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AGRICULTURE IN THE TWENTY-FIRST CENTURY: The role of transgenic plants in the technological development of agriculture

Introduction

There is considerable agreement among forward-looking organizations regarding the forces that are forging nations in the twenty-first century. Two are economic globalization and the geopolitical movements to form strategic and trade alliances among groups of countries. The third is human knowledge, through science and technology. A trend that will bring about a sea change in the situation worldwide is the full development of the biotechnology revolution to agriculture. The marketing of genetically modified products resulting from the use of the new biotechnologies will not only contribute markedly to boosting production and productivity, it will also alter the very characteristics of agricultural supply.

We are presently living under three superimposed paradigms: a fading industrial era, a developing information technology era (due to the production of low-cost, high-capacity chips), and the biotechnology era, which stemmed from the 1956 discovery of the structure of DNA by J. Watson, F. Crick, R. Franklin and M. Wilkins. That era was consolidated in the early 1980s with the discovery of the action of restriction enzymes and ligases, giving rise to recombinant DNA technology. Through this technology, it has become possible to isolate, slice and sequence DNA fragments from an organism that has one or more genes that express specific characteristics and incorporate these into the genome of another organism, regardless of whether the donating and receiving organisms are from the same species. With few exceptions, this had been a barrier for natural evolution for millions of years. The marketing of transgenic plants has propelled this technology into a growth stage.

In this period, many biological processes will systematized, and numbers, words, sounds and images have been the four predominating types of information to date. However, information reaches us in different forms, including smell, taste, feeling, imagination and intuition, and in the next 20 years, technologies will be developed that make it possible to commercially systematize these biological processes. The essence of the sense of smell is being rendered digital (as was done earlier with sound and images) by companies such as DigiScents of Oakland and Ambryx of La Jolla, California, which have developed digital smells, and Cyrano Sciences, which is developing a medical diagnosis technology that can "smell" diseases.

The first map of the human genome was completed in June this year. Thousands of scientists all over the world had been involved in this project for the past decade. Two efforts were competing to be the first to finish the work:

- The Human Genome Project, a joint effort by the public and private sectors (US National Institute for Health and the Sanger Centre), funded by the Wellcome Trust, a London-based philanthropic organization.
- The other involved Celera Genomics, a firm based in Rockville, Maryland.

Both programs announced that they had completed the "working draft" of the entire sequence of the genetic code, which consists of a compilation of 3500 million nucleotides: Adenine, Thymine, Guanine and Cytosine, or simply their initials (A, T, G and C). The sequence of these components, which varies depending on the function of each gene, codifies each of the instructions for the sequence of the proteins, which determines physical characteristics and the propensity to certain diseases. The New York Times stated that this was a great step forward - as if private enterprise had announced that it would put a man on the moon before NASA.

Once the genetic map has been concluded, another, even more important stage will get under way: an effort to discover the role played by each of the 60,000 human genes. This will make it possible to identify all genes that are useful for treating diabetes, Alzheimer's disease and cancer, for example. This discovery also raises questions about the use of a technology that deals with the very essence of human beings. One key concern is the patenting of this discovery: should someone own it? Or only those genes that are characterized, i.e., whose functions are identified? Another fear is that increasingly precise knowledge of the genetic code could lead to discrimination in employment and medical insurance.

In three years time, the human genome will have been characterized by Celera Genomics, a company directed by Dr. James Watson, one of the geniuses who deciphered the structure of DNA. According to the New York Times, this can be likened to a private company announcing that it would put a man on the moon before NASA, the United States space agency.

All mergers, acquisition and strategic alliances between pharmaceutical, chemical and seed producing industries will be strengthened by the developments of multinational information science companies. For example, Compac built one of the most powerful instruments for sequencing the human genome. Similarly, IBM launched its Discovery Link, which makes it possible to compare pharmaceutical data bases with molecular nucleotic sequences; it also announced that it will be marketing a new super computer that is 500 times faster than current computers and that will undoubtedly help further genetic research.

The development of new technologies gives rise to controversy, which grows at the same pace as the benefits. The principal problem of the information science era is the possibility of the invasion of privacy. In the case of biotechnology, the main problem will be ethical: for example, cloning, eugenics, the patenting of genes and the identification of hereditary diseases will affect people's decisions to have children. These are some of the issues that are generating controversy.

Conceptual framework

The international community is aware that without biotechnology, it will be impossible to double or triple agricultural output by the year 2050 in order to satisfy the needs of a population of 11 billion. Biotechnology makes it possible to develop products with specific agronomic features such as resistance to herbicides; resistance to pests and diseases (primarily virus, bacteria and fungi); late ripening (to reduce post-harvest loss); and better product quality (to meet consumer requirements). Throughout the world, current research is improving the efficiency and reducing the cost of developing transgenic plants. The use of genetic markers in breeding processes has increased accuracy and reduced the amount of time it takes to develop new cultivars.

Biotechnology can incorporate positive features into crops; it can increase their nutritional content or the possibility of growth under adverse climatic or soil conditions. For example, the natural qualities of some plants to produce seeds without fertilization can be introduced into some crops. In this phenomenon (apomixis), embryos have the same genetic information as their mother plant; in other words, they are clones. This is a very important characteristic because, as opposed to hybrid seed, the grains harvested by the farmers can be used indefinitely as seed.

In regard to joint agricultural-pharmaceutical research, it is expected that in the near future vaccinations that use crops as bio-reactors will be marketed for human beings. Vaccinations against hepatitis B or a medicine for diarrhea will be produced using potato and banana plants; rice genotypes will be produced that are capable of producing beta carotene, a precursor of vitamin A, and a mineral (iron); human genes that express a specific hormone, which cannot be produced by carriers of illnesses such as Crohn's disease, will be introduced into plants.

In agriculture, research is being conducted to develop more environmentally friendly products so as to reduce the use of pesticides and other chemicals used in processing. Some of these products are: cotton plants that produce colored, non-wrinkle and flame-retardant fibers, which would reduce the need for post-harvest dying or processing; poplar trees that require less chlorine and less energy to make paper; ornamental plants that express special aromas; and crops that visibly manifest (with fluorescence) their need for water or that they are under some other kind of stress.

Most of this research is being conducted in the industrialized countries on crops of economic interest to them. Unless the LAC countries want to be left behind in technology development, they must take advantage of these products, but they must make a technical and objective assessment of the possible risks to human health, the environment and agricultural production stemming from their introduction into our tropical ecosystems.

Regional agricultural production indices for the 1990s show an increase in the import-export trade dynamics of agricultural products; in per capita terms, however, the region is exporting less than 20 years ago. Significant changes have occurred in production, with increases in the petroleum sector, fruits and vegetables. There has been a downfall in the production of sorghum, cotton, potato, wheat, cassava and to a lesser degree coffee, rice and beans. These changes in the structure of production have occurred primarily through increases in the area cultivated (a total of 23 million hectares over the past 22 years) and greater agricultural specialization in the Southern Cone countries.

The global setting, characterized by economic liberalization, geopolitical integration, the struggle against poverty, and the strategic importance of the generation of knowledge, oblige the countries, especially developing countries, to make substantial efforts to adjust to this new world order.

The Western Hemisphere, and the LAC region in particular, is foremost in the world in terms of biological diversity. The Amazon Basin alone is home to more than 90,000 different species of higher plants, 950 of birds, 300 of reptiles, more than of 3,000 of fish and about 500,000 of insects. This wealth is being threatened by the gradual destruction and degradation of humid tropical forests, plains, coral reefs, wetlands and other natural habitats.

The LAC region is a center of origin, diversity and domestication of numerous plants that feed humanity including: the potato (Solanum tuberosum), sweet potato (Ipomoea batatas), corn (Zea mays), tomato (Lycopersicum esculentum), bean (Phaseolus vulgaris), cassava (Manihot esculenta), peanut (Arachis hypogaea), pineapple (Ananas comosus), cocoa (Theobroma cacao), pepper (Capsicum annum, C. pubescens and C. frutecens), papaya (Carica papaya) and blackberry (Rubus glaucus), among others.

This biodiversity is a key aspect of the pharmaceutical, food and agrifood industries; it is also an indispensable resource for farmers that select and cultivate species appropriate to their individual production, environmental and cultural needs.

The challenges and opportunities facing the countries of the region are great, given the importance of agriculture in their gross domestic products (GDP) and their rich natural resource base, especially of flora, fauna and microorganisms essential to the pharmaceutical and food industries.

The application of these new technologies can cause imbalances of an ecological, socioeconomic and institutional nature. The impact of some can be prevented through legally binding international commitments, such as the Cartagena Biodiversity Protocol; others will be harder to control, such as in the case of tropical export crops substituted by others produced in different climatic zones.

The marked impact on the production and productivity of commercial crops has produced well-known benefits but also considerable controversy regarding the likely adverse effects on technical change, natural resources, environment, trade and human health.

Adoption of transgenic crops

In 1996, 2.8 million hectares of land were planted to transgenic crops; in 1997 that figure increased fourfold to a total of 12.7 million hectares; in 1998, 27.8 million hectares were planted to transgenic crops, 74% in the United States. By 1999, the figure had reached 39.9 million hectares. This last figure holds true for 2000.

Factors of concern regarding the introduction, use and marketing of modified living organisms (MLOs)

Because the introduction of any new organism into an ecosystem carries a potential risk, the release of MLOs into the environment requires careful supervision and monitoring, especially if it takes place in countries that are a center of origin and diversity of cultivated species, such as in LAC.

While some of the countries of the region have mechanisms in place to regulate biosafety, most do not. Of even greater concern is the fact that most countries do not have the multidisciplinary technical capabilities needed for conducting risk analysis and management in a methodological, regulatory, modern and effective manner, so as to be able to tap potential benefits, ensure compliance with the safety requirements in order to protect the environment, human health and agricultural production, and equitably distribute income among the population.

The main concerns expressed throughout the world with regard to the use of transgenic plants are:

Religious: regarding the consumption of MLOs that contain the genes of animals for which religious restrictions exist.

Ethical: regarding the use of MLOs that contain copies of human genes; human vegetarians raise a similar objection regarding animal genes incorporated into plants.

Political: regarding national development or internal decisions of the countries

Socioeconomic: regarding the fear that private ownership of these technologies can affect poorer countries through substitution of their basic export commodities.

Ecological: regarding the possibility of creating new weeds, damaging species which are not the object of control, upsetting the populational equilibrium of biotic communities and ecosystems, losing and eroding genetic resources, and reducing crop diversity.

The positions taken with regard to transgenic products are radical. Some people believe they should be banned; others claim they are harmless and that marketing thereof should be under no control. The soundest ecological position, however, is that a case-by-case multidisciplinary analysis be the norm until sufficient experience exists on future effects. This position has been taken by the European Community, many of the industrialized nations and Colombia, following the recent adoption of relevant regulations by the Colombian Agricultural Institute (ICA).

Risk and risk evaluation criteria

In general, it is considered that organisms improved by conventional means are relatively safe, while transgenic organisms, because of the nature of their modification, could in time affect the ecological equilibrium. The ecological viewpoint therefore provides a broad and sound base for evaluating risk and regulating biosafety.

The attitude toward risk

The importance of risk control policies for biotechnology in order to evaluate the possible adverse impact of MLOs is only recently being recognized. The stages of formulation, implementation and control must still be dealt with, before we can really say that the problem of biosafety is being addressed in a priority manner.

A risk control policy is also affected by the attitude toward risk, which can be reduced to three:

Avoid risk: This is a negative attitude in which the worst is expected. It is defended by skeptics, persons who are intolerant, who cannot stand uncertainty and feel they must have exhaustive information before they can make a decision or take action.

Prevent risk: This approach is technical in nature, and is based on the ability of experts to calculate the negative impact of modern biotechnology. There are two kinds: a) cautious calculation, which is prudent and cautious and seeks to avoid risk if there is no clear evidence of sufficient benefits to balance the associated costs; and b) bold calculation, which is a more optimistic approach, one that has positive expectations for biotechnology, pays certain attention to risk and assumes this risk unless there is proof of unacceptable loss or threat of loss.

Seek risk: This approach is proactive and is based on the belief that everything will be all right, that anything is possible. This thinking has shown its devastating power. Science is no longer operating at the level of the possible, but rather at the level of the desirable. Only those who dare to overcome natural forces can innovate and tap opportunities. Good business does not wait.

Risk evaluation, which will be discussed in greater detail below, follows a critical path starting with identification of danger and including evaluation thereof. The path that will be followed will depend largely on the attitude toward risk, and is a direct function of perception-action. The perception of risk is multidimensional, varying from person to person and from context to context: it cannot be reduced to a single value based on the probability of injury.

A risk policy involves confrontation, balance and compromise as the different social actors may not be willing to take the same amount of risk. This is part of cultural diversity.

In this context, risk is defined as uncertainty in the face of a potential threat to the environment associated with the management and release of transgenic plants, as the probability of the occurrence and magnitude of impact are assumed to be unknown.

Risk is expressed in quantitative terms according to the basic equation: risk is equal to the probability of occurrence times the magnitude of impact. Scientific risk evaluations are a practical way (precautionary approach) to assess the possible environmental impact of MLOs. The issue of biosafety relative to MLOs can be approached from several angles, but from the environmental and agricultural perspective, the key point is the decision making process that results in prohibiting, approving or postponing the release of a MLO into the environment or in authorizing its release under certain conditions and possible future deregulation.

It is of vital importance to understand that the risks to biological diversity do not wholly depend, either qualitatively or quantitatively, on the MLO or the technology used to produce it. In other words, corn developed to tolerate herbicides can involve a low environmental risk in Canada but it could carry high risk in regions where teocintle, a close relative of corn, grows interspersed with corn in the fields. Accordingly, risk evaluations must be made on a case-by-case basis, taking into account the parent organism, the particular genetic modification, the receiving environment, and the capacity to identify and manage risk.

The decision to release a MLO into the environment must be assessed on a case-by-case basis, using sound scientific, multidisciplinary, professional and ethical criteria. The risks assumed should be balanced and should be outweighed by the productive, economical and environmental benefits to the ecosystem. In conducting comprehensive assessments of this nature, it is necessary to have biotechnology development policies in place that are articulated with agricultural and environmental/biosafety policies.

Risk analysis should involve examination of the following variables:

- ¨ Characterization of the MLO: The biology of the original organism (for example, commercial variety of corn), the identity and distribution of wild parents, the compatibility of their reproductive systems, details on the genetic modifications introduced, stability of the new genetic composition, and known or expected phenotypical consequences.
- ¨ Intention of use: Production, propagation, experimentation, bioremediation, biological control, or industrial processing for consumption. The key point here is to determine whether usage involves an intentional release into the environment, whether release could occur accidentally, or whether release is impossible or unlikely to occur.
- ¨ Receiving environment: If release into the environment is planned, it is important to be familiar with the ecology of the site, the production system (management intensity and crop control), the presence of wild species related to the MLO in the region, and the possibilities of the MLO "escaping" or of isolating it.
- ¨ Risk management capabilities: Information on the three above points makes it possible to identify and estimate the most evident risks. Once this is accomplished, an assessment should be made to determine whether there are sufficient regulatory, technical, financial and ecological capabilities to manage the risks in a satisfactory manner, in order to prevent them or reduce them to the absolute minimum

The National Regulatory Framework: Brief reference to Colombia

The safe use of genetically modified organisms (GMOs) requires the committed participation and action of different bodies: the ministries of agriculture, health and the environment and their related agencies; representatives of the scientific community; civil society; agricultural producers; nongovernmental organizations; commercial firms, and others.

In this framework, the Colombian Agricultural Institute (ICA) is responsible for developing the institutional capacity for evaluating and managing risks in agricultural production associated with the introduction, export, management and marketing of transgenic organisms.

At the national level, the ministry of agriculture and its agricultural institute (ICA), cognizant of the importance of this issue, carefully reviewed and analyzed the standards and regulations of more than 25 countries of different continents in national and international fora, with the participation of the scientific community.

On that basis, it established two basic regulatory instruments in its area of competence: Agreement 13, dated December 22, 1998 and Resolution 3492, passed on that same date. These instruments set out the rules for introducing, producing, releasing into the environment and marketing transgenic organisms used as planting material.

The above explanations make it clear that Colombia must continue, firmly and persistently, to develop and improve the existing regulatory instruments in conformity with international agreements on the matter that have either been signed or that will be signed in the future, with a view to preventing or minimizing possible risks stemming from the management and use of transgenic products in our territory.

In Colombia, although the commercial planting of transgenic crops has not yet been authorized, requests have been received for authorization to conduct experimental field trials in small areas, under strictly supervised conditions, relative to the production of reproductive materials for carnations, cotton, coffee, cassava, fodder and potatoes.

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