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IICA

Agro-biotechnologies: bio-logical tools at the service of agriculture

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Summary

Agro-biotechnology is an effective technology in which numerous and varied techniques such as hybridization, in vitro cell and tissue cultivation, fermentation, biological control through microorganisms, and some other techniques that do not make use of living organisms are used. In this article, these techniques are described concisely and some concepts are presented to clarify the relationship between transgenesis, one of the multiple techniques, and agro-biotechnology. In addition, the position of the Inter-American Institute for Cooperation on Agriculture (IICA) on biotechnology and its interrelationship with other areas is briefly explained.

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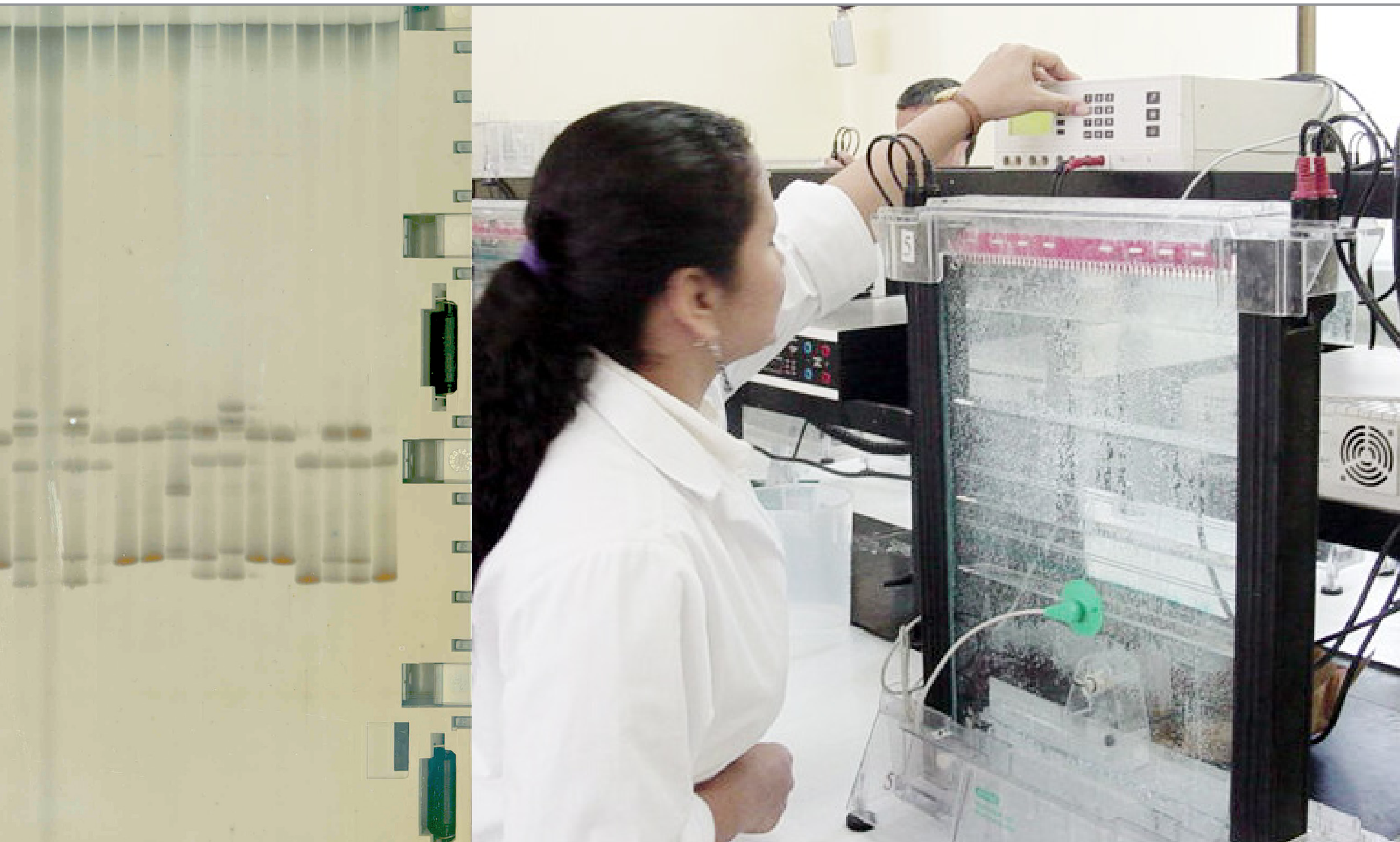

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INTRODUCTION

Technology, defined by the Diccionario de la Real Academia Española (DRAE) as the "collection of theories and techniques that allows the practical use of scientific knowledge" and its interaction with politics, economics and culture, among other areas, are essential to making agriculture competitive and ensuring its desired economic, social and environmental sustainability.

Since the early stages of humanity, some of the biological technologies[2], referred to as biotechnology, have been used with the aim of providing solutions in different spheres including the pharmaceutical, food, industrial and agricultural sectors. Due to their growing importance for the agricultural sector, it is necessary to have available factual concepts and information that allow decision making and objective valuation of the actual impact caused by these technologies.

Some of the multiple agro-biotechnology techniques will be outlined in this article. In addition, due to its relevance, reference will be made to IICA's position on biotechnology and its interaction with other areas, in order to introduce technical knowledge and contribute to making agriculture competitive, sustainable and environmentally friendly.

AGRO-BIOTECHNOLOGY

Among the technologies used in agriculture –conventional, organic, etc.-, those based on the activity or presence of living organisms or their by-products are considered important. Biological technologies used in agriculture are known as "agricultural biotechnology" or "agro-biotechnology." These terms make reference to a collection of different techniques (a set of procedures and resources) that can be used to help solve some agricultural problems.

The diverse techniques of agro-biotechnology are based on biological sciences such as ge-

[2] *The Convention on Biological Diversity (CBD, 1992) defines biotechnology as "any technological application that uses biological systems, living organisms, or derivatives thereof, to make or modify products or processes for specific use."*

netics, physiology, microbiology, biochemistry, and molecular and cell biology. Furthermore, they relate to other disciplines such as chemical and bioprocess engineering, computer science, statistics and economics, *inter alia.* Although some biotechnological techniques have been used for thousands of years for different purposes (such as food and beverage production), about four decades ago, techniques characterized by their specificity, precision, speed and versatility have been introduced into agriculture and have clearly surpassed or strengthened some of the natural processes relating to living organisms. Some of these techniques are briefly described below.

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1 ***Hybridization*** is a process that consists in cross-mating different parents of plant varieties (or animal breeds) to take advantage of their parental characteristics, in order to generate a crop with new or improved characteristics that satisfies the condition of distinction, homogeneity and stability required to produce a new plant variety. During the early decades of the twentieth century, the use of this technique in agriculture resulted in noticeable increased crop productivity (mainly corn) and still has significant impact today.

2 ***In vitro* cell and tissue cultivation**, which includes numerous techniques and procedures, is carried out based on the fact that a plant fragment (cell, tissue or organ) can be cultured under aseptic conditions in a solid or liquid artificial medium (substratum) that possesses a particular chemical composition and is kept under controlled environmental conditions. In practice, all crops of commercial interest have undergone study with respect to *in vitro* cultivation, most of them with the aim of multiplication or massive propagation of elite plants, pathogen elimination in planting material, haploid generation or conservation (i.e. embryo rescue and cryopreservation). This biotechnology is used routinely and, as a result of its application, large extensions of banana, sugar cane, oil palm, fruits, flowers, and forest species, among other "biotechnological crops", have been produced for decades.

3 ***Fermentation*** is a biological process in which sugars, in the presence of microorganisms or isolated enzymes originating from them, are converted into energy and diverse metabolic products such as alcohol or acids. The fermentation technology is one of the oldest biological technologies known and has been widely used in the production of different types of food, beverages, medicines, and biofuels (ethanol). Additionally, fermentation is an important stage of composting processes (essential for biofertilizers production in the agricultural sector) and of different industrial activities generally associated with the use of bioreactors.

Although the use of this bioprocess is evidently advantageous, it can also be harmful for plants affected by bacterial or fungal diseases (rotting). As a consequence, vast research has been done in connection with this technology to determine how to avoid damage in crops and make use of microorganisms in other activities.

4 ***The biological control through microorganisms*** is another biotechnological technique used in agriculture. Its purpose is to cause diseases naturally in insects through several microorganisms (bacteria and fungi).

The *Bacillus thuringiensis* is the most commonly used bacterium for the biological control of coleopterans (beetles), lepidopterous pests (butterflies and moths) and dipterans (flies). It produces a protein crystal that works as a toxin when in contact with the intestines of such insects' larvae. Through the development of bioreactors, the bacterium can be cultured to extract the crystal, which can then be sprayed on a crop to protect it against pests that are susceptible to the toxin. Some fungi (such as vg. *Trichoderma sp., Beauveria bassiana, Paecilomyces sp., Metarhizium sp., Lecanicillium sp., and Cordyceps sp., inter alia*) can be used to achieve biological control of different pests (whiteflies, trips, aphids, weevils and mites).

Techniques of isolation, study and culture of these biocontrol micro-organisms, along with the design of methods for their growth (in bioreactors) and use (inoculation) in crops, are agro-biotechnology techniques as well. A crop treated by this kind of control could be considered also a biotechnological crop. Similarly, the insect control that reduces the reproduction of a determined bug in a particular place through the release of sterilized males by means of radiation can be considered a biotechnological control method (IAEA, 2011a).

5 Direct ***genetic modification*** (also known as transgenesis) is a technique that overcame the biological obstacles imposed by nature and allowed the generation of organisms that express other organisms' genes (viruses, bacteria, animals, human beings or other plants). In 2010, genetically modified crops (mainly corn, soy, cotton and colza) occupied an area of 148 million hectares in 29 countries, cultivated by 15.4 million farmers, 90% of whom own land smaller than 0.6 ha (James, 2010).

Widely discussed in different fora, transgenic technology has fostered regulation in the countries measures, for example, with respect to biosecurity (Cartagena Protocol, 2000)[3] and has been quickly adopted by the agricultural sector (James, 2010). In addition, it is considered an essential tool to satisfy, in a timely manner, the current challenges of agriculture (for example, adaptation to climate change, increase in crop yields, decrease in certain inputs, water and soil resource optimization, etc.).

However, in order to produce new materials, transgenic technology requires genes, in vitro regeneration systems and gene introduction systems, for which molecular marker, cloning and tissue culture techniques are indispensable.

[3]*Information on biosecurity current status in the countries can be found in http://www.bch.cdb.int*

The potential of transgenic technology applied to agriculture is so remarkable that it was considered the representative tool for agro-biotechnology and, as a result, the term "biotechcrops" was used to refer to "genetically modified crops (GM)". Nonetheless, as mentioned before, GM crops are biotechnological cultures too, but not all biotechnological cultures are transgenic.

In terms of genetic modification, it is worth mentioning that there are other techniques that can be included in the biotechnology toolbox. For instance, through the use of radioactivity, it is possible to induce mutations (changes). The results of such mutations are currently applied (IAEA, 2011b). However, transgenics is recognized as a method that implies greater precision and control.

6 ***"Biotechnological" techniques that do not use living organisms.*** Strictly-speaking, a practice is considered biotechnological if it includes the use of living organisms (as was shown in the cases of *in vitro* cell and tissue cultivation, fermentation, bioinput generation and transgenesis). Nevertheless, even if there are techniques (molecular markers, DNA sequencing, "omics" –genomics, transcriptomics and proteomics–, bioinformatics, etc.) that do not make use of living beings, some of them have been used as essential tools for agro-biotechnological development and serve to analyze organisms at an unprecedented level of resolution. Moreover, within the inputs required, biotechnological products are used almost mandatorily and routinely.

Among the biotechnological techniques, molecular markers are important for the genetic characterization of germplasm, the creation of genetic and molecular maps, the identification of genes associated with characteristics of agronomic relevance, as support for improvement in breeding programs and for diagnostic, follow-up and control activities.

The DNA sequencing of multiple species and the procurement of a huge amount of information have opened up new areas of study ("omics") and possibilities for analysis (bioinformatics), which offers obvious opportunities relating to detailed knowledge and the subsequent use, in the agriculture and livestock sectors, of each gene identified. To date, the sequences of 1,749 complete genomes

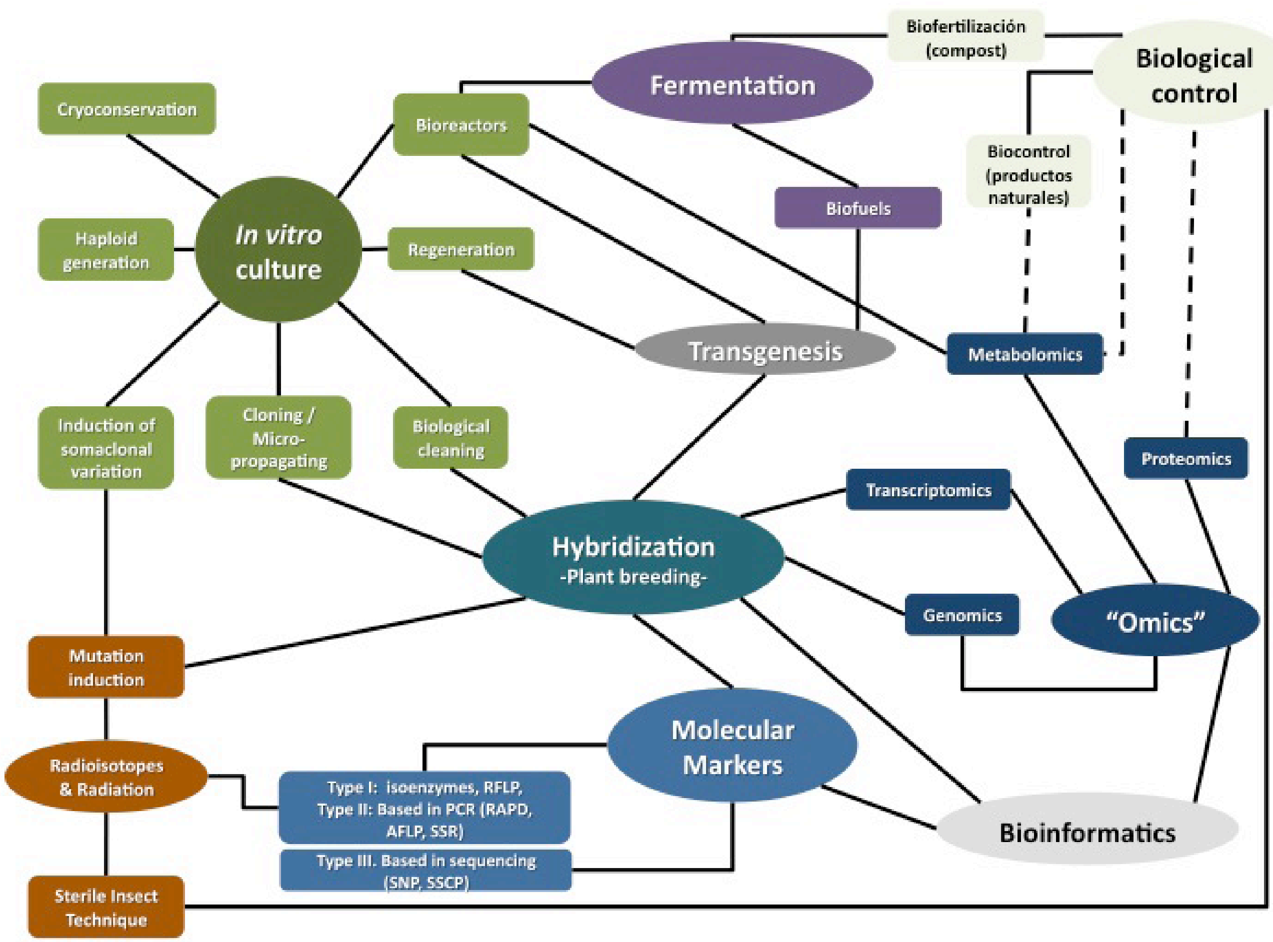

FIGURE 1. SOME TECHNIQUES USED BY AGRO-BIOTECHNOLOGY AND ITS INTERACTIONS.

of diverse organisms have been reported and 10,337 sequencing projects have been carried out (GOLD, 2011). Similarly, sequencing tools have opened up the possibility of sequencing communities (metagenome) of complete organisms with no need to isolate them, which will have a huge impact on agriculture. At the present time, 249 metagenomes of 323 reported projects have been analyzed (GOLD, 2011).

IICA's position on agro-biotechnology

With the aim of "strengthening the development and safe use of agro-biotechnologies as a key tool for improving the productivity and competitiveness of the agricultural sector and the sustainable use of genetic resources for agriculture and food security" (IICA, 2010), the Biotechnology and Biosafety Area of IICA has committed to providing technical, impartial, updated and scientifically validated information on the progress, benefits and risks of biotechnology. In this way, it is hoped to provide support to the governments of IICA Member States through information that allows the creation or the strengthening of institutional frameworks and the formulation of biotechnology and biosafety policies and strategies and consequently, contribute to the support for decision making processes relating to the responsible and efficient use of the different agro-biotechnology tools.

Based on this line of thought, it is IICA's responsibility to provide the public with technical knowledge, in order to make concepts clear and indicate the technological advances with the potential to contribute to making agriculture efficient, sustainable and environmentally friendly. Consequently, at the request of the governments of its Member States, IICA is seeking to strengthen institutions that carry out activities related to biotechnology and is interested in supporting technical-scientific, capacity-building processes in agro-biotechnology (in a broad sense, as shown in this document). Furthermore, the Institute wishes to demonstrate that most agro-biotechnology tools are compatible with different types of agriculture and therefore, farmers (small and medium size) are called upon to explore the potential of agro-biotechnology and make it a reality for their own and their families' advantage.

With respect to IICA's position regarding the use of modified living organisms (MLOs) obtained through transgenesis, IICA presents information, but neither takes sides nor participates in the sovereign decision of the countries to adopt or not such technology (CBD, 1992). However, in terms of transgenesis technology, IICA is in favor of the implementation of regulatory frameworks on biosafety by the countries (Cartagena Protocol, 2000), regardless of their position in support of or against MLOs, since these represent tools that guarantee the sovereign decisions of the States.

Final considerations

The rapid growth in the world population (UN, 2008) and the increasing food and industrial requirements (fuels, medicines, fibers, etc.) resulting from it, the alteration of arable lands (FAO,

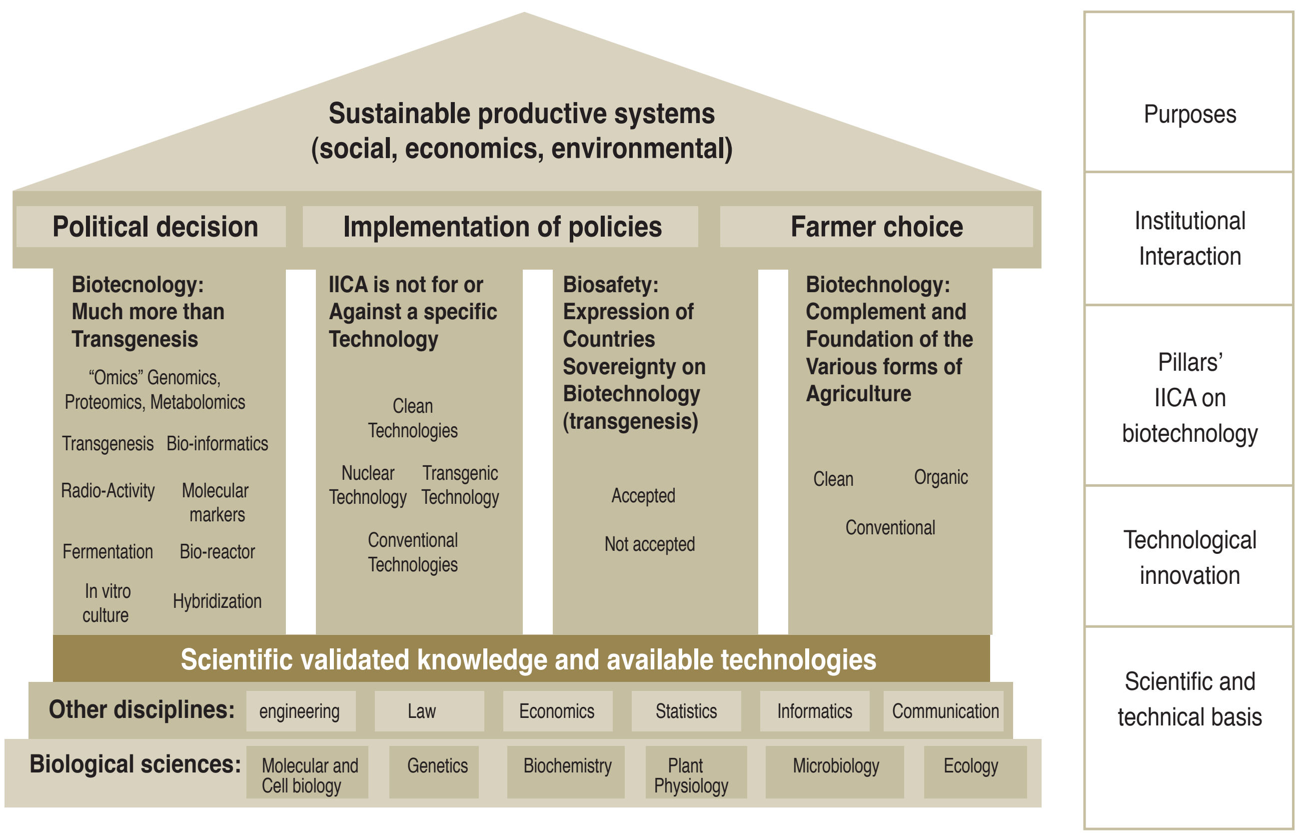

Figure 2. Statements that sustain IICA's actions and position on biotechnology

2011), the pressure caused by water availability, and the multiple current and potential effects of climate change (IPCC, 2001) make it necessary to adjust agriculture rapidly and efficiently to these and other forthcoming challenges.

In the previous paragraphs, agro-biotechnology was described as a box of solid tools (or techniques) that do not belong exclusively to any science, discipline or sector, but can interact with each other and contribute to facing the challenges mentioned before.

It is worth mentioning that, even if numerous and varied biotechnology techniques have been available for several years, some people associate agro-biotechnology only with MLOs or transgenic organism production, which has misinformed users and polarized agriculture into two main types: organic agriculture and MLOs-based agriculture. In keeping with the regulations governing organic production in the countries, organic agriculture does not allow the use of the transgenesis and ionizing radiation biotechnology tools[4]. However, organic agriculture, agroecology and the other forms of agriculture have always used and will continue to make routine and efficient use of all biotechnology techniques available (hybridization, in vitro cultivation, fermentation, compost, biological control, etc.).

In conclusion, agro-biotechnology has generated significant changes in production methods and supply of new products. As a result, there are more opportunities for technology to contribute to solving not only agricultural problems in particular, but also humanity's in general. Nevertheles, technology in and of itself is not good enough. As a matter of fact, in order to create a meaningful impact and achieve the development of rural communities, science, research and technology, along with timely and correct political decision-making, as well as implementation of such decisions, should be the mainstays of sustainable productive systems at the social, economic and environmental levels. However, we will need to act rationally, maturely and in a timely manner. IICA, as the House of Agriculture in the Americas, is willing to support all the different processes required to achieve this goal.

[4] Further information can be found on the Inter-American Commission on Organic Agriculture (ICOA) web site http://www.agriculturaorganicaamericas.net

Table 1. Description, achievements and status of some agro-biotechnology techniques in LAC

Technique	Date of introduction	Description	Achievements	Status in LAC
In vitro cultivation	1968	Allows cell and tissue cultivation in culture media. Important for basic (physiology, phytopathology, etc.) and applied research. Works as a germplasm conservation tool. Useful in productive processes such as: elite material cloning, plants massive propagation and material cleaning. Essential for transgenesis.	*In vitro* techniques have been applied in almost all plants of agronomic interest.	Routine use, with corporate outlook for plant species.
Bioreactors	70's	Organisms or metabolite production in closed crops. Technology associated with engineering and productive processes.	Bioinput production (fertilizers, biocides, etc.). Used in food, beverages and biofuel industries.	Routine and industrial use by most biotechnology-based enterprises.
Molecular markers	1977	Allows the indirect analysis of DNA. Used to carry out genetic diversity analysis, the creation of genetic maps, gene identification, assisted selection and diagnostic systems.	Numerous studies on genetic diversity. Marketable varieties issued. Diagnostic kits available.	Frequently used for academic purposes.
Transgenesis	1980	Allows gene insertion and expression from one organism to another. Transcends natural reproductive barriers. Requires genes, transformation, regeneration and regulation systems. Is the basis of metabolic engineering.	Technique standardized practically in all crops of trade interest, although only few of them are marketed (soy, cotton, rape and corn). Not approved by organic agriculture.	Up to 2010, ten LAC countries possessed marketable cultivations of genetically modified crops.
Genomics	1976 (beginning)- 2000	Groups high efficiency techniques (reduction in the number of analyses and in time and cost). Requires expensive infrastructure and highly qualified staff. Simultaneous detailed study of genomes or multiple gene sequences. Based on DNA sequencing.	10,337 sequenced genes and 323 metagenomes developing.	Incipient development, although Brazil becomes the global leader of this application in agriculture.
Proteomics	2000	Sequences proteins and carries out functional trials.	Developing.	Poor development.
Metabolomics	2000	Metabolite identification and isolation.	Remarkable experience in molecular characterization and isolation.	Incipient development.
Bioinformatics	1962 (beginning)	Devoted to the management (compilation, analysis and use) of a great deal of biological information. Includes the management of databases, annotation, DNA sequencies and aminoacid analysis, biological systems modeling, and image analysis.	World databases including several billions of genes and protein sequences.	Growing development.

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