcane for food, whilst approval for feed is pending; 50 hectares of sugarcane were planted in 2014 for planned commercialization in 2015. In 2014, it is estimated that approximately 18 million farmers grew GM crops, about 90 percent, or 16.5 million, were small farmers in developing countries. In addition to economic gains, farmers benefited enormously from at least a 50 percent reduction in the number of insecticide applications, thereby reducing farmer exposure to insecticides, and importantly contributed to a more sustainable environment and better quality of life. All of these GM crops were introduced via PPPs.

b) Embrapa in Brazil: PPP-led GM crop development

Embrapa is the major public agricultural R&D organization in Brazil with an annual budget of US$1 billion and has been especially active in fostering PPPs in agricultural biotechnology. It is one of the few public bodies to have developed and commercialized GM crops that are grown by farmers ranging from smallholders to large international combines. In 2014, Brazil planted GM soybeans with insect resistance and herbicide tolerance commercially on 5.2 million ha, up substantially from 2.2 million ha in 2013. In 2015, Embrapa gained approval to commercialize its GM virus-resistant bean, planned for 2016, plus a novel herbicide tolerant soybean, which it developed via a PPP with BASF (this variety is currently awaiting EU-import approval prior to planned commercialization in 2016). Embrapa is also developing GM folate-fortified lettuce and drought resistant sugarcane. Embrapa is an example of a large state enterprise that has taken the lead in innovative biotechnology crop development with PPP engagement, which has been primarily commercially focused but with increasing trickle-down to smallholders.

c) Emergence of agricultural biotech PPPs in Africa

Over the past decade there has been a range of PPP ventures in Africa that have focused on both GM- and non-GM crops aimed at smallholders. For example, Cameroon, Egypt, Ghana, Kenya, Malawi, Nigeria and Uganda have conducted field trials on the following broad range of staple and orphan crops: rice, maize, wheat, sorghum, bananas, cassava and sweet potato. The water efficient maize for Africa (WEMA) is a major PPP that is expected to deliver its first GM drought tolerant maize with Bt insect resistance in South Africa as early as 2017, followed by Kenya and Uganda, and then by Mozambique and United Republic of Tanzania, subject to regulatory approval. Over the past two years there has been a distinct improvement in state engagement with biotechnology-related PPPs in much of Africa.

Future lessons

The major lessons from recent PPP experiences are that success is dependent on a full commitment by host countries, appropriate regulatory systems, and the sustained participation of all partners, especially smallholders, over the entire duration of what can be complex and long-term ventures. Such lessons are especially important given recent developments in agricultural biotechnology. During the last few years, and especially in 2015, there has been a veritable revolution in genetic technologies with the development of gene editing methods such as CRISPR and TALEN. In terms of crop breeding, this means that it will soon be possible to progress from the random insertion of single or small numbers of genes into a genome (as in traditional genetic modification) to the highly precise insertion into a defined location of large numbers of genes, chromosome segments or pseudo-segments encoding entire metabolic pathways into virtually any plant species.

These new technologies will make current genetic modification methods (and their regulation) obsolete and there are already calls that organisms altered by gene editing should not be characterized as GMOs. Gene editing can considerably widen the range of traits (especially smallholder relevant traits in hitherto orphan crops) to be altered much more rapidly and cheaply than was hitherto possible. This provides a golden opportunity for the emergence of a new generation of PPPs aimed specifically at improving smallholder agriculture as we face up to increasing food security challenges across the world.

5.4.4 Building partnerships, empowering champions: The case of the Cornell Alliance for Science

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We face a global challenge of ensuring access to safe, nutritious food for an unprecedented population, while simultaneously seeking to minimize agriculture's negative impacts on the environment. Innovations in the field, such as the tools of genetic engineering, should help us address this challenge.

Many promising products generated using the tools of genetic engineering are in the late stages of development and testing. Public sector institutions, including universities and national agricultural research programmes, have played an important role in the development of these products. In many cases, scientists in the developing world not only lead these projects, but their farmers are the intended beneficiaries. In order for these products to reach their intended beneficiaries and to have impact on increasing access to a safe, sustainably-produced food supply in the face of an increasingly erratic climate, the proper enabling environment must be established.

Private foundations have demonstrated their willingness to make higher-risk investments to ensure these technologies do not bypass the poor. The Bill and Melinda Gates Foundation has invested across diverse areas of the biotechnology ecosystem to ensure its impact, making significant investments in the research and the development of products that will address the biotic and abiotic constraints that some of the world's most vulnerable farmers face. In addition, they have invested in programmes to help foster an effective regulatory environment. The Gates Foundation invests in capacity building to address the dearth of voices in the community that can help lead the debates around agricultural biotechnology and help to bring a rational, evidence-based voice to the global conversation around it. The Cornell Alliance for Science is one such initiative.

Founded in 2014 with a grant from the Foundation, the "Alliance" is addressing this challenge by building an international network of concerned scientists, farmers and humanitarian organizations working to restore the place of science in food policy decisions. The organization works to ensure that scientists have access to the tools they need to innovate for the grand environmental and food security challenges we face today; the organization also works to give voice to farmers, regardless of where they live, who need access to the advances in science to help them provide the world with a safe, stable and environmentally sustainable food supply.

Hunger, poverty, malnutrition and sustainable agricultural growth problems impact less developed countries more than others. Solutions such as biotechnology are often inaccessible to those who need them most. In the global biotechnology discussion, opponent activists continue to spread misinformation, obstructing the voices of those who would benefit most. Stakeholders around the world now must face the ambitious task of fostering constructive public dialogue and policy that employs biotechnology as a tool to help solve global challenges.

Recognizing this, the Alliance has three primary objectives:

Our first goal is to build a globally coordinated alliance of individuals and organizations who share our mission of promoting access to scientific innovation as a means of enhancing food security, improving environmental sustainability and raising the quality of life globally.

We believe that as a coordinated community, this global alliance will have a much stronger voice for science that can favourably shift the global conversation around biotechnology. We want to serve as a platform where individuals and organizations can lend their voices to advocate for science-based decision-making and encourage global coordination of a proactive pro-science community. Just over a year into our initiative, we have engaged over 6 200 "science allies" in 109 countries.

It is our hope that we can engage not only "likely" allies who already co-habit our shared "echo chamber," but also the "unlikely allies." These are the people who share our core values around access to safe, sustainably-produced and nutritious food, but who maintain a healthy scepticism of the technology.

Our second goal (and the focus of the oral presentation) is to strengthen the global network we are building through innovative training programmes in forward leaning and strategic communications. The Alliance uses a people-focused, metrics-driven approach to train and support knowledgeable, empowered champions to build effective communications strategies in their own country contexts.

We host two types of training programmes: The Global Leadership Fellows Program, a 12-week, Cornell University certificate programme designed to equip and empower emerging leaders who will advance our shared mission for a more enabling environment for the adoption of biotechnology globally. This programme, held in August through November on the Cornell University campus in Ithaca, New York State, combines modules on strategic planning and grassroots organizing, training on digital and traditional communications tools, exposure to global thought leaders, weekly colloquia, and field trips. Through this programme, we host and build the capacity of 25 fellows from approximately seven to ten countries.

Additionally, in a series of week-long "short courses" held regionally around the world, we work with the global leadership fellows to strengthen their networks through courses in strategic communications planning and grassroots organizing.

Global leadership fellows come from diverse backgrounds; from communications specialists working at national agriculture research programmes, to organizers at NGOs, religious leaders, scientists and others. Upon completion of the programme, the fellows are members of a growing collaborative

international cohort of forward-leaning communicators uniquely equipped to promote evidence-based decision-making around global issues such as food security, environmental sustainability and agricultural growth and to ensure that the tools of science, tools like biotechnology, do not bypass the poor.

5.4.5 North–South/West–East cooperation in agricultural biotechnologies: Some lessons from Italy and China in buffalo

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A case of applied solutions through capacity development and partnerships is illustrated in the sector of buffalo production between Italy and China. The operative steps in the process of capacity development and the accomplishments in terms of partnership are illustrated. Operational steps are focused on existing difficulties and possible solutions in the buffalo breeding sector of mutual interest for both countries through complementary use of different biotechnologies. The set of operational steps could also be fitted to buffalo improvement programmes in different countries of the Southeast Asia region.

Buffalo in the world

The world buffalo population is estimated to amount to about 195 million animals, spread over more than 40 countries. Ninety-seven percent or 189.79 million buffaloes are in Asia (Perera, 2011). India has 112.9 million (approximately 57.8 percent of the total), followed by Pakistan (16.2 percent) and China (12 percent). Buffaloes provide more than 10 percent of the world’s milk supply; their milk has a higher fat, lactose and protein content than cow milk. In the domestic water buffalo (*Bubalus bubalis*), we find two subspecies which are interfertile: the river buffalo, which is the predominant type in India, West Asia, America and Europe, and the swamp buffalo which is found more frequently in Southeast Asia and China. The two subspecies differ in morphology, behaviour and chromosome number. In fact the river buffalo has $2n = 50$ chromosomes and the swamp buffalo has $2n = 48$ chromosomes.

River buffalo

The population of river buffalo is estimated to amount about 158 million animals. River buffalo breeds have become mainly dairy animals and among those, Mediterranean, Murrah and Nili-Ravi are the most productive breeds for milk yield. The Italian Mediterranean breed has a well-established recording system, supporting since the early 1990s an official breeding programme for the genetic improvement of dairy traits. The Italian Mediterranean buffalo breed is a small population compared with Asian buffalo populations, representing only 0.19 percent of the world buffalo population. However, it is the largest “active population” in the world. In fact about 54 000 Mediterranean buffaloes in more than 300 herds are currently milk-recorded in Italy. This recorded population is used to run a national genetic improvement programme allowing progeny testing of at least five young bulls every year. Currently more than 20 proven bulls are producing frozen semen in Italy.

The Murrah buffalo is mainly found in the Indian sub-continent. Murrah has spread widely to other parts of Asia and in the world and it has been broadly used as an improver breed. The population size is over six million animals (Borghese, 2005).The Nili-Ravi buffalo is mainly farmed in Pakistan but it is also present in India. The population size is of about 6.5 million head (Borghese, 2005). The three dairy river buffalo breeds present differences in dairy performance. Currently the Italian Mediterranean breed shows the highest milk yield production per day as compared with Murrah and Nili-Ravi breeds. Additional important traits to be compared are body weight, age at first calving and calving interval. For all these traits the Mediterranean breed has the most suitable phenotypic values for a dairy buffalo type. In particular, it is important to underline the smaller body size of the Mediterranean breed, about 20 percent and 10 percent smaller than Murrah and Nili-Ravi, respectively. This means that Mediterranean buffaloes need less energy for body maintenance.

Swamp buffalo

The population of swamp buffalo is estimated to amount about 37.16 million, representing 19 percent of the total world population (Perera, 2011). The history of swamp buffaloes is rooted in the traditional agriculture based on smallholdings; in fact they play a major role in the practices and economic income of small farmers. These buffaloes are easy to raise, the costs involved in raising them are low, and they can make full use of low-quality local forage. They may be used for the cultivation of crops and for rice field preparation, and their dung is used as a soil fertilizer so reducing expenditure on chemical fertilizer and preserving the environment. Swamp buffaloes are smaller than water buffaloes and they are very poor in milk production, the average milk yield ranging from 1.0 to 1.5 kg/head/day over 270 to 305 days of lactation.

Buffalo breeding and greenhouse gas (GHG) mitigation

Methane emission from enteric fermentation is a major source of agricultural GHG emissions. Enteric fermentation from ruminants is the largest single source of methane total emissions. The world buffalo population contributes significantly to such methane emissions. It is well known that the following actions can mitigate the total GHG emissions from ruminants per unit of milk and/or meat produced: 1) increasing productive and improving reproductive traits in a given population; and 2) improving feeding strategies in a given herd. Both of these goals could be achieved by suitable buffalo breeding and buffalo herd management programmes. Increasing the efficiency of production can reduce the total number of animals needed to produce a fixed level of output. In the world buffalo population, room exists for such improvement and modern genetic improvement technologies should be more largely adopted.

Use of biotechnologies to improve buffalo milk production in China

In China, 23 million swamp buffalo are farmed and about one million of swamp buffalo have been mostly crossed with Murrah and Nili Ravi river buffalo to produce milk. Cross-breeding has improved milk production in the first generation but, in the long-term, crossing alone will not improve milk yield in the Chinese buffalo population. CREA has proposed a five-year project based on three applied biotechnologies: 1) using artificial insemination to replace a subpopulation of swamp crosses with Mediterranean buffalo; 2) using genotyping technology to improve milk and meat production traits and to reduce methane emissions from buffalo population; and 3) establishing nucleus herds of Mediterranean buffalo with higher production levels and optimized management.

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5.4.6 South–South collaborations in agricultural biotechnology: Lessons learned

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South–South collaboration is an important mechanism in technology development, transfer and diffusion. Thanks to the support of the respective governments, with massive investments in R&D, many developing nations have developed home-grown technologies in agricultural biotechnology. They may range from tissue culture to development of GMOs and gene stacking.

A RIS study of biotechnology capacity in the Asia-Pacific region showed that while many countries remain at the low end of agricultural biotechnologies, some have moved rapidly to high-end technology. The picture in Africa and Latin America is no different. In Africa, agricultural biotechnology has taken roots in few countries such as South Africa while in many countries it is in the initial stages. Similarly in Latin America, while countries like Argentina, Brazil and Mexico have applied this technology rapidly despite controversies, in many countries it is in the initial stages. Another important concern in agricultural biotechnologies is that of biosafety and many developing nations have ratified the Cartagena Protocol on Biosafety. In fact, countries with very limited activities in agricultural biotechnologies have ratified the Protocol and hence are bound by it.

For effective utilization of agricultural biotechnology, it is essential that countries have a functional innovation system in the agricultural sector. This is important for technology adoption and further development of agricultural biotechnology.

This talk presents three case studies where South–South cooperation (SSC) has helped countries move upward on the trajectory. The areas captured are cooperation for capacity building in biosafety management; India-Bangladesh cooperation for Bt brinjal; and cooperation for primary biotechnology.

The presentation concludes that, in the long run, SSC in agricultural biotechnology should be based on an integrated approach that includes product development along with capacity building. The groupings like India, Brazil, South Africa (IBSA) and Brazil, Russia, India, China and South Africa (BRICS) can play important roles as they can engage in SSC as a group complementing each other's strengths. As the countries in these groups have the capacity to develop GM and non-GM boutiques of agricultural biotechnology, they can jointly promote SSC projects in this field.