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An Overview of the Current State of Agricultural Biotechnology in Brazil

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1 INTRODUCTION

After years of legal debate, the Brazilian Congress passed a law on biosafety (Bill 2401, of March 2003), whereby the country exits from a long-standing state of illegal action, only mitigated by the edition, once every year, of specific Provisional Measures allowing for the cultivation of transgenic soybeans. In the course of these last 8 years, we have lived under a situation that clearly illustrates how it is possible to resort to the detours of the courts with the intent of procrastinating a vital decision, an attempt which, had it succeeded, in the case of biotechnology, would have resulted in a moratorium on transgenic seeds in agriculture, leaving Brazil behind two of its major competitors, the USA and Argentina, which have widely applied this technology in its staple crops of soybeans, maize and cotton, besides canola in Canada.

The enactment of the new Law of Biosafety (Law 2401) by the Brazilian Congress and its sanction by the President of the Republic in March 2005 overcame a major obstruction to the conduction of activities related to modern biotechnology in Brazil. Over these last 10 years or so, the scientific community in this country has gained worldwide recognition for results obtained in genomics and in genetic engineering. In the specific field of biotechnology, Brazil has accrued a respectable know-how in the course of the 20th century, and has become one of the very few Super NARs in the world, i.e., a developing country with a strong infrastructure in agricultural research. Besides Brazil, other developing countries such as India, China and Mexico are also known as Super NARs (Traxler, 2000).

The recent efforts conducted in Brazil to develop competence in the manipulation of the new technologies are the fruit of a historical relationship in the country between scientific research and the conduction of agricultural activities. Throughout the 20th century, the investment in research, despite the natural advantages of the country, has been a crucial factor ensuring the outstanding performance of Brazilian agribusiness.

Brazil is the only tropical country considered to be a major player on the world's agricultural field. This position has been conquered thanks to many years of scientific research with the aim to enhance the natural advantages of the country: tropical and subtropical climate, savannas (which allow for a rapid expansion of the cultivated area

and fast rise in productivity) and a selected and well-adapted varied germoplasma (a need in view of the great environmental variation). Scientific research has contributed not only to the increase in productivity, but also to an improvement in the quality of the products and in an increased diversification of production. The soybeans crops in the Center-West and the fruit harvests in the Northeast are examples of the contribution of research to diversification.

The acknowledgment of the importance of research to the competitive edge in agribusiness and to the economic development of the country has lead several agents – both public and private – to promote and intensify scientific development in Brazil. The leading position in the Brazilian biotechnology research network is held by the public sector, but it also counts on the participation of several private companies directly involved in the expansion of knowledge and its commercial applications. In the case of genomic research, for instance, several stages of the research have been conducted with the assistance of the private sector.

The public sector in Brazil participates in the research network through three kinds of institutions: public research institutions, public universities, and funding agencies. The progress of research in vegetal biotechnology in Brazil shows that the country is achieving significant results in two main application vectors of contemporary biotechnology: transgenics and genomics.

Transgenic research in Brazil is conducted under the leadership of public institutions, such as the Empresa Brasileira de Pesquisa Agropecuária (*Brazilian Corporation for Farming and Livestock Research* – Embrapa) and a number of universities, with the participation of private domestic and multinational corporations. Research is geared not only to the development of GMOs with 'agronomic properties', e.g. resistance to plagues and tolerance to pesticides, but also to the development of transgenic organisms with changes in the features of the product, as is the case of the research which aims at developing a strain of eucalyptus with a greater cellulose output.

Another field in which Brazil excels is that of genomic studies. Genomic research was initiated in Brazil in May 1997, when the State of São Paulo Research Foundation (FAPESP) set up the ONSA (Organization for Nucleotide Sequencing and Analysis) Network, a virtual genomic research institute initially encompassing 30 laboratories located at several research institutions within the State of São Paulo.

Besides the FAPESP, the Ministry of Science and Technology (MCT) and the National Council of Research (CNPq) are funding several genome projects in the country. In December 2000, they launched the Brazilian Genome Project, with the participation of 25 laboratories of molecular biology, involving all major geographical regions in the country (Dal Poz et al., 2004).

Despite the funding of several genomic studies in the field of human health[1], a significant part of these studies are directed to the solution of problems faced by agriculture. Furthermore, in 2002, the FAPESP began to fund a study of the functional genome of cattle, which may strongly impact on livestock activities in Brazil.

Besides the public sector, the research and innovation network in Brazil also counts on an active participation of the private sector. A survey completed in 2001 by the Biominas Foundation, based on data provided by the Tropical Data Base (BDT) and of the Brazilian Association of Biotechnology Companies (ABRABI) has identified the existence of 304 biotechnology companies in the country, distributed among 10 different market sectors. Out of these 304 companies, 37 are active in the agribusiness sector (Judice, 2004).

A significant part of the biotechnology companies in the agribusiness sector are engaged in the production and marketing of improved seeds, with the participation of major multinational corporations such as Monsanto and DuPont. But there are also companies operating in other fields, e.g. the production of seedlings and matrixes, of inoculants, and biological control (Fonseca et al., 2004).

Despite the existence of a strong R&D network and the fact that Brazil is a major producer and exporter of agricultural products, the dissemination of GMOs in agriculture lies very much behind that of the competitors on the world market, such as the USA and Argentina. In 2003, the production of GMOs in Brazil represented only 4% of the world production. Furthermore, RR soybean was the only transgenic crop produced in the country, although Brazil is also a major player in maize and cotton (James, 2004).

The main cause of the lingering position held by Brazil as compared to its competitors stems from the difficulties faced in setting up a stable regulatory

[1] The genomic studies network created by the Ministry of Science and Technology and by the FAPESP includes several studies related to human health: the human cancer genome; the genome of the parasite *Schistosoma mansoni* and the sequencing of the genome of the parasite *Leptospira interrogans*, to mention but a few.

framework. Despite Decree n°. 1752, of December 20 1995, which regulated the provisions of the Law of Biosafety, n^{0} 8974, and conferred upon the CTNBio the power to issue final opinions, a suit brought by the Brazilian Consumer Protection Institute (IDEC) and by Greenpeace has halted the production and marketing of such products since 1998.

This state of affairs, however, has not hindered a clandestine dissemination of transgenic soybeans in the country, specially in the State of Rio Grande do Sul. The large volume of the transgenic crop in this state compelled the Federal Administration to issue a Provisional Measure authorizing the 2003 harvest.

In 2004, the area sown with transgenic soybeans in Brazil amounted to 5,160 million hectares, the equivalent of almost 1/3 of the area sown with conventional soybeans. Given the advantages of transgenic soybeans for producers and a possible advancement in the regulatory framework for biosafety, forecasts indicate an increase in the participation of transgenic soybeans in the Brazilian production.

Thus, the recent approval and sanction of a Law of Biosafety, n^{0} 11.105, March of 2005, has created great expectations in several sectors involved in activities related to the field of biotechnology: public research institutions, universities, domestic and foreign private companies and risk capital investment funds.

In the subsequent chapters, we will discuss in greater detail the three aspects presented above. In Chapter 2, we describe the agricultural biotechnology research network in Brazil, focusing on the role of the public research institutions and their relationship with the other agents. In Chapter 3, we describe the institutional environment and its main problems. The subject matter dealt with includes scientific infrastructure, the training of human resources and the legal aspects involved, specially property rights and biosafety laws and regulations. Chapter 4 discusses the major impacts of the dissemination of transgenic soybeans in Brazil, with emphasis on the economic perspective.

2 Institutional Organization of Modern Biotechnology Research in Brazil

The concern with scientific research in Brazil in the field of agriculture harks back to the 19th century, when the first research institutions were set up in the country. But it is specially over these last 20 years that the scientific community, together with sectors of private enterprise and government agencies, has conducted significant efforts to strengthen the research system, both in terms of approaching the knowledge generated in Brazil with the trail-blazing technologies – e.g. genomics and transgenics – as well as in the search for institutional arrangements which will further the dissemination of new technologies.

In the field of scientific research, these efforts have led to the organization of a number of research groups throughout the country and the training of human resources qualified to work with the new technologies. In 2000, biotechnological research in Brazil had the following figures to show: 6,616 researches, distributed among 1,718 groups and 3,814 lines of research. Agrarian sciences held the leadership among the groups, with 1,075 lines of research. A major part of this research was being conducted at public institutions but, over these last years, the participation of private enterprise has been on the growth (Salles-Filho, 2001).

The data shown in Table 1 clearly illustrate the advancement of biotechnological research in Brazil as from the 90's, when the number of research groups created each year practically doubled as compared to the 80's.

Table 1. Evolution of the number of research group´s in biotechnology in Brazil

Year	*Groups number formed per year*
Até 1980	181
1981 - 1985	149
1986 - 1990	229
1991 - 1995	441
1996	89
1997	141
1998	87
1999	90
2000	310

Fonte: Salles-Filho et al, 2001.

The Brazilian biotechnology research network essentially comprises four different groups of agents:

- Public Research Institutions or Key Institutions
- Funding Agencies
- Public Universities
- Private companies

2.1 Key Institutions: Production and Technology Transfer

One of the great advantages of Brazil as compared to other developing countries is the existence of several different research institutions in the agricultural and human health sectors, qualified to act as vectors for the development of modern biotechnology.

According to Silveira et al. (2004), these institutions play the role of key institutions, i.e., institutions with a potential to "undertake an organizational and technological leadership in the process of interaction with other innovation agents (in, but not limited to, biotechnology) in a specific local environment. Thus, in order to attract new companies, it would be essential to develop synergies, training centers for human resources, conduct specific marketing efforts of certain groups of products and attract investments. Finally, these institutions ought to develop competences for interacting with other areas. The *Boston* and *Bay Area* (San Francisco) regions in the USA are successful examples of the organization of biotechnological clusters." (Silveira et al., 2004).

In the Brazilian case, key institutions are dedicated to basic research, to the development of new industrial applications, and several of them actually market their products. Some have pioneered the introduction of biological and genetic research in Brazil and in Latin America.

The foremost Brazilian key institution is the Empresa Brasileira de Pesquisa Agropecuária (*Brazilian Corporation for Farming and Livestock Research* – EMBRAPA), which, since 1992, coordinates the Sistema Nacional de Pesquisa Agropecuária (*National Farming and Livestock Research System* – SNPA), in cooperation with other research institutions and universities.

Besides the Embrapa, several state institutions also contribute to research in agricultural biotechnology in Brazil. Among these, the most prominent is the Instituto

Agronômico de Campinas (*Campinas Agronomic Institute* – IAC), an institution that has been conducting research for the benefit of Brazilian agriculture for over a century.

2.1.1. Embrapa

Embrapa is the major center for tropical agriculture and livestock technology in the world. It was organized in 1973, with the purpose of conducting R&D in agriculture and livestock, and of transferring technologies derived from its research work.

Embrapa has played a fundamental role in the increase in grain crop yields in Brazil. Its research activities were essential to the introduction and dissemination of soybeans in Brazil. A temperate climate crop, soybeans were adapted to the specific climatic conditions of Brazil and this country is currently the second largest producer in the world. Approximately 50% of the area covered by soybean plantations in Brazil employs cultivars developed with the participation of Embrapa. In the case of rice and beans, approximately 90% of the cultivated area employs cultivars developed by Embrapa.

Embrapa has currently 40 research units, 33 of which are directly related to R&D. Another group of operational units is in charge of transferring technologies, service databases, business organization, maintenance of an information and user assistance network.

Embrapa's budget has remained stable since 1994 including expenses on personnel, operations and capital (see Table 2) . However, the exchange devaluation of 1999 and the shock in late 2002 undoubtedly prejudiced the company's buying power in certain lines of research, especially in equipment and imported inputs (reagents, for example). One current problem is the reduction in resources due to compliance with fiscal goals that compromises the company's research activities.

Since 1992, the Embrapa coordinates the National System for Research in Farming and Cattle-Raising (*Sistema Nacional de Pesquisa em Agropecuária – SNPA*). The SNPA includes the Embrapa itself and its several units, the State Organizations for Farming and Cattle-Raising (*Organizações Estaduais de Pesquisa Agropecuária – OEPAS*), universities and federal or state research institutes, as well as other public and private organizations, directly or indirectly concerned with agricultural and livestock research. Approximately 22 state organizations throughout the five major regions take part in the SNPA. Out of these, 7 conduct research in the field of agricultural biotechnology.

Table 2 – Embrapa's Annual Budget (US$ milhões) – 1994-2001

Year	Total personnel	Operational costs	Capital	Personnel	Total
1994	0.70	51.28	28.21	188.21	267.69
1995	0.66	51.28	51.28	199.49	302.05
1996	0.70	72.82	35.38	256.41	364.62
1997	0.64	83.59	34.36	212.82	330.77
1998	0.67	86.67	17.95	208.21	312.82
1999	0.67	85.64	16.92	205.13	307.69
2000	0.68	73.85	28.72	220.51	323.08
2001	0.71	58.46	34.36	222.00	313.33

Source: adapted from Avila and Souza y Silva (2002)
Note: (*) Average exchange rate for December 2000, equal to 1.95 (IPEA)

In terms of the huge success of Embrapa in consolidating a consistent platform of R&D in agriculture that assures the country a minimum strategic capacity to face the great challenges of sustainably exploring its base of natural resources and positioning it as a major player in the international context, one must recognize the difficulties faced in contributing to the inclusion of enormous numbers of farm-worker families into the innovation process. It is also necessary to recognize certain debilities that have affected the country's performance, among which are gigantism, dependence on government funds and the concrete difficulty in articulating the various working units involved in the programs

Research in Biotechnology

Research projects covering genetic modifications are conducted at units 10 (Cerrados), 13 (rice and beans), 20 (maize and sorghum), 27 (soybeans), 31 (wheat) and 33 (Embrapa Genetic Resources and Biotechnology – CENARGEN). Besides research with transgenics, at some of these units projects are being conducted involving genomic technology, genetic diversity analysis, fingerprints, purity in hybrids, use of high performance markers and polymorphisms, etc. The three units in which approximately 30% of their budget is geared to modern biotechnologies – Embrapa Wheat, Soybean, and Maize and Sorghum – conduct collaborative research, specially at Embrapa Wheat and Embrapa Maize and Sorghum for the development of new soybean cultivars (Fonseca et al. 2004).

The Center of Applied Biology at Embrapa Maize and Sorghum already offers the market a genetically modified maize cultivar with improved nutritional features. With the use of bioballistics, the PROM regions, involving genes promoting ORF

regions, where manipulated, whereby the production of the nutritional protein δ-zein, rich in essential aminoacids, was quadrupled. The research team was funded by the PRONEX and the CNPq (Fonseca et al., 2004).

The CENARGEN maintains germoplasma banks for animals, plants and soil microorganisms, pathogenics and biological control. As an entity responsible for maintaining genetic resources, it has provided significant progress in the use of biotechnology for determining fauna variety, **genomic analysis** – as in the case of backcross-breeding assisted by markers in *Orysa* sp, – comparison of native wood genotypes by microsatellites, development of transgenic potato and bean, and transgenic papaya resistant to the ring-stain virus, the latter in cooperation with Embrapa Manioc and Fruits (Fonseca et al., 2004).

In the specific case of transgenic plant varieties, it is important to mention that Embrapa leads one of the best genetic plant improvement programs for yearly crops cultivated in the tropical and semi-temperate regions, and, with the safe incorporation of genetic constructs aimed at improving resistance to plagues and diseases, adaptation of specific varieties to adverse environmental conditions, as well as accrual of nutritional and pharmaceutical properties, it may contribute to consolidate this leading position of the country in the production of grains, fibers and oleaginous plants on the world scale. Strategic projects for the production of transgenic plants, conducted by Embrapa jointly with research institutions and private companies in Brazil and abroad, are currently under development, specially for soybeans, rice, potatoes, maize, papaya, eucalyptus and beans (see Table 3).

Table 3. Embrapa research projects for the development of genetically modified plants

Plants	Description
Plants to produce hormones	The Embrapa and the Unicamp had developed varieties of soy and maize that synthecize genes of the hormone of human growth and insulina.
Virus Resistant Papaya	The papaya production is affected severely by papaya ring spot virus (PRSV), which is transmitted by aphids and extremely difficult to control. It cause reduction in the size of the plants and leves, provoking significant losses to the fruits. The research of the Embrapa aims at to produce resistant transgênicas papaya to the PRSV.
Virus Tolerant Bean	The Embrapa makes research to develop tolerant bean to mosaic virus.
Herbicide Tolerant Soybean	The Embrapa had developed varieties of herbicide tolerant soybean, with tolerance to herbicida Imazapir and glifosate.
Aluminun Resistant Maize	Aluminum toxicity is the major factor limiting plant growth in the acid soils that comprise large agricultural areas, principally in tropical and subtropical regions. The Embrapa makes research to develop aluminun resistant maize.
Virus Resistant Potato	The potato production in the world are susceptible to diseases caused by viruses. The Embrapa had developed varieties of virus resistant potatos.

Fonte: Embrapa, 2004.

Besides conducting research, Embrapa is the leading Brazilian Science & Technology and Research & Development institution in formalizing and implementing technology transfer instruments, contracting of cooperation agreements, legalization of technology licenses, as well as issues related to intellectual property.

Thus, for instance, the Technology Transfer Service is protected by international copyright laws. It provides mechanisms for the dissemination, distribution and transfer of knowledge, e.g. by means of field days, courses, specialist systems, etc. This service is supported by a high-speed Communications Network, which is being set up by a consortium involving Fapesp, Embrapa and the World Bank. It also provides, without charge to the farmers, a site containing agricultural softwares (*Agrosoft*), which includes programs for the control and management of rural properties, plague control, etc. These programs are protected by international software laws.

During the nineties Embrapa have consolidated as a key organization of Brazilian Agriculture Research System, introducing a more decentralized and participatory framework to build its Annual and Pluri- annual Strategic Plan. In spite of the good results obtained, Embrapa will face in the near future a broad agenda, based on six “macroplans” ranging from global warming challenges to diffusion of appropriate technologies to small farmers, with the same stable annual budget. Their hope is based on the capacity to develop new partnerships

2.1.2 Agronomic Institute of Campinas

Among the OEPAs that conduct biotechnological research, the foremost is the Agronomic Institute of Campinas (IAC). The IAC was founded in 1887, as the Imperial Agronomic Station of Campinas, and, at the time, its main mission was to study coffee. Its studies were geared to developing cultivars adaptable to the several Brazilian regions. In the course of the 20th century, several new coffee strains were developed: plants with different sizes, different maturation periods, with greater or lesser resistance to rust, strains for colder regions, for high altitude regions, etc.

The studies conducted by the IAC had a major impact on the Brazilian coffee complex, and represented a major factor in overcoming the extensive and predatory agricultural model originally practiced in Brazil. In 2002, in pursuance of its role as a modernization agent for agriculture, the IAC initiated research in the coffee genome, at the R&D Center for Vegetal Genetic Resources. This project is funded by the Fapesp, and its goal is to develop an ideal plant, which is plague-resistant, with fast maturation and agreeable flavor.

Besides coffee, the Science & Technology project center of the IAC also works on the genetic improvement of more than a dozen other crops, covering the great groups of vegetables, cotton and grain-bearing plants. Most of these projects involve conventional improvement procedures, but, in some of them, e.g. the Citrus and Sugarcane Projects, research in molecular biology and genomics have begun to change the scenario.

Projects involving the development of genetically modified cultivars for specific markets, e.g. **genomic selection** of low lignification wood for the production of pulp and paper, are being developed in cooperation with the Cenargen-Embrapa, and make use of knowledge on microsatellites that allow for a precise selection of relevant genotypes; bio-remediation projects of soils and rhizosphere with Embrapa Environmental are also on the portfolio of the IAC, as well as projects involving the genetic recognition of sugarcane, developed in collaboration with the CBMEG – Center for Molecular Biology and Genetics of the State University of Campinas, a laboratory which coordinates the SUCEST/Sugarcane Genome project (Fonseca et al., 2004).

2.2 The Public Funding Agencies and the Genome Projects

The recent development of biotechnology in Brazil is supported by several government bodies, including the Ministry of Science and Technology and the Secretary of Science, Technology, Economic Development and Tourism of the State of São Paulo. The participation of these two bodies is channeled through its funding agencies for science and technology, respectively the National Council for Scientific and Technological Development (CNPq) and the State of São Paulo Research Foundation (FAPESP).

The CNPq, an agency linked to the Ministry of Science and Technology (MCT), has assisted in the implementation of the Brazilian Genome Project, a network covering several Brazilian institutions and universities. In 1997, the FAPESP set up the ONSA (Organization for Nucleotide Sequencing and Analysis) Network, a virtual genomics institute initially including 30 laboratories linked to research institutions within the State of São Paulo.

Besides the research foundations, another institution linked to the MCT, the Research and Projects Financing (*Financiadora de Estudos e Projetos* – FINEP) has also contributed to the development of biotechnology in Brazil. Whilst the priority of the CNPq and the FAPESP is to fund research conducted at the universities, the FINEP focuses mainly on research developed by private companies.

2.2.1 National Council for Scientific and Technological Development (CNPq)

The CNPq was set up in 1951, and is subordinated to the Ministry of Science and Technology. It is the major scientific research funding institution in Brazil. Its main line of action is to grant scholarships for the training of M.Sc., Ph.D and specialization students, besides providing other forms of funding for research projects in several fields of knowledge.

In 2000, the CNPq, in cooperation with the FINEP, Embrapa and Fiocruz, organized the Program for Biotechnology and Genetic Resources, with emphasis on actions aiming at the conservation of genetic resources and at the development of biotechnological products and processes applicable to industrial processing, farming and livestock, and human health.

Law no. 10,332/2001 set up the Biotechnology Sector Fund – CT-Biotechnology, for the purpose of providing incentives to the Brazilian scientific and technological development, in the form of funding of R&D activities of interest to the field of biogenetics and genetic resources. The Fund is sourced with 7.5% of the Intervention of Economic Domain Contribution (*Contribuição de Intervenção de Domínio Econômico* – CIDE).

The main goal of the Fund is to strengthen Brazilian competence in biotechnology, and specially in genomic research, by means of partnerships among teaching institutions, scientific research institutions, technological development and private initiative.

In December 2000, the MCT and the CNPq launched the Brazilian Genoma Project, with the participation of 25 molecular biology laboratories spread throughout the country. The Table 4 lists the genoma projects coordinated by the CNPq. Besides the Brazilian Genoma, the Regional Genoma Project has also been launched, focusing on local conditions for qualifying human resources and stimulating the use of existing institutional structures.

Table 4. Regional Network created by Brazilian Genoma Project

Network	Project / Aim
Center West Region Network	Genome of Paracoccidioides brasiliensis
State of Minas Gerais Network	Genome of Schistosoma mansoni
Northeast Region Network	Genome of Leishmania chagasi
State of Paraná Network	Functional Genome Analysis of Trypanosoma cruzi
	Genome of Herbaspirillum seropedicae"
State of Rio de Janeiro Network	Genome of Gluconacetobacter diazottrophicus
State of Bahia Network	Genome of Crinipellis perniciosa
State of Amazônia Network	Genome of Guaraná
South Region Network	Genome of Mycoplasma hyopneumoniae
Genolyptus Project	Genome of Eucalipto

Source: MCT.

2.2.2. The State of São Paulo Research Foundation – FAPESP

The FAPESP is one of the major funding agencies for scientific and technological research in the country. It is linked to the Secretary of Science, Technology, Economic Development and Tourism of the State of São Paulo, and its funds are guaranteed by the Constitution of the State of São Paulo, which ensures it a 1% share of the total tax revenue of the State.

As in the case of the CNPq, the FAPESP provides support to scientific and technological research by means of scholarship and research grants, besides a further three funding lines: Regular Lines, Special Programs and Technological Innovation Programs.

The Table 5 presents the distribution of the investments made by the FAPESP per field of knowledge. In 2003, 45% of the total investments were channeled to the three fields of knowledge that comprise life sciences: Agronomy and Veterinary Sciences (7.22%), Biology (18.56%) and Health (19.45%).

Table 5. The distribution of the investments made by the FAPESP per field of knowledge in 2003

Field of Knowledge	US$	Participation %
Life Sciences	52.137.135	45
Agronomy and Veterinary Sciences	8.321.177	7,22
Biology	21.396.854	18,56
Health	22.419.104	19,45
Others		
Architecture and Urbanism	502.815	0,44
Astronomy and Space Science	1.255.591	1,09
Humans and Social Sciences	8.805.753	7,64
Economy and Management	943.517	0,82
Engineering	18.453.645	16,01
Physics Sciences	7.581.149	6,58
Geoscience	3.036.745	2,63
Interdisciplinar	12.730.425	11,04
Mathematic	2.632.998	2,28
Chemistry Science	7.209.082	6,25
Total	115.288.855	100

Fonte: FAPESP, 2004.

The Table 6 shows the evolution of the investments by the FAPESP from 1996 to 2003. Among the four types of funding, the Technological Innovation Program was that which showed the greatest increase in total participation, rising from 0.35% in 1996 to 12% in 2003. This increase resulted from the investments made by the FAPESP in two major areas of modern biotechnology research: the Genoma Project and the Biota Project.

Table 6. Investiments made by the FAPESP per types of funding: 1996 to 2003 (US$ mil)

Types of Funding	1996	1997	1998	1999	2000	2001	2002	2003
Fellowships	34.362	56.502	80.448	83.624	96.725	74.323	52.438	44.151
Regular Programs	58.296	70.803	87.914	85.015	87.605	80.474	67.671	47.452
Special Programs	112.669	104.981	87.672	75.909	43.912	24.796	15.486	9.582
Technological Innovation Program	715	3.930	6.635	18.504	23.773	30.097	20.351	14.055
Genome Project	0	2.894	2.405	12.004	16.405	11.303	5.094	1.692
Biota Project	0	0	0	1.891	1.893	2.551	1.868	1.439
Total	206.041	236.217	262.670	263.052	252.015	209.690	155.947	115.241

Source: FAPESP, 2004.

Within the framework of Technological Innovation, the FAPESP has created several projects in the field of modern biotechnology: the Genoma Project, the Biota Project, the Structural Molecular Biology Network and the Virus Biological Diversity Network. The first three are focused on research with applications in agriculture, whilst the last is centered on health research.

i. The Genoma Project

In 1997, the FAPESP organized the ONSA Network, a virtual genomics institute initially comprising 30 laboratories linked to research institutions in the State of São Paulo.

The first project, conducted in association with the Fund for the Defense of Citrus Plantations (Fundecitrus) deciphered the genetic material of the *Xylella fastidiosa* bacteria, which causes citrus variegated chlorosis (CVC). The project was completed in November 1999, and Brazil made history as the first to obtain a sequencing of a phytopatogen – an organism causing disease in an economically relevant plant.

Subsequently the sequencing work on the *Xylella* led up to two further subprojects, the Functional Genome of the *Xylella* and the Agronomic and Environmental Genome project, which studies agronomically relevant microorganisms. By 2003, there were 14 genome projects funded (completed or in course) by the FAPESP, of which 9 focused on issues relevant for Brazilian agriculture.

The Table 7 presents the four FAPESP genome projects created within the framework of the AEG. The FAPESP is also funding two other projects of interest for agriculture and cattle-raising: The Sugarcane Genoma and the Functional Cattle Genome.

Table 7. Agronomic and Environmental Genomes funded by FAPESP and with partnerships.

Project	Descrition
Genome of Leifsonia xyli	The genome sequence of Leifsonia xyli subsp. xyli, which causes ratoon stunting disease and affects sugarcane worldwide. This was the first entirely national project of the AEG and was concluded in June of 2001.
Sugar Cane EST Genome Project	The aim of the project is to identify 50,000 sugarcane genes.
Genome of Coffe	The aim of the project is to identify 200.000 DNA sequences. This project is being carried through in partnership with Embrapa.
Genoma of Eucalipto - ForESTs	This project has for objective to decipher the origin of the problems that compromise the development of eucalipto by means of the functional analysis of the genes of the wood, root, leves and flowers. This project is being carried through in partnership with four private companies.
Genome of Xylella Fastidiosa	The aim of the project is to study two variatios of the Xylella Fastidiosa. This project is being carried through in partnership with Joint Genome Institute (JGI).

Fonte: FAPESP, 2004.

ii. The Biota Project

Launched in March 1999, the goal of this program is to map and analyze the biodiversity of the State of São Paulo, including flora, fauna and microorganisms. Organized in a manner similar to the FAPESP-Genoma Program, the BIOTA-FAPESP is carried out by means of a virtual network interconnecting over 500 São Paulo scientists who participate in 50 research projects.

iii. The Structural Molecular Biology Network

The Structural Molecular Biology Network (SMOLBnet) was set up in December 2000, in a partnership between the FAPESP and the National Laboratory for Synchroton Light, linked to the Ministry of Science and Technology and to the CNPq.

The Network has been organized in order to study tri-dimensional structures and functions of approximately 200 proteins. The aim of the Network is to study the structure of proteins based on genes mapped in the Xylella Genome Project, the Xanthomonas Genome, the Sugarcane Genome and the Human Cancer Genome projects.

2.4 The Universities

Besides the key institutions and the research funding foundations, two other groups of actors are fundamental in the development of modern biotechnology in Brazil: public universities and private companies.

Public universities play a central role in biotechnology research in Brazil. Firstly, they train human resources. Secondly, they are the major producers of research in biotechnology in the country. In 2000, there were 1.718 research groups involved in biotechnological projects in Brazil, of which 760 were located at Federal public universities, and 460 at State public universities (Salles-Filho, 2001).

The major contribution of the research groups at the universities relates to transgenics and genomic studies. Out of nine genetically modified products currently under development in Brazil and presented at Table 8, four are being developed at public universities.

Table 8. Researchs with Genetically Modified Crops in Brazil

Crops	Stages	Trait	Institution or Private Companie
Rice	R&D	Insect Resistant	Universidade Federal do Rio de Janeiro
Banana	R&D	Fungus Resistant	Embrapa
Bean	R&D	Insect Resistant	Embrapa
Orange	R&D	Vírus Resistant	Allelyx
Papaya	R&D	Virus and Fungus Resistant	Embrapa
Maracujá	R&D	Diseases Resistant	ESALQ-USP
Soybean	Tests	Herbicide Tolerance	Embrapa
Cantaloup	R&D	Slower matureness	Universidade Federal de Maringá
Eucalipto	R&D	To increase the cellulose production	ESALQ-USP

Fonte: CIB.

The relevance of the universities to research in biotechnology in Brazil becomes clearly evident when one analyses the structure of the genome networks set up in the country. In the Brazilian Genoma network of the MCT/CPNq as well as in the Genoma-FAPESP network, the universities play a central role. They concentrate a major portion of the research infrastructure in the country – laboratories, equipment, human resources and experimental fields. Furthermore, they act as important links between basic research and the market, since many biotechnology companies were originated by research conducted at the university laboratories.

2.4 Private companies

Biotechnology is currently part of the productive base of several sectors of Brazilian economy, with a market for biotechnological products corresponding to approximately 3% of the GDP. Studies conducted in 2001 by the Biominas Foundation, based on data provided by the Tropical Data Base (BDT) and by the Brazilian Association of Biotechnology Companies (ABRABI) have identified the existence of 304 biotechnology companies in Brazil, distributed among 10 different market sectors (see Table 9).

Table 9. Biotechnology Companies in Brazil in 2001, distibuted among 10 different market sectors and principal states

Market Sectors	Companies							
	(N=304)			Principal States n=272 (90% of N)				
	Nº Total	% Total	% Only SP+MG	SP (n=129)	MG (n=89)	RJ (n=28)	PR (n=16)	DF (n=10)
				%				
Human Health	74	24,0	72	27,0	45,0	16,0	5,0	-
Human, Animal and Plant Health	14	5,0	79	36,0	43,0	-	-	14,0
Animal Health	14	5,0	64	21,0	43,0	-	7,0	-
Agrobusiness	37	12,0	57	35,0	22,0	8,0	13,5	13,5
Enviroment	14	5,0	78	14,0	64,0	14,0	-	7,0
Complementary instrument	11	3,0	63	45,0	18,0	-	9,0	9,0
Fine Chemistry and Enzimes	8	2,0	63	62,0	12,5	-	12,5	-
Em Sinergia	15	5,0	73	13,0	60,0	7,0	-	-
Suppliers	51	17,0	92	76,0	16,0	2,0	2,0	-
MNCs, Públic Institutions, Fármacos, Genérics	66	22,0	64	53,0	11,0	14,0	4,0	1,5
TOTAL	304	100,0	71	42,0	29,0	9,0	5,0	3,0

Fonte: Judice, 2004.

As can be seen in Table 9, 37 of these companies are active in the agribusiness sector, and 14 in animal health; in other words, 17% of all these companies operate in sectors related to agriculture and livestock. The Table also shows the regional concentration of biotechnology companies, 71% of which are to be found in the States of São Paulo and Minas Gerais.

Several of these companies take active part in research, both in genomics as well as in the development of GMOs. They normally conduct their research activities in association with public research institutions and universities.

2.4.1 Private Companies and Genomics.

Private companies take part in practically all of the genomic studies networks set up in Brazil. The *Xylella* Genoma Project, for instance, was organized as a partnership between FAPESP and Fundecitrus, a private organization which represents the citrus producers. The project involved resources of some US$ 15 million, of which 3.2% were contributed by the private sector (Dal Poz et al., 2004).

The SUCEST Genoma Project, for the sequencing of sugarcane, benefited from the participation of Copersucar, an agro-industrial organization which is equipped with R&D laboratories. Copersucar conducted sequencing and data-mining work for the SUCEST Genoma.

The MCT financed Genolyptus Project involves as partners seven universities, the Embrapa and 12 private companies. Its purpose is to achieve gains in productivity, reduction in industrial pollution and increase the competitive edge of the Brazilian pulp and paper market. The first stage of the project, expected to extend over five years, involves a US$ 4,1 million investment, of which 70% from public funds and 30% from private initiative (Dal Poz et al., 2004).

As for the Forest Eucalyptus Genome Sequencing Project Consortium, coordinated by the FAPESP, it is being carried out in a consortium involving 4 pulp and paper and wood agglomerate manufacturers: Votorantim, Ripasa, Suzano and Duratex. The purpose of this study is also of major interest to private companies: a greater efficiency in wood production and in product quality. The first stage of the project, involving sequencing, now allows for the identification of the genes responsible for commercially relevant plant features.

2.4.2 Private Companies and the Seed Industry

A major part of the vegetal biotechnology market is related to the production and marketing of improved seeds. In Brazil, the seed market has been estimated at approximately US$ 1.2 billion, of which 70% for grain and cotton, 17% for foraging plants, 8% for potatoes and 5% for vegetables (Wilkinson & Castelli, 2000).

The market is divided into three groups of companies: multinational corporations, private domestic companies, and state-controlled companies (IAC and Embrapa). The foreign companies began to enter the Brazilian seed market back in the

60's: Pioneer in 1964, Cargill in 1965, Limagrain and Asgrow in 1971, Dekalb in 1978, and Ciba-Geigy in 1979 (Fonseca; Dal Poz & Silveira, 2004).

In the 90's, with the approval of the new Law on the Protection of Cultivars, multinational corporations have increased their market share in Brazil. This increase has resulted from takeovers of several domestic companies. In the late 90's, Monsanto (USA) purchased 29 seed companies, of which 4 in Brazil; DuPont (USA) took over 5, of which one in Brazil; Novartis (Switzerland) 16; Aventis (France/Germany) 9, of which 4 in Brazil; Dow AgroScience (USA) 13, of which 5 in Brazil; Sakata Seed Crop (Japan) and Savia S.A. (Mexico) took over the control of 31 companies, of which 3 in Brazil. Thus, at least 22 Brazilian companies have been purchased by multinational corporations (Fonseca et al., 2004).

Multinational corporations have not only increased their share in production and marketing, but also in research focused on the development of new genetically modified varieties. In the soybean market, for instance, the four major seed producers in Brazil offer 42 transgenic cultivars. Monsoy, Embrapa, Pioneer and Coodetec provide, respectively, 20, 11, 7 and 4 genetically modified soybean cultivars.

Mergers and takeovers have modified the market structure in the three major sectors of the seed industry: hybrids, varieties and vegetables. The hybrids market is the most concentrated and denationalized of the three, and the major market for hybrids in Brazil is maize.

The increase in the participation of multinational corporations has been very significant in the hybrid maize seed market. As can be seen in Table 10, the market share of foreign companies jumped from approximately 40% in 1996/7 to 87% in 2000/1. Embrapa, under a partnership with Unimilho, holds only 5% of the current market.

Table 10. Distribution of the hybrid maize seed market in Brasil: 1996 to 2000/01

1996/1997		*2000/2001*	
Companies	Partipation (%)	Companies	Partipation (%)
Agroceres	26	Monsanto (Dekalb + Agroceres)	48
Cargil	26	Dupont (Pioneer)	13
Pioneer	14	Syngenta	14
Novartis	11	Dow Agro Sciences	7
Braskalb/Dekalb	8	Aventis	5
Dinamilho Carol	3	Agromen	6
Agroeste	1	Embrapa/Unimilho	5
Outros	11	Outros	2
Total	100	**Total**	100

Source: Santini, 2002.

In the market for variety seeds, the presence of multinational corporations is still rather modest. This segment is dominated by the public sector, specially by Embrapa, by cooperatives and minor regional companies. In 2001, the joint market share of the four major private companies did not exceed 20% of the total output for soybeans, rice and wheat (Martinelli, 2003).

Specifically for the soybean market, despite the increase in the participation of multinational corporations from 1996 to 2001, the data shown on Table 11 indicate that Embrapa still held the largest market share: 55% in 2001. The third position was held by Coodetec, a cooperative of the State of Paraná. The three multinational corporations – Monsoy, Pioneer and Aventis – jointly held only 22% of the market.

Table 11. Distribution of the soybean seed market in Brasil: 1996 to 2000/01

1996/1997		*2000/2001*	
Companies	Partipation (%)	Companies	Partipation (%)
Embrapa	70	Embrapa	55
FT Pesquisa e Sem	12	Monsoy	20
Coodetec	10	Coodetec	10
IAC	2	CTPA-Engopa	5
Dois Marcos	1	Pioneer	1
Outros	5	Aventis	1
		Outros	8
Total	100	**Total**	100

Source: Santini, 2002.

In the State of Rio Grande do Sul – one of the foremost seed markets in Brazil – state-controlled companies and cooperatives are still the major suppliers of soybean seeds. As shown in Table 12, in the 2002/3 crop, state-run companies supplied seeds for

56% of the planted area, whilst cooperatives provided 18% and multinational corporations 20%.

Table 12. Distribution of the seed market in State of Rio Grande do Sul in 2002/03: per area planted

Companies	*Partipation %*
Public Setor	**0,56**
Embrapa	0,39
Fepagro	0,17
Multinational Corporations	**0,20**
Monsoy	0,20
Cooperatives	**0,18**
Codetec	0,15
Ocepar	0,03
Minor Regional Companies	**0,06**
Fundacep	0,06
Others	**0,01**
Total	1,00

Fonte: Apassul, 2005.

3. Institutional Environment

Concurrently with its efforts in the fields of scientific research, Brazil has also engaged in setting up an institutional framework adequate to the new demands of modern biotechnology. In this chapter, we will discuss the following aspects

- The infrastructure for scientific and technological research;
- The training of human resources;
- The property rights legislation on strains;
- The biosafety legislation.

3.1 Research Infrastructure

A significant part of biotechnology research in Brazil is conducted at public universities and public research institutions, because they concentrate the country's scientific and technological infrastructure – laboratories, experimental fields, machines and equipment. But this infrastructure faces certain deficiencies which, if not remedied, may set barriers to the future development of biotechnology in Brazil.

The excessive concentration of infrastructure at public institutions and the absence of a domestic industry for machines and equipment, associated to the recurrent restrictions on imports, are the main causes for the deficiencies in research infrastructure in Brazil.

One of the major challenges for the advancement of scientific research in Brazil are the difficulties faced by research institutions in the purchase of machines and equipment. These difficulties are related to the absence of funds and to the difficulties faced with imports, specially under foreign exchange crises. Even when resources are made available, often on a stop-and-go basis, there are still two further difficulties faced by the institutions: the red tape required for carrying out the imports, and the constant fluctuations in the currency rates, which at times reduces the purchasing power of these institutions, since they receive their funds in Brazilian currency (Couri, 2004).

The difficulties faced by the institutions in the purchase and maintenance of their machines and equipment becomes all the more evident when one reviews these institutions on a regional basis. According to Couri (2003), 88% of the equipment used in Brazil is concentrated in the Southern and Southeastern regions. Whilst the PCR equipment/institution rate is 1.6 in the Central-Western region, 1.2 in the Southeastern

and 1.0 in the Southern, in the Northeastern and Northern regions this rate drops to 0.5 and 0.6, respectively. Couri (2003) points out that in these last two regions, several institutions, although they possess modern equipment, often do not have basic equipment. Another significant problem noted in the survey was the obsolescence of the equipment, since the institutions often do not have specific funds for setting up preventive maintenance agreements. The Northern and Northeastern regions are more subject to this problem, since most maintenance providers are located in the Southeast.

Besides the machines and equipment issue, several research institutions face problems related to inadequate infrastructure, e.g. insufficient physical space, precarious water and power supplies, poor environmental control, low security level, and difficulties in communication among institutions.

The most dramatic situations are those faced by the Public Federal Universities, especially in the Northern and Northeastern regions, which have not been receiving infrastructure maintenance funds for several years. The major problems faced by these institutions are the inadequate supply of electric power (which is detrimental to the adequate operation of the equipment), of water (certain universities in the Northeast have to resort to well water, below the minimum quality standard for research, a situation which compels them to purchase all the water they need for their research projects), besides the lack of physical space.

3.2 Training of Human Resources

Human capital is one of the key factors for companies to achieve competitive gains, especially in sectors undergoing a fast pace of change and innovation, as in the case of biotechnology. But beyond the pace of innovation, biotechnology is also typically a multidisciplinary field, with a number of different implications for society as a result of its technological innovations. As a result, the task of training professionals to work with biotechnology presents greater difficulties than in other fields of knowledge.

The recent development of modern biotechnology places a demand on professionals from several specialty fields, not only from the traditional areas of biology, agrarian sciences and health sciences, but also from informatics, bioprocess engineering, technological management, commercial and financial management, etc. It involves professionals from several fields of knowledge, who must be highly qualified due to the nature of the technology involved and its respective implications.

In Brazil, the State is the main agent responsible for training human resources for scientific research. The vast majority of researchers in Brazil are trained at the public universities, with the financial support of public funding agencies. In 2003, the two major funding agencies – CNPq and FAPESP – jointly spent approximately US$ 230 million in scholarships. Out of this total, some US$ 91 million were directed to life sciences (see Table 13 and Table 14).

The Table 13 shows the evolution of the CNPq funding for the training of researchers, covering the period from 1999 through 2003. Life sciences was the field of knowledge which held the greatest share: from 1998 to 2003, its share rose from 38.7% to 40.8%. Within life sciences, biological and agrarian sciences received, respectively, 18.3% and 14.4% of the total volume of funds available.

Table 13. Evolution and distribution of the CNPq funging for the training of researches and scholarships, per field of knowledge: 1999 to 2003

Field Knowledge	Scholarships and Funding for the Training of Researches (US$ mil)					Participation %				
	1999	2000	2001	2002	2003	1999	2000	2001	2002	2003
Exact Sciense and engineering	**83.473**	**96.562**	**92.582**	**69.675**	**69.057**	**39,2**	**40**	**41,5**	**39,9**	**38,5**
Life Science	**82.376**	**94.210**	**84.966**	**67.774**	**73.351**	**38,7**	**39**	**38,1**	**38,8**	**40,8**
Biology Science	34.722	42.589	37.512	28.143	32.776	16,3	17,6	16,8	16,1	18,3
Health Science	18.115	20.193	18.106	14.639	15.090	8,5	8,4	8,1	8,4	8,4
Agrarian Science	29.539	31.428	29.349	24.992	25.486	13,9	13	13,2	14,3	14,2
Human and Social Science, Arts and Linguistic	**46.908**	**50.744**	**45.519**	**37.158**	**37.166**	**22**	**21**	**20,4**	**21,3**	**20,7**
Total	**212.756**	**241.516**	**223.068**	**174.607**	**179.575**	**100**	**100**	**100**	**100**	**100**

Source: MCT/CNPq, 2004.

Table 14 presents the 2003 figures for the investments made by FAPESP in the training of human resources. Here again, life sciences hold the largest share, representing 43% of the total grants.

Table 14. The FAPESP funging for the scholarships, per field of knowledge: in 2003

Field Knowledge	*US$*	*Partipation %*
Life Science	19.114.244	43,29
Agronomy and Veterinary Sciences	3.933.794	8,91
Biology	8.465.063	19,17
Health	6.715.387	15,21
Architecture and Urbanism	346.004	0,78
Astronomy and Space Science	371.791	0,84
Humans and Social Sciences	5.684.978	12,88
Economy and Management	259.294	0,59
Engineering	7.657.670	17,34
Physics Sciences	3.840.676	8,70
Geoscience	1.141.005	2,58
Mathematic	1.578.000	3,57
Chemistry Science	4.157.766	9,42
Total	44.151.428	100

Source: FAPESP, 2004.

Despite the efforts and the number of graduate courses in Brazil, a recent survey has shown that there are certain sectors lacking in qualified professionals for the purpose of conducting several of the activities relevant for biotechnology, e.g. bioprocess engineering[2], genetic sequencing[3], legal assistance in environmental and intellectual property issues, valuation of biodiversity and administrative and financial management (Batalha et al., 2004).

According to the Batalha et al (2004) survey, most of the research group leaders in biotechnology in Brazil[4] believe that Brazil will have difficulties in recruiting professionals qualified in biotechnology over the next years. The specific areas of biosafety and bioethics, immunetechnology, microorganism biotechnology, livestock improvement, bioinformatics and pharmaceutical agents are those that will probably face the greater recruiting difficulties. The three last areas are of greatest concern, since they represent the areas with the greatest growth potential in Brazil.

[2] This is a crucial tool for the development of biotechnology companies, since it is responsible for the transfer of knowledge from the laboratories to the production line.

[3] The genomic research projects conducted in Brazil revealed the lack of professionals specializing in this field, specially as the demand for such professionals increased over time.

[4] The survey selected 1729 Brazilian research groups in biotechnology, based on information provided by the CNPq.

The specialty fields with the greatest demand by graduate studies candidates were Molecular Biology, Support Tools for Biotechnology, Natural Products and Processes and Protheomy, whilst Pharmaceutical Agents and Livestock Improvement were those with the lowest demand.

The supply of professionals in biotechnology was analyzed by Batalha et al (2004), based on a review of the profile of the professional that the graduate studies programs are training. The analysis took as a starting point 2,774 theses and dissertations, completed at 295 different graduate studies programs. These same works were grouped into four major areas: Agriculture and Cattle-Raising, Biological and Health Sciences, Environmental Sciences and Process Engineering. Among the results of this investigation, the following are worth quoting (Batalha et al., 2004):

- A high concentration of graduate biotechnology programs in the Southeastern region. The best courses and almost 90% of the PhD dissertations submitted are concentrated in this region;
- Most graduate biotechnology programs are offered by public institutions (97%);
- The research funding agencies (CAPES, CNPq and FAPESP) are the major providers of M.Sc. and PhD scholarships in biotechnology. CAPES and CPNq answer for 87% of the total number of scholarships granted to graduate students in biotechnology;
- 31.2% of the theses and dissertations submitted in Brazil and related to biotechnology were not financed with scholarships;
- There is a marked concentration of the theses and dissertations in certain thematic fields: 60% of the total relate to natural products and processes, livestock improvement and vegetal biotechnology;
- Within the thematic field of environmental studies, biodiversity is that which is turning out the majority of the M.Scs. and PhDs;
- In certain areas of strategic value for the development of the country, such as pharmaceutical agents, tissue technology, bioinformatics and protheomics, the number of graduate students is very modest. The volume of theses and dissertations in biotechnology management is also very limited.

3.3 Intellectual Property Rights on New Cultivars

The Brazilian intellectual property rights system (DPI), as it was set up in the 90's, "has attempted to respond to the requirements of the TRIPS and likewise to meet the demands defined by the Biological Diversity Convention" (Dal Poz et al., 2004).

The two Laws that regulate property rights in the field of vegetal biotechnology in Brazil are:

- Law of Patents, enacted on May 14, 1996;
- Law of Cultivars Protection, enacted on April 25, 1997.

These laws provide for "the appropriation of innovations, and ensure intellectual property on cultivars, opening up for the collection of royalties and technology fees" (Fuck, 2005). They have stimulated the wave of mergers and takeovers which took place in the 90's, resulting in a greater participation of multinational corporations in the Brazilian seed market.

In the case of transgenics, however, current Brazilian law does not acknowledge gene patents. The object of the patent could then be the plant resulting from the modifications arising from the insertion of genes. But plants cannot be patented in Brazil. Thus, there only remains the possibility of accepting a patent on the insertion of the gene in the plant. Thus, "a patent covering the insertion of the gene provides guarantees to the effect that the farmer cannot reproduce transgenic seeds without the authorization of the holder of the patent" (Fuck, 2005).

There are two further possibilities for harmonizing access to the technology and the protection of property rights. First, the Law of Industrial Property provides for the possibility of licensing a gene for insertion in third party plants.

Second, it is also possible to execute joint technology transfer agreements. According to Fuck (2005), this "is one of the forms of access to state-of-the-art technology which unites local R&D efforts and the transfer of know-how generated abroad." The Embrapa, for instance, has such a technology transfer agreement with Monsanto for transgenic organisms (Fuck, 2005).

The Law of Cultivars Protection, although it has allowed for an increase in the participation of multinational corporations in the market, has also lead to a new form of action on the part of the state-run companies, specially by Embrapa, in the form of partnerships with several private initiative companies. The Law has imposed a new form of relationship between Embrapa and the seed production industry, "which began

to invest in the generation of cultivars in exchange for exclusivity in the production and marketing of the resulting seeds over a given period of time" (Fuck, 2005).

In RR soybean market, a technical cooperation agreement was executed between Embrapa and Monsanto in 1997. Under this agreement, "Embrapa obtained legal support to conduct efficiency evaluation research on the gene and on the genetical construction of glyphosphate pesticide resistant soybeans, and concluded that this Monsanto technology is technically efficient" (Fuck, 2005).

In 2000, a commercial agreement was executed enabling Embrapa to lace its transgenic soybean cultivars on the market, all of them protected under its exclusive brand name.

3.4 The Law of Biosafety

Similarly to the European Union, Brazil adopts the principle of precaution as to genetically modified organisms. This principle, as opposed to the "**principle of substantial equivalence**" acknowledges the possibility of GM products becoming risks to human health and to the environment. These risks require therefore the setting up of specific regulations and institutions for the purpose of evaluating the risks represented by these products.

This was the intent that led to the approval of Law no. 8974, of January 5 1995, known as the Law of Biosafety. The purpose of this law is to regulate all activities and stages of biotechnology, ranging from fundamental research, through experimentation and sowing and up to handling, transportation, marketing, storage and dissemination in the environment. To carry out these tasks, the law set up the National Biosafety Technical Committee (*Comissão Técnica Nacional de Biossegurança – CTNBio*) as a body under the Ministry of Science and Technology.

Being the instrumental body of a law that intends to regulate all biotechnology activities, the CTNBio was vested in sufficient authority to issue final and binding opinions on the safety of specific GMOs, including as to its environmental safety. Decree no. 1752, of December 20 1995, which regulated the Law of Biosafety, conferred upon the CTNBio the power to demand, if needed, environmental impact studies.

The authority to issue final opinions on themes related to the environment created a point of conflict with the other environment regulating bodies and agencies,

including the Ministry of Environmental Affairs and the State Departments of Environmental Affairs. For the sectors of society opposing biotechnology, the power conferred on the CTNBio was deemed to represent a possible weaking of the Ministry of Environmental Affairs and other bodies and agencies, as related to the GMOs.

This conflict effectively hindered the enforcement of the Law of Biosafety. In 1998, the CTNBio issued an opinion favorable to the clearance of the Monsanto RR soybeans for marketing in Brazil. As a response to this decision, the IDEC and the Greenpeace filed a Public Civil Action against the technical opinion of the CTNBio, for the purpose of hindering the sale of RR soybeans in Brazil. The Courts granted an injunction, making the clearance of transgenic soybeans conditional upon the submittal of an environmental impact survey. According to Monteiro (2003), this court decision was grounded on two issues:

1) The Federal Constitution (Article 225 (1)(IV_2)) requires the Public Authorities to demand a prior environmental impact study for any activity representing a potential risk for serious environmental damage;

2) The CTNBio was not deemed to be the competent "Public Authority" to require a prior environmental impact study, much less to exempt anyone from conducting such survey.

As a consequence of this injunction, since 1998 the production and marketing of RR soybeans is prohibited in Brazil. But this did not stop a major part of the farmers in the State of Rio Grande do Sul from making illegal imports of RR seeds from Argentina. The clandestine dissemination of RR soybeans reached such proportions that the Federal Administration was forced to permit its use up to the 2003/2004 crop, by means of the enactment of a Provisional Measure.

Besides the injunction prohibiting the commercialization, Brazil faces a situation in which several regulatory bodies are superimposed, creating other obstacles for research with genetically modified plants. The tangle of laws and provisions has created a highly complex and bureaucratic system, which increases research time and costs in Brazil.

The approval of a genetically modified product requires permits and authorizations from several government bodies. If a specific company desires to obtain approval for conducting research with its product, it must overcome a number of stages (Amâncio & Sampaio, 2005):

1) Obtain a Biosafety Quality Certificate;
2) Procure authorization to conduct research with GMO, which, in the case of agricultural products, must be requested from the Ministry of Agriculture, Cattle-Raising and Provisioning (MAPA);
3) Obtain an Environmental Registration for activities to be conducted in an enclosed area;
4) If the GMO contains pesticide features – as in the case of the Bt varieties – the company must secure a Special Temporary Registry (RET), related to the pesticide legislation;
5) Once the RET has been secured, it will be necessary to obtain a prior and final technical opinion from the CTNBio, before the GMO can be liberated in the environment;
6) Thereafter, it will be necessary to obtain a Temporary Field Experiment Authorization (ATEC) from the MAPA;
7) For all and any GMOs, an Operation License for Research Area is required.
8) Once the field research has been conducted and before the product is commercially launched on the market, the company must obtain an Environmental License for pre-commercial launching;
9) Should such license be granted, a further license will have to be procured: the Environmental License for Commercial Launching;
10) Finally, before actual commercialization is initiated, the CTNBio must give its approval.

With the intent of harmonizing this "regulatory chaos", the Federal Administration submitted Bill no. 2401/2003, which purports to establish new rules for regulating biotechnology activities. After it was approved by the National Congress, on March 3, 2005, it was sanctioned by the President of the Republic on March 25 2005.

The new law reasserts the power of the CTNBio to issue final opinions on the clearance of transgenic products. It sets up a second decision instance after the opinion issued by the CTNBio, but the role of this second instance is limited to issuing opinions solely on the convenience and on the social and economic opportunities of the commercialization of a given GMO.

4. Socioeconomic Impact of GMO Diffusion in Brazil

4.1 Background: the status of impact assessment in Brazil

Brazil had no proper legal framework for research and marketing of GMOs and related products until March 2005, when Congress passed the Biosafety Act (Law 2401). The negative consequences of this long period without clear rules and regulations include the almost complete absence of scientific assessment of the socioeconomic and environmental impacts of GMOs. The debate in Brazil, albeit polarized, focused almost exclusively on assessing the economic advantages of genetically modified soybeans. Rather than agricultural biotechnology and its implications, the debate revolved around glyphosate-tolerant soybean cultivars. It was explicitly recognized that "other GM products" would present even more complex problems.

The lack of a clear legal framework led those interested in GMO diffusion to adopt a cautious position with regard to assessment. Performing an assessment not required by law might suggest that studies of the kind should become mandatory in all situations. For example, one point of conflict related to the use of information obtained in environmental impact studies by companies in other countries.

Assessments carried out in Brazil could be used to bolster the arguments used by GMO critics, who claimed that there was no local research on all dimensions of the environmental impact of gene flows on microfauna and microflora (e.g. on nitrogen-fixing bacteria of the genus Rhizobium, of considerable economic importance to soybean farming). The impasse also resulted in a lack of detailed research into a specific impact which could surprise environmentalists, i.e. the claim that changes in soybean farm management would have a positive impact on the environment. The environmental impact debate was circumscribed to a discussion of soybean crop management, and in particular the use of herbicides.

Studies of economic impacts, and dealing secondarily with environmental impacts, not only require researchers with resources, qualifications and time, but also address points of enormous importance to the debate. Recent research can be summed up as assessing five types of impact: a) savings in production costs; b) higher yields; c) growth of crop acreage and exports (as seen in Argentina); d) reduction in the use of

agrochemicals (especially the most toxic). These studies provide "raw material" for an assessment of the impacts on markets, which is beginning now, partly using the multimarket methodology (Borchgrave et al, 2003), and others based on the computable general equilibrium model.[5]

4.2. Assessment of the impact of GM soybeans in Brazil

4.2.1. Overview of assessments in 1999-2002

A number of "quick assessments" designed to question the importance of GM crops were published in the period, claiming to demonstrate that herbicide-tolerant cultivars caused a "fall in yields" for soybean farms in the South, especially Paraná. The trouble with these assessments is the lack of a control group and the small sample size.[6]

For a synthesis of assessments carried out between 1999 and 2002, mainly in the United States and Argentina, as well as some localized studies in Brazil, see Pelaez et al. (2004). The conclusions of this paper focus on the following findings:

a) GM soybeans do not significantly increase yield per hectare. The statistical differences between conventional and GM soybeans are not material, according to the studies cited. In some cases in the U.S., yields actually fell with GM cultivars.
b) The 5%-20% cost saving obtained by using GM varieties does not offset the additional expense incurred with biosafety compliance and identity preservation systems, let alone the payment of fees to the owner of the technology patent.
c) Herbicide use increases — glyphosate in the case of soybeans. Although it is claimed that this product is class IV and hence far less toxic than herbicides applied to conventional soybeans, the increased amount needed to spray GM crops more than makes up for the difference.
d) It is widely acknowledged that growers generally like GM soybeans because they are easier to manage, but at the same time this factor is of real importance only to very large farms.

The authors note that according to U.S. research, growers have been disappointed in their expectations of higher yields and reduced expenditure on agrochemicals. Improved conditions of crop management, seen as the main advantage of GM varieties in all studies cited by this paper, was only the third priority for growers.

[5] A group of professors at the University of São Paulo's School of Economics & Business Administration (FEA/USP) are conducting a study of the market impact of GM soybeans for Monsanto in the first half of 2005.

[6] A typical example is an assessment based on a few small farms in areas marginal to the main soybean growing zone. However, the overall hypothesis is that insertion of GM soybeans disorganizes the genome and reduces cultivar yield per hectare.

The paper seeks to establish the economic feasibility of non-GM soybeans as the main crop, with GM soybeans as a residual activity if produced in Brazil.

4.2.2. Impact assessments in Brazil: Embrapa's study

This section presents a summary of the GM soybean economic impact assessment by Roessing & Lazzarotto (2004).[7] The study resulted from a broad investigation combining technical coefficients determined by researchers who had significant experience in soybean growing and were strongly committed to the research effort, and field interviews with local technicians associated with Embrapa in eight states, covering almost 25% of the acreage under soybeans nationwide. This comprehensiveness distinguishes the study from most research on the subject performed in Brazil to date, which is localized and much more limited.[8]

The synthesis focuses mainly on microeconomic gains from diffusion of GM soybeans, if any. Aggregate macroeconomic impact is hard to compute since it requires a series of restrictive assumptions (see Roessing & Lazzarotto, 2004), which in any event are not important to the present discussion. Nevertheless, selected findings from the Embrapa study are highlighted below.

The assumptions and rationales used by Roessing & Lazzarotto (2004) take into account several points from the critiques contained in the synthesis by Pelaez et al (2004):

a) Use of potential yield by region does not reflect the historical average for local varieties and given levels of management in normal years. GM cultivars obtained by backcrossing rather than plant breeding programs initially had yields 3% lower than conventional cultivars. Over time, however, yields converged as a result of breeding programs. The study also analyzed differences in physical yield between regions. For short-term GM soybeans, the weighted average for all regions was 2,826 kg/ha. For conventional crops and long-term GM crops, the average was 2,914 kg/ha.
b) The public and private structure of research and seed production, now that legal obstacles have been overcome, is prepared to meet demand for both types of cultivar in the 2005-2006 crop year. This eliminates the constraint imposed by varieties imported from Argentina, which have not adapted to areas in lower latitudes.
c) No-till systems do not eliminate application of glyphosate in the post-emergence stage (the last stage of the soybean crop), instead of the post-emergence herbicides

[7] The EIA was specially prepared for a series of Biotechnology Prospecting Workshops organized by Centros de Gestão de Estudos Estratégicos (CGEE), an agency of Brazil's Science & Technology Ministry. The workshop organizers were Sergio Salles Filho (IG/Unicamp) and Marcio Miranda (CGEE). Silveira, Buainain & Borges (2004) delivered a paper on the international scenario in agricultural biotechnology.

[8] The areas visited, chosen as representative of the relative importance of soybean growing in Brazil, ranged from Tupanciretã, Rio Grande do Sul, to Sinop and Sorriso, Mato Grosso. For details, see Roessing & Lazzarotto (2004).

used in conventional tillage. Thus it is assumed that two applications are made in no-till, involving 1.5 liters of herbicide per hectare.

d) Seed cost increases by US$20 per hectare (3%-5% of crop value), more costly and less flexible than charging R$0.60 per 60 kg bag harvested, as used in the 2004-2005 crop year under an agreement between co-ops and Monsanto.[9]

e) Prices ranged from 590 US cents per bushel (very high) to 542 cents per bushel (close to the current price of R$30 per 60 kg), reflecting increased production and yields.[10] The study did not consider the possibility of a premium for conventional soybeans.[11]

Detailed estimates of production costs per unit area are summarized in the following table:

Table 15. Soybeans: estimated production cost per hectare in selected municipalities

Municipality	Variable cost (US$/ha)		Fixed cost (US$/ha)		Total cost (US$/ha)	
	GM (MP)	Conv.	GM (MP)	Conv.	GM (MP)	Conv.
Palmeira das Missões	316.0	336.0	64.0	64.0	380.0	404.0
Tupanciretã	323.7	343.2	66.3	66.3	390.0	413.4
Campo Mourão	310.0	325.0	65.0	65.0	375.0	390.0
Cascavel	325.0	335.0	70.0	70.0	395.0	405.0
Diamantino	360.0	360.0	75.0	75.0	430.0	430.0
Primavera do Leste	374.4	369.2	72.8	72.8	447.2	447.2
Sinop	438.6	423.3	86.7	86.7	520.2	504.9
Sorriso	416.0	442.0	78.0	88.4	499.2	530.4
Itumbiara	335.8	349.6	78.2	82.8	414.0	432.4
Rio Verde	370.0	365.0	75.0	75.0	445.0	440.0
Brazil (weighted ave.)	**349.8**	**359.2**	**72.2**	**73.3**	**421.6**	**432.8**

Source: Roessing & Lazzarotto (2004)

As shown in Table 15, for a weighted average of regions representing Brazil there was a reduction of 2.9% in the variable cost of medium-term GM soybeans compared with conventional soybeans. The reduction in fixed cost was negligible, as a result of the assumption distinguishing Brazil from Argentina in item "c" above. The reduction in total cost per hectare for Brazil was therefore between 2% and 3%.

It is important to note that the variable cost of medium-term GM soybeans is higher than that of conventional soybeans in the Center-West while the reverse is true in Rio Grande do Sul (Palmeira das Missões and Tupanciretã), where reductions reach 5%

[9] Strictly speaking, the technology fee charged by Monsanto cannot be termed a royalty since Brazilian patent law does not recognize gene patents. The charge actually relates mainly to the fact that soybeans are exported and therefore subject to reprisals in the destination country under the TRIPS agreement. See Carvalho (2003) and Dal Poz et al (2004).

[10] According to Roessing & Lazzarotto (2004), based on data from USDA and Conab, between 1993 and 2004 Brazil's production increased at a geometric rate of 6.28% per annum and yield per hectare rose 3.40%. Argentina, China and India increased production by expanding acreage, with far more modest gains in yield (0.5%, 2.3% and 0.68% respectively).

of total cost. This explains the success of GM soybeans in that state, even using seeds imported from Argentina. The explanation relates to the key role of glyphosate for weed control in the South; the situation is quite different in the Center-West, where many crops are new arrivals and crop rotation is practiced far more intensely. This point brings us back to the discussion of production scale.

The study by Roessing & Lazzarotto (2004) also shows a cost saving of about 2% per unit of production, with a corresponding increase in the grower's contribution margin, considering payment of U$20 per hectare in fees to the company that owns the technology (about 5% of total production cost). Once again the largest gains are in Rio Grande do Sul, confirming the importance of this type of crop management for growers in the region and the fact that the potential impact projected by the innovation is much less significant in the Center-West.

Table 16. Soybeans: estimated net income in selected municipalities (US$)

Municipality	GM (CP)		GM (MP)		Conventional	
	sc	ha	sc	ha	sc	ha
Palmeira das Missões	3.5	135.8	3.8	152.0	3.2	128.0
Tupanciretã	3.0	113.5	3.3	128.7	2.7	105.3
Campo Mourão	5.6	271.6	5.8	290.0	5.5	275.0
Cascavel	5.1	247.4	5.4	270.0	5.2	260.0
Diamantino	3.2	155.2	3.4	170.0	3.4	170.0
Primavera do Leste	3.2	161.4	3.4	176.8	3.4	176.8
Sinop	1.5	74.2	1.8	91.8	2.1	107.1
Sorriso	2.2	110.9	2.4	124.8	1.8	93.6
Itumbiara	2.8	124.9	3.0	138.0	2.6	119.6
Rio Verde	2.9	140.7	3.1	155.0	3.2	160.0
Brazil (weighted ave.)	**3.8**	**177.5**	**4.0**	**194.8**	**3.8**	**183.6**

Source: Roessing & Lazzarotto (2004)

As shown in Table 16, based on net income for Brazil as a weighted average GM soybeans offer a gain of 6% in the medium term and practically no gain at all under current conditions. This raises an important question: if the short-term gain is zero on average, with the payment of technology fees, while medium-term gains result from plant breeding programs designed to insert the gene into lineages adapted to different edapho-climatic and plant health conditions in different parts of the country, who is expected to undertake this R&D effort and how will it be remunerated?

This point highlights the fact that the impact of introducing GM soybeans goes well beyond cost savings. Sharing of gains among stakeholders is crucial. A formula

[11] The premium for non-GM soybeans and meal is estimated at 4%-10% of the price, as determined by contract and not by the commodities market. The cost of these processes is discussed below.

that does not remunerate the labor involved in plant breeding to insert the gene would greatly undermine the feasibility of GM cultivar diffusion.

4.2.3. Other impacts of introducing GM soybeans into Brazil

The polarized debate about introducing GMOs into Brazil does not justify talk of "winners and losers". A priori, the adoption of a European-type biosafety system is a victory for the environmentalist lobby, aligning Brazil with the precautionary principle. On the other hand, the environmentalists' main goal was to delay growing of GM crops indefinitely and they can therefore be considered defeated by Law 2401, which does not make EIAs mandatory and contemplates the possible existence of GMOs that do not constitute environmental or health hazards (GM soybeans and cotton had earlier been classified as hazards).

Evidence of the environmental impact of GM soybeans is limited to observations of an increase in the application of a herbicide that is not especially toxic — glyphosate is a class IV herbicide, together with Pivot (imidazolinone) and Scorpion, also used by soybean growers — instead of highly toxic class I post-emergence herbicides, such as Blazer, Flex or Cobra, and equally toxic class II products such as Fusiflex, Gamit, Poast and Select.

From the standpoint of distribution, the technology introduced by GMOs favors market-oriented family farmers (Guanzirolli et al, 2002). Furthermore, ultra low volume (ULV) herbicides require more technical knowledge and appropriate equipment on the part of users, so from this angle too the technology favors family farmers, who lack the resources to buy equipment for application of ULV herbicides.

The Table 17 highlights two important points: the use of GM cultivars increases seed costs and, in most regions, reduces expenditure on post-emergence herbicides. The data proves the statement above that in "new" soybean growing areas such as Sinop the advantages of using GM soybeans is negligible and that its use in such areas is not advisable, at least in theory.

Seed cost including technology fees corresponds to between 6% and 9% of revenue and between 5.4% and 12% of production costs.[12] This shows the importance of the technology fee. The system whereby it is calculated on the basis of the amount of soybeans harvested eliminates the additional risk of using GM seeds. Payment for seeds

transfers additional production and market risk to the grower. In any event, the fee system clearly points to the limitations of transferring the cost associated with the use of modern technology to seeds, which can be multiplied by growers themselves or by informal producers (the "white market" in Argentina), as a response not just to the additional cost but also to the formation of crop expectations. This may indicate a less technology-intensive production strategy (adaptive flexibility).

Governance of GM soybean diffusion and adoption is therefore central to the discussion. A market-centered treatment, in which the supplier of this key input is an oligopoly with a temporary monopoly on the technology ranged against a "multitude of producers", can lead to negative effects on the organization of the seed industry.

Table 17. Soybeans: estimated expenditure on seeds & post-emergence herbicides

Municipality	Seeds (US$/ha)			Post-emerg. Herbicides (US$/ha)		
	GM	Conv.	Diff. (%)	GM	Conv.	Diff. (%)
Tupanciretã	52.0	32.0	62.5	14.0	53.9	-74.0
Palmeira das Missões	52.0	32.0	62.5	14.0	53.9	-74.0
Campo Mourão	52.0	32.0	62.5	11.0	42.4	-74.1
Cascavel	49.0	29.0	69.0	14.0	42.4	-67.0
Diamantino	48.4	28.4	70.3	11.0	31.5	-65.1
Primavera do Leste	47.5	27.5	72.7	11.0	29.0	-62.1
Sinop	43.3	21.7	100.0	12.9	20.5	-37.2
Sorriso	36.0	16.0	125.0	11.0	20.5	-46.4
Itumbiara	52.0	32.0	62.5	13.3	19.4	-31.8
Rio Verde	52.0	32.0	62.5	14.7	17.6	-16.5
Brazil (weighted ave.)	**48.8**	**28.7**	**70.2**	**12.6**	**35.1**	**-64.1**

Source: Roessing & Lazzarotto (2004)

Interviews with growers and representatives of the seed industry in the Southern states of Brazil show that the main negative effect of GM soybean introduction (via illegal imports of cultivars from Argentina) was a reduction in percentage seed acquisition, which is crucial to maintain plant health, among other factors.

[12] Considering a price of 525 US cents per bushel (60 lbs).

Table 18. Use of certified & inspected soybean seeds in Rio Grande do Sul (RS)

Crop year	Seeds		Sales		Surplus (t)	Use (%)
	Gross received	Certified	Total	In RS		
1996/97	340096	232485	171127	124066	61358	60
1997/98	373173	213338	186101	127601	27238	60
1998/99	371042	191563	134303	91116	57260	43
1999/00	267072	162505	124573	90457	37933	42
2000/01	235154	144344	120667	71021	23677	38
2001/02	198978	117582	83318	47371	34264	23
2002/03	235516	133848	77768	27705	56080	12
2003/04	67645	36930	32425	25350	4505	10
2004/05	60000	33000	30000	13000	3000	5

Source: Apassul, 2004

The Table 18 shows the drastic reduction — from 60% to 5% — in seed use by growers in Rio Grande do Sul due to the introduction of GM cultivars.[13] This trend is all the more striking in light of the fact that despite the process of concentration seen since 1999, Rio Grande do Sul has 446 accredited seed producers, 581 seed processing units and 42 seed labs (Abrasem, 2004).

A "return to normal" depends not only on the Biosafety Act but also on the seed industry's capacity to meet demand for GM cultivars bearing the characteristics of the elite genetic material available for non-GM cultivars. A survey involving interviews at co-ops and research centers shows an estimated 42 GM cultivars (20 Monsoy, 11 Embrapa, 7 Pioneer and 4 Coodetec) available for multiplication in Brazil in 2005, with the key advantages of adaptation to edapho-climatic conditions and resistance to disease. However, there are less optimistic estimates which reduce the total to 9 cultivars throughout Brazil, configuring a severe constraint.

Two other factors are required to "restart" the seed industry, involving agreements and costs for the various parties:

f) An agreement between growers and Monsanto on the amount of technology fees and method of payment.
g) Identity preservation (IP).

Item "a" reflects the possibility that growers could continue to produce their own seeds as a way of putting pressure on Monsanto and suppliers of genetic material to reduce fees. Item "b" relates to the fact that estimated costs for soft IP processes, according to interviews, are much lower than in the United States and European Union (Borchgrave et al, 2003; Pelaez et al, 2004).

[13] Provisional Measure 131, issued in 2003 to regulate GM soybean growing and marketing, rightly required growers to declare their

Before moving on to the topic of IP as a possible additional cost imposed by the technology, it is pertinent to discuss the impact on family farming, since the Landless Workers Movement (MST) is clearly opposed to GM diffusion and advocates a total ban. As mentioned above, this position transcends the discussion conducted by FAO (2004) and the analyses by Silveira (2004) and Silveira & Borges (2004), all of which are confined to the positive and negative technological impacts. Social movements are opposed to GM technology because they see it as strengthening big agribusiness and income concentration in the countryside, starting with the obligation for growers to buy seed from oligopolistic suppliers.

A survey by IBGE of soybean production in Rio Grande do Sul (Melo et al, 2004), alongside evidence of the importance of GM soybeans in the state, shows that establishments of up to 50 hectares account for a larger area of the 50 largest soybean-producing municipalities than in the state as a whole (see Table 19). At the opposite extreme, municipalities that specialize in soybean growing have 0.53% of the number of establishments (more than double the percentage for the state) but 10.97% of the area, compared with 12.68% for the state. Typical beneficiaries of GM soybeans are growers with 50-500 hectares: the number of establishments in this group is almost double, and their percentage of the area, 42%, is 22% larger than for the state.

Table 19. Number of establishments and share of area in 50 largest soybean-growing municipalities compared with Rio Grande do Sul, by size of farm

Farm size	Rio Grande do Sul		Top 50 soybean-growing municipalities	
	No. of establishments (%)	Share of area (%)	No. of establishments (%)	Share of area (%)
Up to 50 ha	85.71	24.36	74.45	26.4
50-500 ha	12.46	33.98	21.95	41.79
500-2000 ha	1.63	28.97	3.47	27.15
More than 2,000 ha	0.2	12.68	0.53	10.97

Source: IBGE (calculation by authors)

As indicated by Table 19, specialization in soybean growing does not imply concentration of land tenure: most growers are in the 50-500 hectare group, which is medium size for a farm in Brazil and includes market-oriented family farmers.

What advantages accrue from GM soybean growing under Brazilian conditions? The conclusions in Roessing & Lazzarotto (2004) largely match those in Pelaez et al (2004):

h) Yields (production per hectare) are slightly lower.
i) Variable cost is lower in areas where glyphosate is effective for weed control, as it has proved to be in Rio Grande do Sul.
j) Fixed cost (not computed in the study) may be reduced if less machinery is used to grow GM soybeans.
k) Part of the increase in net revenue is offset by the technology fee ranging from 3% to 5% of gross sales.[14]

In sum, where is the advantage of GM soybeans? What led family farmers and small to medium growers to defy the law and risk introducing GM soybeans into Brazil? On this point there is a striking contrast with the view taken by Pelaez et al (2004), who in speaking of soybean growing in the United States conclude somewhat hastily that the simplification and greater flexibility of crop management made possible by GM cultivars is not a priority for growers. In the Brazilian case, survey data and interviews clearly show that GM cultivars with minimum tillage and two applications of glyphosate recouped crop yields in Rio Grande do Sul.

4.3. Identity preservation and market impact

As already noted, market impact assessments are in their infancy in Brazil, largely owing to lack of official recognition for GM soybean growing. Brazil's part in the discussion of the minimum criteria for identity preservation (IP) required by consumer countries, especially the E.U. and China, centers on the following issues:

l) Until 2005 there was a technical protection scheme that guaranteed the existence of large non-GM soybean growing areas in Brazil, especially in the Center-West.
m) Geographic isolation was and still is responsible for a far lower cost of IP in Brazil, based on documentation and detection.
n) There is no evidence to date that the designation of "free zones" has resulted in segmentation of the market into GM and non-GM soybeans for export.
o) In sum, Brazil's situation is compatible with the hypothesis proposed by Borchgrave et al (2003), as confirmed by interviews carried out in various parts of the country, which is that the non-GM market is based on contracts with buyers who demand IP and pay a premium for it, albeit in the modest range of US$21-US$32 per hectare (geared to yields in the Center-West).[15] Commodity soybeans are GM.

[14] Assuming 525 US cents per bushel (60 lbs) and yields of 2,800-3,000 kg/ha.

[15] The barriers imposed by the Paraná State Government on exports of GM soybeans from Mato Grosso do Sul relate to the alleged difficulty of guaranteeing segregation at the Port of Paranaguá. The state government was evidently counting on an undeclared moratorium on GM soybeans so that non-GM product could be exported with minimal IP costs. The facts have shown that this option, which contradicts the hypothesis propounded by Borchgrave et al (2003), is unrealistic.

Thus the existence of GM soybeans creates a transaction cost for the non-GM soybean market. Given the points made above, if hard IP systems (segregation and testing at every point in the chain) were to be mandatory for all soybeans produced in Brazil, GM soybean growing would not be economically viable. Moreover, such a move would conflict with the reality of markets in importer countries, especially the E.U., where demand for soybeans as raw material is far higher than the potential supply of non-GM soybeans covered by hard IP (traceability, segregation and labeling in the final stages).

Market segmentation would therefore have different outcomes depending on the institutional regime adopted in countries that supply raw material (soybeans and meal), such as Brazil:

- **Implementation of a complete traceability, segregation and labeling regime as a mandatory requirement for soy exports**

This regime would require investment upstream in the production chain so that products could be segregated, increasing costs throughout the chain. Estimates given by interviewees range from 4% to 7% of product value to adapt the entire production system, using appropriate seeds (which would be costly in any situation), isolating crops, changing machinery handling methods, and periodically cleaning equipment to avoid contamination. Such estimates do not include the cost of testing, certification and inspection.

Imposition of such a system would entail advantages only for areas capable of meeting more rigorous detection criteria because they already comply with a milder IP regime. Thus this scenario would be feasible only if entire regions were either GM or non-GM across the board, from agriculture to exports. The case of Rio Grande do Sul would be the first: the premium would be lost and it would be assumed that soybeans were all GM, entailing lower IP costs. Even so, a wide-reaching agreement would be required to prevent non-GM growers from going to court to have compliance with rules prohibiting blends guaranteed by practices that increase production cost (e.g. through crop isolation).

A decision by a producer country to implement the “European system” of IP would paradoxically increase the price and reduce exports of soybeans, as well as encouraging production of meal in importer countries. It is hard to predict the effect on

the market mix. Non-GM soybeans are currently estimated to account for 20% of the total and would probably increase their share since by law the imposition of IP systems would apply to GM markets as well.

- **IP regime applied only to non-GM soybeans**

This case would produce an interesting paradox: the stricter the IP regime, the higher would be the offer price for soybeans and meal and the lower the price received by growers. The cost of the process could lead to a negative premium, according to several interviewees. In addition, there would be a sharp fall in E.U. demand for meal, affecting mainly Argentina and the U.S. This effect would stimulate European production of soy-based protein meal, but exports of non-GM soybeans would not fall significantly.

A survey by Gomes (2003) highlights the following specific issues for Brazil:

p) The extension of IP to new areas would raise costs by increasing distances between growers and consumer markets, mainly affecting logistics (from US$9 per ton, or about 5% of product value, to US$15 per ton).
q) The cost of testing would be in the range of US$3-US$4 per ton, or 2%-3%, higher than the opportunity cost of not planting GM soybeans, which as shown above is a little less when the technology fee is included.

Thus in more distant areas such as the Center-West of Brazil, IP cost could reach 12% of product value, a percentage that has never been covered by premiums paid to growers.[16] There is a perception that premiums accrue to trading companies, but this depends on who pays for traceability. None of this eliminates the fact that even though European consumers prefer non-GM soybean products, higher prices of bulk goods, especially meal, move the demand curve upwards and to the left and reduce prices paid to exporters, all other things being equal.

Brazil's situation since 1996 favors the option of establishing a credible process to separate non-GM soy products by contract. This is done, not without difficulties,[17] by some agribusiness firms for certain applications (mainly vegetable protein for human consumption), and does not exceed 5% of total crushing volumes to date.

[16] According to interviewees, premiums for non-GM soybeans are highest in Japan (around US$7-US$12 per ton).

[17] The difficulty of implementing a system to segregate beans and meal in Brazil is evidenced by the fact that Bunge, a crusher located in Rio Grande do Sul, buys non-GM soybeans in the Center-West, almost 2,000 km away from its mill. It would be hard to operationalize segregation, because it would involve a large number of agents who are not willing to change their operating routines.

As shown by Borchgrave et al (2003), IP cost mainly affects the early stages of farm production, creating a problem as regards how to share it out along the chain. In the Brazilian case (Silveira, 2004), low IP costs compared with those of U.S. non-GM growers reflect the soft IP system adopted on the basis of documentation (tax invoices) and testing only at the port rather than all the way along the production chain. It would be difficult to implement hard IP in Brazil because of deficient infrastructure, from roads to ports via low storage capacity in the countryside.

5. Conclusion

For seven years Brazil experienced the uncomfortable situation of using GM seeds without recognizing their existence. A framework for legalization of GMOs has been put in place under the Lula Administration after a number of legal disputes and hesitations that were not brought to an end with the passage of Law 2401 by Congress in March 2005. The situation does not seem to have been totally resolved and it is possible to foresee that agencies responsible for regulating issues in human health (Anvisa) and the environment (Ibama), alongside certain ministries (mainly Environment), NGOs and consumer advocacy groups, will maintain the "trench warfare" in which they have been engaged for some years.

At the center of the debate is acceptance that the Technical Committee on Biosafety (CTNBio) is competent to identify hazards and to formulate rules for monitoring them. The committee includes representatives of the Justice and Agriculture Ministries. For environmentalists, each and every GMO must be required to undergo environmental impact assessment testing and licensing, which would substantially raise the cost of new cultivars. The law currently in force leaves CTNBio free to decide whether such studies and tests are necessary.

It should be borne in mind that the entire debate revolved around GM soybeans, owing to the fact that growers in the South of Brazil had decided in a decentralized manner to adopt GM cultivars from Argentina. However, this fact does not provide parameters for an analysis of the implications of the rules and regulations for other crops with relatively small-scale production and economic importance, such as kidney beans or papaya.

The adoption of GM soybeans in Brazil, the most important fact in Brazilian agricultural biotechnology, has produced several lessons in this early stage of diffusion:

a) The importance of agriculture and agribusiness for the trade balance has a major impact on decisions about technology regulation regimes.

b) Countries that import soybeans depend strongly on the commodity as a source of protein. While this favors the adoption of identity preservation (IP) systems, given the product's low demand elasticity, it also prevents the implementation of a moratorium on marketing of GM food. Thus even with the Cartagena Protocol

it is hard to force countries that produce GM cultivars to comply with rules that unify the two market segments. The stricter the rules, the more they increase the cost of non-GM soybeans and the smaller the premium for segregation.

c) Thus there will not be strong economic incentives to justify investment in infrastructure in the producer countries to meet IP requirements. Such investment will be undertaken for sanitary reasons or because governments deliberately intend to implement agricultural traceability systems. The difficulty of doing so in the meat industry production chain shows how unrealistic it is to propose making traceability mandatory throughout the soy production chain in a short period of time.

Are other GMOs in the pipeline in the same situation as GM soybeans? Apparently not. GM cotton produced by big growers could be in a similar situation, but with the key difference that deciding whether to use Bt cotton is not subject to a prior requirement of defining GM and non-GM acreages. The advantage of GM cotton is that it offers an additional choice for pest control without forcing growers to take a calculated risk. Given the absence of scale economies in the IP process, it is not easy to see at what point the use of GMOs would be justified in applications where flexibility is fundamental.

It makes no sense to prepare a whole infrastructure to identify GM corn when it is known that cultivars of this type will be used only in areas and years with higher expected rates of pest occurrence. No one would incur 10% additional variable cost to use GM seeds without the prospect of higher profit. Unlike GM soybeans, Bt technology offers volatile return on investment. One way to mitigate this risk is to introduce another resistance or tolerance gene into the plant without entailing an increase in the technology fee. This matter is still pending in Brazil.

It is therefore of paramount importance that the scheme with which Borchgrave et al.(2003) propose to segment markets between GM and non-GM should gradually lose relevance. GM diffusion requires acceptance of the idea that all cultivars will have some standard genetically modified traits in the years ahead and that this is an ineluctable trend. In line with this vision, rigorous prior selection of events by companies, researchers and biosafety committees should guarantee acceptable levels of

impact on the environment and human health based on calculations of the costs and benefits of using GM cultivars.

Brazil has developed a substantial infrastructure for biological research and for training skilled human resources in this field. It has temporary advantages in plant breeding, located in key research institutions with Embrapa as the most important node. It has prepared institutions for the new intellectual property regime called for by TRIPS (Dal Poz, Silveira & Fonseca, 2004) and built the foundations for advanced research in plant biotechnology, financing networks of genomics and proteomics. It is also prepared to establish collaborative networks with leading global companies and universities, especially in tropical agriculture.

But all this effort is insufficient for Brazil to remain a player because, as shown in the agricultural biotechnology workshops organized by CGEE/MCT, the central countries, especially the U.S. and its major corporations, invest far larger sums in research than Brazil, where most of the money for R&D in this field is public.

Thus if the option to compete in the markets for platform products — soybeans, corn, cotton, and some horticultural seeds — becomes less viable as the GM market is consolidated, the alternatives will be smaller, more segmented markets such as kidney beans, papaya and banana, and large markets for tropical products such as sugarcane and oranges, in which multiplication vectors hinder appropriation by the technology owner.

However, this option depends on how Brazil develops its biosafety and hazard warning systems. As noted in Section 2.3, the cost of identity preservation (IP) accounts for a relatively small share of value added and does not vary with production scale. On the other hand, the return on investment in plant breeding, estimated by interviewees at US$5 million over a 12-year period per cultivar obtained, does depend crucially on production scale, not to mention remuneration of prospecting for the genes involved. Strict requirements for hazard monitoring could make it unviable to adopt GMOs, since as already mentioned the investment returns are volatile, especially in relation to pest and disease resistance.

Two basic scenarios can be depicted for the coming years:

a) Acceptance of GM food by consumers leads to the implanting of several genes in the same cultivar without incurring non-linear cost increases with IP.

b) Strict rules are imposed on the sale of GMOs, leading to a reduction in growing of platform products and a self-fulfilling prophecy in which innovation serves only major markets and products, losing the social function it would have if it served products with less economic importance, normally grown by small farmers.

An intermediate scenario would entail segmentation of markets and regions, more tolerance within the country, and a narrower margin for exports to countries with more restrictions. This scenario depends on the level of strictness, as discussed in Section 4.3.

The main conclusion is that the economic impact of first-generation GMOs does not justify investment in market segregation. Furthermore, charging fees for intellectual property by innovators faces obstacles such as the need to negotiate with growers who are territorially dispersed but organized in associations and co-ops, as well as limits imposed by the nature of the innovation vector itself, the seed. These general constraints are more severe in countries such as Brazil and Argentina with persistent technological and socioeconomic inequality in the countryside (Buainain, Souza-Filho & Silveira, 2002).

Lastly, the Brazilian case also illustrates the importance of institutional questions and of building a viable and efficient regulatory apparatus. The illegality experienced in Rio Grande do Sul, due partly to the tolerance that is characteristic of Brazil and partly to inept application of the precautionary principle (indecision as a hallmark of our Judiciary), had perverse secondary effects, especially on the seed industry in the state, highlighting the importance of information and the danger of the "trench warfare" waged by environmentalists and their associates.

References

ABRASEM – ASSOCIAÇÃO BRASILEIRA DE SEMENTES E MUDAS. **Anuário**, 2004.

AMÂNCIO, M. C.; SAMPAIO, M. J. **Legislação de Biossegurança no Brasil: Cenário Atual.** CIB: Apresentações Técnicas, 2005.

APASSUL – ASSOCIAÇÃO DOS PRODUTORES E COMERCIANTES DE SEMENTES E MUDAS NO RIO GRANDE DO SUL. **Estatísticas de Sementes** (Vários anos) http://www.apassul.com.br/conteudo.asp?content=08

BATALHA, M. O. *et al*. **Pós-Graduação e Biotecnologia: Formação e Capacitação de Recursos Humanos no Brasil.**

BORCHGRAVE, R. et al. **Economics of "Non-GM" Food-Feed Supply Chains in Europe**. London: Agra Europe, 2003.

CIB - CONSELHO DE INFORMAÇÕES SOBRE BIOTECNOLOGIA. **Apresentações Técnicas** (Várias). http://www.cib.org.br/

COURI, S. **Infra-estrutura de Serviços e Equipamentos em Biotecnologia no Brasil**. IN. SILVEIRA, J. M. F. J. *et al* (Org.) Biotecnologia e Recursos Genéticos: Desafios e Oportunidades para o Brasil. Campinas: Instituto de Economia/FINEP, 2004.

FAPESP. **Relatório de Atividades 2003**. São Paulo: FAPESP, 2004.

DAL POZ, M. E. et al. **Políticas Governamentais de apoio à Pesquisa Genômica**. IN. SILVEIRA, J. M. F. J. *et al* (Org.) Biotecnologia e Recursos Genéticos: Desafios e Oportunidades para o Brasil. Campinas: Instituto de Economia/FINEP, 2004.

DAL POZ, M. E. et al. **Direitos de Propriedade Intelectual em Biotecnologia: um processo de construção.** IN. SILVEIRA, J. M. F. J. *et al* (Org.) Biotecnologia e Recursos Genéticos: Desafios e Oportunidades para o Brasil. Campinas: Instituto de Economia/FINEP, 2004.

EMBRAPA. **Nota Informativa: Pesquisa Biotecnológica na Embrapa.** http://www.cenargen.embrapa.br/.

FONSECA, M. G. D. *et al*. **Biotecnologia Vegetal e Produtos afins: Sementes, Mudas e Inculantes.** IN. SILVEIRA, J. M. F. J. *et al* (Org.) Biotecnologia e Recursos Genéticos: Desafios e Oportunidades para o Brasil. Campinas: Instituto de Economia/FINEP, 2004.

FUCK, M. P. **Funções Públicas e Arranjos Institucionais: o Papel da Embrapa na Organização da Pesquisa de Soja e Milho Híbrido no Brasil**. Campinas: Instituto de Geociências/Unicamp, 2005. (Dissertação de Mestrado)

INSTITUTO BRASILEIRA DE GEOGRAFIA E ESTATÍSTICA – IBGE**. Censo Agropecuário**, 1995.

JAMES, C. **Preview: Global Status of Commercialized Transgenic Crops: 2004**. ISAAA Briefs No. 32. Ithaca, NY: ISAAA, 2004.

JUDICE, V. M. M**. Biotecnologia e Bioindústria no Brasil: Evolução e Modelos Empresariais**. IN. SILVEIRA, J. M. F. J. *et al*(Org.) Biotecnologia e Recursos Genéticos: Desafios e Oportunidades para o Brasil. Campinas: Instituto de Economia/FINEP, 2004.

MCT/CNPq. **Resenha Estatística do CNPq**. Brasília: CNPq, 2004.

MELO, R. W. et al. Indicadores de produção de soja no Rio Grande do Sul comparados ao zoneamento agrícola. **Pesquisa Agropecuária Brasileira**, Brasília, vol. 39, n. 12, p. 1167-1175, dez. 2004.

MONTEIRO, A. J. L. C. Lei de **Biossegurança – A Legislação que não deixam aplicar**. CIB: Apresentações Técnicas, 2003.

PELAEZ, V. et al. Soja Transgênica versus Soja Convencional: uma análise comparativa de custos e benefícios. **Cadernos de Ciência & Tecnologia**, Brasília, vol. 21, n.2, p.279-309, maio/ago. 2004.

ROESSING, A. C.; LAZZAROTTO, J. J**. Soja Transgênica no Brasil: situação atual e perspectivas para os próximos anos.** Brasília: Centro de Gestão e Estudos Estratégicos, 2005. (Texto apresentado em Seminário)

SALLES-FILHO, S. L. M. **Instrumentos de apoio à definição de políticas em biotecnologia**. Brasília: FINEP/MCT, 2001.

SANTINI, G. **A Reestruturação da Indústria de Sementes no Brasil**. São Carlos: Departamento de Engenharia de Produção/UFSCar, 2002. (Dissertação de Mestrado)

SILVEIRA, J. M. F. J. *et al*. **Biotecnologia no setor de saúde humana: *bio-commodities* e as fábricas biológicas**. IN. SILVEIRA, J. M. F. J. *et al* (Org.) Biotecnologia e Recursos Genéticos: Desafios e Oportunidades para o Brasil. Campinas: Instituto de Economia/FINEP, 2004.

SILVEIRA, J. M. F. J. *et al* (Org.) **Biotecnologia e Recursos Genéticos: Desafios e Oportunidades para o Brasil.** Campinas: Instituto de Economia/FINEP, 2004.

TRAXLER, G. Traxler, Greg, 2000. Assessing the benefits of plant biotechnology in Latin America. Conferência apresentada no BID, 7 de novembro de 2000.