Current Activities on Field Tests and Safety Issues in South American Countries.

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Abstract

In South American countries, like in many developing countries of the world, biotechnology is an area of research that is seen with much hope, some respect and sometimes terror because of the safety issues that concern the area and are not completely understood. In technical grounds, many countries are beginning to develope their capabilities to work on such approaches and also many are developing their respective legislation in regard to biotechnology products, field tests of such products, and their releases when and if they are eventually approved. Private investments in biotechnology research in those countries are often limited and research priority setting for public investments is mainly done by representatives and experts of national government with the occasional help of international agencies and experts. In agriculture, most of the released transgenic crops are herbicide-resistant plants and a few are improved for disease or insect resistance and product quality. There is a large concern and much misunderstanding about the potential risks of transgenic releases in "centers of diversity"(many of the South American countries are). The present paper draws some information from a so far unpublished survey conducted by Dr. Claudia Golz, FEDA (German Federal Environmental Protection Agency), made available to the REDBIO (FAO Network for Biotechnology in Latin America). The status of biotechnology research for agriculture, biosafety legislation and data on field tests of transgenic plants in South American countries is presented. There were already more than 60 releases in South American countries, the great majority of them in maize, mainly made by private companies (most transgenics are herbicide-resistant : glyphosate and glufosinate resistance).

Introduction

South American countries comprise 12 independent nations and one colony (French Guyana), which are mostly Spanish speaking and have similar backgrounds. Such nations are Brazil, Argentina, Uruguay, Paraguay, Chile, Bolivia, Ecuador, Peru, Colombia, Venezuela, Suriname and Guyana. A large area of South America includes the Amazon basin: the largest tropical forest of the world and an area that is largely unknown and rich in biodiversity.

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South America is a region where many important agricultural species originated. All the countries of the region are considered as developing countries although there are large differences among them and even among regions within them, in the degree of development, relative poverty and education of the population, organization and sophistication of their research system, industrialization, financial support for research, legislation, etc.

Another factor to be considered is the recent implementation of the first regional common market in the area (Mercosur), involving Brazil, Argentina, Paraguay, Uruguay and more recently, Chile. The whole process is being developed at this moment and market regulations are being reviewed and adjusted in order to make them compatible among countries.

There has been a large investment, in most countries of the region, to develop better qualified human resources. The number of highly skilled professionals in almost all areas of research has increased substantially in the last 20 years although the availability of financial resources (support) to such professionals is not at levels that are considered adequate.

Biotechnology includes tissue culture, micropropagation and all related techniques, as well as molecular biology, biochemistry, and genetic engineering. Like in the rest of the world, including the utilization of tissue culture, biotechnology in South America began around 20-25 years ago. Biotechnology was seen a few years ago, as some sort of "panacea" (the universal medicine for all diseases), by the molecular biologists and biochemists, and with disdain and mistrust by the breeders and agriculturists. These two groups did not interact because they did not share a common language.

Besides, there was also the science fiction view that biotechnology would produce whatever the researcher wanted, simply by making new gene constructs and introducing them into organisms. Only recently, even in developed countries, has biotechnology begun to be seen as a powerful new tool to be used by almost all branches of biological sciences, either to improve the understanding of basic principles, or to directly generate new products. However, to achieve such results, it has to be associated with other areas of scientific knowledge.

Another major development to be considered in order to set the stage for the present discussion, is the growing recognition in the popular and scientific press and international conferences, of the increasing threats to Earth's biodiversity (Fowler and Mooney, 1990). Species are being lost at an alarming rate but local populations and land races are being displaced everywhere at a faster pace than the rate of extinction (Ehrlich and Dailey, 1993). The disappearance of local populations and land races, represents a loss of important genetic diversity that could be useful to improve crop adaptation to environmental variation. Such losses, together with species extinction, can potentially threaten human survival on Earth.

In the last decades, releases of improved varieties of plants and animals and the virtual disappearance in some areas of the original variability of some important agricultural species, led to new discussions on the subject, with the additional concern related to the release of genetically modified organisms, and resulted in the inclusion of article 19 in the Convention on Biological Diversity, which specifically relates to the issue of transgenic organisms.

Biotechnology research and transgenic releases in South America

Some South American countries are already working at the forefront of research in almost all areas that relate to biotechnology in food crops, animals and microorganisms. Such is the case of Brazil and Argentina just to mention some examples. Most of the others are not working in the full range of biotechnology issues, but tissue culture is a common practice.

Research, in many South American countries is mainly carried out at Research Institutes, State Institutions and Universities (government support). Private research, mainly by seed corporations or agrochemical industries, is also important in some countries.

Research investments by most governments are low and a large concentration of those is directed to the development of human resources. Such investments are relatively unbalanced: biotechnology has taken "the lion share" in many cases, with areas of related fundamental interest being relatively neglected and until now there were special lines of funds just for biotechnology. It is the fashion and the fad of the governments in the region. Since biotechnology has not achieved large breakthroughs so far (which is impossible in the short term), policy makers have started to feel that the promise may be larger than the reality. Funds which were never adequate, may begin to decrease. Additionally, a few private companies that had invested in the development and setting of laboratories for crop improvement using those new techniques, have reached the conclusion that they are very expensive to maintain and the results are not as striking as they expected. As a result, at least MONSANTO in Brazil, decided to close its biotechnology laboratory and donate their equipment to Universities. On the other hand, companies dealing with microorganisms for medical purposes seem to be prosperous.

Biotechnology research in South America is largely concentrated in areas related to agriculture and medicine. Research objectives (priority setting for funding) are usually formulated by government representatives with the assistance of national and international experts.

Plant biotechnology has been mainly applied to: 1) micropropagation of some high value crops; 2) bacterial nitrogen fixation in leguminous species; 3) characterization and preservation of genetic resources;4) utilization of anther culture and somaclonal variation for breeding; 5) genetic engineering.

In livestock production, biotechnology has concentrated its efforts on the development of diagnostic methods, diagnostic kit, "*in vitro*" fertilization, embryo transfer, production of pathogens and manufacture of vaccines (Villalobos, 1995).

Most of the genetic engineering activities are concentrated on the production of plants resistant or tolerant to a variety of biotic or abiotic stresses, and microorganisms that produce some natural hormones, antibiotics, or some compounds for medical purposes. Paradoxically, herbicide resistant plants account for the majority of released transgenic crops because research is carried out by transnational companies outside the region, with the final tests, when legislation allows, being carried out in the specific countries. Therefore, the pattern of releases does not reflect the research interest of the national institutions. According to a survey conducted by Dr. Claudia Golz, from the German Federal Environmental Protection Agency (FEPA), that had not been published up to now, but was made available to REDBIO (FAO Biotechnology Network for Latin America and the Caribbean), more than 60 releases (Table 1) were already made in South America, mostly in Argentina (42), followed by Chile (17), Bolivia (5) and Peru (2). All the other South American countries have not reported official releases so far. Some of these numbers still need confirmation and may not be exact because the survey has not been completed yet. Regarding herbicide resistance, the most common includes resistance to glyphosate and glufosinate. For insect resistance the most commonly used is the *Bacillus thuringiensis* toxin. In terms of product quality, it is the "flavor saver" for tomato, but in other cases there is no information.

Countries where neither technical guidelines nor a legal framework for risk assessment existed until very recently are the ones that do not report any transgenic release so far.

Biosafety concerns

In the South American countries there are similar concerns to those expressed by populations of developed countries when it comes to the release of transgenic plants, since the subject is usually misunderstood by the general public, in both situations. Within the scientific community, in South America as well as in the entire American Continent, a great additional worry refers to the potential damage derived from the release of transgenic plants in a center of origin/diversity of important crop species.

Common bean, potato, tomato, cocoa, peanuts, pineapple, rubber tree, cassava, are just common names of a few species originating in those countries. Discussions centered only on transgenics, do not reflect the real dimension of the possible damage that can be caused to the environment, whenever the introduction of an exotic genotype occurs in an area of great diversity of a certain crop.

Since the past century, plant and animal breeders have utilized the wealth of genetic resources of land races, ecotypes and varieties for the improvement of their target species. They sought the understanding of the evolutive history of the domesticated species in order to capture some of the useful genetic traits from their wild ancestors. Species were grouped according to their relatedness and the possibility of obtaining fertile descendants from crosses among them, in primary , secondary and tertiary gene pools.

Although breeders valued the possible contribution of genes from wild ancestors and other species in the same gene pool, most of them have avoided using these genotypes due to traits related to adaptation to cultivation (domestication) which are not usually present in the wild germplasm. Such genotypes, besides the trait that the breeder is interested in, usually bring some disruption to the genome equilibrium and to adaptation to cultivation. The breeders' work results in new improved genotypes that belong to the same gene pool as before in addition to new combinations of traits that better suit their needs. Those individuals do not have in their genome any stretch of DNA that has not appeared in the gene pool before.

Biotechnology techniques allow the breeder to create combinations that would not be possible using the regular procedures, because the species being improved and the gene source may belong to unrelated taxa or even to different natural kingdoms (Kareiva, 1993).

More important than ever before is to understand the available diversity and its function. It is now possible to dream about solving all problems of providing humanity with adequate food supply, clothing, wood, fiber in a more efficient and less polluting way with the utilization of less fertilizers and pesticides.

The Ecological Society of America (ESA) produced a document with the objective of providing rigorous support for the development of a biosafety policy on a solid scientific basis, to encourage innovation without compromising the adequate and safe management of the environment. In such document, six types of evolutive and environmental concerns related to the potential risks of the new biotechnology methods to the environment and to biodiversity are listed (Tiedje *et al.*, 1989). The potential risks are: 1) the creation of new weeds; 2) the amplification of existing weeds; 3) damage to non-target species; 4) the perturbation of biotic communities; 5) adverse effects on ecosystem processes; 6) waste of precious biological resources. Such aspects will be briefly discussed in the following topics.

Creation of new weeds or amplification of the effect of existing weeds

Domesticated crops are defined as such, due to their dependence on human activities for survival. It is highly unlikely that such crops turn into weedy forms in any ecological systems. This is the case of maize, wheat, and others. Other species, although being cultivated, are not considered as domesticated and maintain many of the weedy traits that are usually lost during domestication. They usually keep those traits of dispersal and aggressiveness and they can, if left alone, revert to the weed condition. Many times they are considered as weed in one situation and as crop in another. Some forage crops like *Brachiaria* spp., *Pennisetum* spp. and some grasses, such as sorghum, can be mentioned as examples (Fontes *et al.*, 1996). Some other crops are either closely related to some weeds or have evolved from them. In regions where crops and their wild forms coexist (centers of diversity), frequently the wild form is a weed for the crop or for other crops.

It is considered that the probability of a cultivated plant to become a weed is very low, even if genes for more aggressive behavior are built in their genomes. However, Glidon (1995) reported about the new weed originating from the introgression between cultivated sugarbeet (*Beta vulgaris* spp. *vulgaris*) as female progenitor, or cytoplasm donor, with the wild *B. vulgaris* spp. *maritima* as male. The weed is *Beta vulgaris* spp. unknown.

On the other hand, the probability for weeds to acquire genes from related crop species and to increase their range of adaptation by invading new habitats, is a real possibility and is considered to be the main ecological risk arising from transgenic plants, animals and microorganisms (Tiedje *et al.*, 1989; Ellstrand and Hoffman, 1990; Hoffman, 1990; Klinger *et al.*, 1991, 1992; Mikkelsen *et al.*, 1996). Individuals may acquire such genes from transgenics through natural hybridization followed by backcrossing to one of the parents. This is a natural phenomenon that occurs very often in nature and is called introgression. If a weed species acquires, from a related transgenic plant, traits such as disease or insect resistance, natural selection will favor the increase of such trait in the population and that species will become more weedy. For introgression to occur, a few natural pollinations with fertile hybrid plants are sufficient.

Natural introgression has been found to have occurred among many species such as maize (*Zea mays*) and teosinte (*Zea diploperenis,Zea perennis* and *Zea luxurians*) from which some weedy forms were recorded (Cowell, 1994, cited by Fontes *et al.*, 1996). Recently Mikkelsen *et al.* (1996) have reported on the herbicide resistance gene for glufosinate, which was introduced into oilseed rape (*Brassica napus*). Spontaneous hybrids were formed between *B. napus* and the weedy *B. campestris*. These hybrids were generally sterile, but after only one backcross generation, they could become fertile plants with *B. campestris* morphology but bearing the transgene. Such a "transgenic" weed, at least while the herbicide is being used, will have an enormous advantage over other plants.

Herbicide resistance accidentally included in a weed is not the worst possible scenario and could be an advantage for these plants only when the herbicide was used. More worrisome would be the accidental transfer to weeds, of genes for cold, salinity, drought tolerance, disease or insect resistance, because any of those would increase the range of adaptation of the weed and its competition with the crop species.

Damage to non-target species and waste of biological resources

The elimination of wild or naturalized species and land races by competition or interference is possible, but it also occurs when a new improved cultivar, or an exotic genotype, is introduced into a region. In the case of transgenes, possibilities that come to mind are those arising from the utilization of the gene for the toxin of *Bacillus thuringiensis* to increase insect resistance in plants. Such toxin that is effective against butterflies, will affect those that are plague to plants as well as others which should be maintained.

Disruptive effects on biotic communities and processes in the ecosystem

The relative abundance of species and the spatial structure of natural communities depend on a complex equilibrium among individuals that can be broken when some of them acquire traits that make them particularly efficient as competitors, predators, parasites, symbionts, hosts or especially efficient to avoid competition, predation or parasitism. Equally disturbing results may be obtained through transgenes or through regular breeding, if adequate care is not taken and careful considerations on the ecology are not observed before release. It is well known that regular human economic activities may be even more disruptive to natural habitats than the mentioned situations, but care must be taken in order to avoid additional damage.

Biosafety legislation

Some South American countries are either in the process of developing legislation or technical guidelines. A few countries already have one or both of them in place. Brazil just began to implement them in the beginning of 1996 (Table 2). For most of them there is no clear information, but there is a tendency to develop compatible legislations among countries.

As a result of the meeting for establishing the REDBIO, in December 1991, a workshop was held in Santiago (Chile) on the Code of Conduct for Plant Biotechnology (Villalobos, 1995). In 1992 a proposal was approved for a subregional program for the development and harmonization of biosafety guidelines for the Southern Cone Countries (Brazil, Argentina, Paraguay, Uruguay and Chile), prepared by IICA (Interamerican Institute of Cooperation for Agriculture) and the Cooperative Program for Agricultural Research of the Southern Cone (PROCISUR). The first activity of the subregional program was a workshop on transgenic plants (IICA, 1992), which resulted in ten recommendations, as follows (IICA, 1993):

1. In short term, to create regulations for the introduction and release of transgenic plants in the countries which were represented in the workshop, based on the existing regulations on quarantine, seeds and other related aspects. Such regulations should be directed to the products related to the proposed use, taking into account the procedure for obtainment that may be hazardous to the environment, to agricultural production or to public health.

2. The respective Ministries or Secretaries of Agriculture,which are responsible for the legislation, approval and monitoring of field tests and commercialization of transgenic plants will appoint the institution which will be entrusted with these responsibilities.

3. To create at the national level, an office for consultancies and technical support, with a committee to assist the appointed institution in the development and administration of the regulation for the introduction and release of transgenic plants. External "*ad hoc*" experts and subcommittees may be utilized when convenient.

4. The committees to be created, should include qualified representatives from different sectors involved in vegetable biotechnology such as institutions from the Ministries of Agriculture, Science and Technology, Health, Environment, National Research Institutes, private enterprises, consumer defense institutions and their equivalents.

5. The costs incurred by the evaluation and follow-up of field tests with transgenic plants should be borne by the institution requesting such a service.

6. The requests for permission to conduct field tests should be evaluated in an adequate period of time for the experimental needs, never beyond four months from the time of the original request.

7. The responsible institution should define the type of information considered confidential and develop the required mechanisms in order to guarantee such confidentiality. The institution requesting the service will indicate that the information should remain confidential.

8. The evaluation of the requests for field tests should be made according to the following set of criteria:

1) The ecosystem where the test will be conducted:
   (1) Determining the national experience with the referred crop, the existence of related plants and the location of active germplasm banks.
   (2) Evaluating the consequences of the potential establishment and persistence in the ecosystem.
   (3) Determining the possibility of exerting adverse effects on other organisms in the environment (the impact on competition levels of competitors, predators, hosts, symbionts, parasites,pathogens, etc.)
2) The biological properties of the organism: Evaluation of the possibility of escape, genetic run away, pathogen movement, pollen dispersal, genetic stability of the plant to be tested in relation to its biological characteristics, etc.
3) The existence of previous experiences in other countries or other geographical regions in the field tests that are proposed and evaluation of the possibility to extrapolate the results to the local conditions of the test.
4) The possible effects on human health in relation to the safety of field laborers involved.
5) Evaluation of the possibility of implementation of biosafety measures (infrastructure, inspections, etc.).
6) the existence of control measures for a potential escape of the organism.

9. The requests to obtain permits for field tests with transgenic plants should contain at least, the information requested in the related document (characterization of the researcher in charge, institution, transportation procedures for the material, characteristics of the material, origin with the description of technical procedure,

schedule for the test, effects, etc.).

10. To prioritize the information to the public opinion based on the following criteria:
    1) To inform all public sector institutions involved in vegetable biotechnology, general public and political instances about the field tests with transgenic plants.
    2) The information should emphasize the potential benefits as well as the potential risks in appropriate terms for each level of public.
    3) The general public should have access to the data banks about such field tests with transgenic plants, except for confidential information.

In conclusion, there is a general tendency to harmonize regional legislations not only in the Southern Cone countries, but to some extent in all the countries of South America, even though some are ahead of others in such aspects.

References

1) Ehrlich, P. and Daily, G. (1993) : Population extinction and saving biodiversity. AMBIO **22**:64-68
2) Ellstrand, N.C. and Hoffman, C.A. (1990) : Hybridization as an avenue of escape for engineered genes. Strategie for risk reduction. BioScience **40**:6:438-455.
3) Fontes, E.G., Sujii, E.R., Batista, M.F. and Fonseca, J.N. (1996) : Biossegurança *In*: Workshop "Biodiversidade" : Perspectivas e Oportunidades Tecnológicas. Campinas, 29/04 to 01/05/96. 16 p.
4) Fowler, C. and Mooney, P. (1990) : Shattering: Food, politics, and the loss of genetic diversity. University of Arizona Press, Tucson, Arizona.
5) Glidon, C. (1995) : The potential role of monitoring in risk assessment and in fundamental ecological research. *In*: Pan European Conference on the Potential Long Term Ecological Impact of GMO's. Environmental Encounters N. 20. Council of European Press.
6) Hoffman, C.A. (1990) : Ecological risks of genetic engineering of crop plants. Scientific and social analyses are critical to realize benefits of the new technique. BioScience **40**:6:434-437.
7) Instituto Interamericano de Cooperacion para la Agricultura (1993) : Harmonizacion de la Bioseguridad en el Cono Sur: Supervision de Plantas Transgenicas. Conclusiones y Recomendaciones del Taller de Trabajo, Buenos Aires, Argentina, 16 to 20/11/92, IICA, San Jose, Costa Rica, 24p.
8) Kareiva, P. (1993) : Transgenic plants on trial. Nature (363) 580-581.
9) Klinger, T., Elam, D.R. and Ellstrand, N.C. (1991) : Radish as a model system for the study of engineered gene escape via crop-weed mating. Conservation Biology **5**:531-535.
10) Klinger, T., Arriola, P.E. and Ellstrand, N.C. (1992) : Crop-weed hybridization in radish (*Raphanus sativus*): Effects of distance and population size. Ameri. Jour. of Bot. **79**: 1431-1435.
11) Mikkelsen, T.R., Andersen, B. and Jþrgensen, R.B. (1996) : The risk of crop trans-

gene spread. Nature **380**(6569) 31.

12) Tiedje, J.M., Colwell, Y.L., Grossman, R.E., Hodson, R.E., Lenski, R.E., Mack, R.N. and Regal, P.J. (1989) : The planned introduction of genetically engineered organisms: ecological considerations and recommendations. Ecology **70**:2:298-315.
13) Villalobos, V.M. (1995) : Current status and future prospects of modern biotechnologies in Latin America and the Caribbean. *In:* FAO. Agricultural Biotechnology in the Developing World. FAO Research and Technology Paper N.6, 122-140.

Table 1 Transgenic plants released in South American countries, by year, reason and company that made the release (from Golz, unpublished data)

Country	Species	N. gen.	Characteristic	Years	Company
Argentina	Cotton	4	HR, IR/HR	1991/92	Calgene
	Cotton	4	IR/HR	1992/93/94	Monsanto
	Maize	5	HR/IR	1991/92/93/94	Ciba Geigy
	Maize	3	HR	1992/93/94	Cargill
	Maize	2	HR/IR/MS	1993/94	PAU/PGS
	Maize	3	IR/HR/Q	1994	DeKalb Genet
	Maize	1	Q	1993	CEFOBI
	Maize	1	HR	1994	AgrEvo
	Maize	1	IR	1995	Pioneer Hi Bred
	Maize	2	IR/HR	1993/94	Monsanto
	Maize	1	IR	1994	Microg./Agric.
	Rapeseed	3	HR/MS	1992/93	Nidera/Hoechst
	Rapeseed	1	Q	1993	Cargill
	Sugar beet	1	HR	1992	Maribo/Agrara
	Soybean	4	HR	1991/92/93/94	Nidera/Asgrow
	Soybean	1	HR	1994	Monsanto
	Soybean	1	HR	1994	Dairyl/DeKalb Genet
	Sunflower	2	IR/Q	1994	Van der Have
	Tomato	1	Q	1995	Calgene
	Wheat	1	Q/MS	1993	CEFOBI
TOTAL		42			
Bolivia*	Cotton	1	HR	1991	Calgene
	Potato	4	Freeze tol.	1991/93/94/95	CIP/IBTA
TOTAL		5			
Chile	Maize**	6	HR/Q	1992/93/94	unknown
	Maize	2	IR/Q	1993/94	Ciba-Geigy
	Maize	1	IR	1994	Pioneer Hi Bred
	Rapeseed**	2	IR/Q	1991/92	unknown
	Soybean	2	HR	1993/94	Pioneer Hi Bred
	Tomato	3	Q	1992/93/94	Calgene
	Sugar Beet	1	HR	1994	Pioneer Hi Bred
TOTAL		17			
Peru	Potato	2	Freeze tol.	1994/95	CIP
TOTAL		2			
General total for region:		66			

*All of which are not readily available

**No information on the company and no confirmation of the release

HR: herbicide resistance, IR: insect resistance,

MS: male sterility, Q: quality

Table 2 Biosafety legislation/regulations in South American countries as reported by Golz (unpublished survey, corrected for the Brazilian situation)

Country	Technical/legal guidelines	Responsible Institution
Argentina	Technical guidelines	Advisory Comm. Agric. Biotech. (CONABIA)
Bolivia	Law in preparation	National Biosafety Committee
Brazil	Technical guidelines and law approved	National Biosafety Committee
Chile	Technical guidelines (law in preparation)	National Biosafety Committee
Colombia	Technical guidelines (law in preparation)	No information
Ecuador	No information	No information
French Guyana	No information	No information
Guyana	No information	No information
Paraguay	No information	No information
Peru	Technical guidelines	CIP Institutional Biosafety Committee
Suriname	No information	No information
Uruguay	No information	No information
Venezuela	No information	No information