Report

Plant Breeding and related Biotechnology Capacity

URUGUAY

Prepared by

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CHAPTER 1. <u>INTRODUCTION</u>

Uruguay is located in the Southern Cone of South America, between 30 and 35º South Latitude and between 53,5 and 58,5º West Latitude, with an area of 176.215 km^2. It is located between Argentina and Brazil, with coast to the Rio de la Plata and Atlantic Ocean. Its total population in 2005 (INE) was 3.305.723 inhabitants, with half of its population located in Montevideo, the country's capital.

The Uruguayan territory is undulated, showing hills and small valleys around the country, which is crossed by a dense hydrographic system. Its highest point is 513 masl. Subsoil is extremely variable, which determines high soil variability. Its climate is humid-subtropical-temperate, with an annual average rainfall of 1300 mm, showing irregular rainfall distribution around the year. Average temperature is 17,5º C, ranging from 23º C in summer to 13º C in winter. Frosts from May to September are expected, with some extreme temperatures of 8 to 10 degrees Celsius below 0 at night.

In general terms, Uruguayan countryside is characterized by a rich number of different environments, and agro-ecosystems, originally with continuous vegetation cover of natural pastures, suitable for cattle and sheep production. Some 2500 species (140 families and 811 genera) have been reported in the Uruguayan flora, being center of origin of several forage species (71% of its territory is occupied by natural pastures, base of its cattle production). Natural forest and wetlands are also special and important environments.

Productive characterization of the country

Uruguay is an agricultural country. Beef and dairy cattle and wool have traditionally been the most important productions for export, representing the most of the income from international trade. Rice, malting barley, soybeans and forestry have also become important in their share of exportations. Extensive crop production is done mainly in the west part of the country in a dryland production system. Toward the east and north part of the country, rice is grown under irrigation.

Plant production has traditionally been done mainly for internal consumption, with the exception of rice, malting barley, and most recently soybeans, (mostly grown for the external market). In the last years wheat has also become an exported commodity.

The most important extensive crops are:
Winter crops: wheat and malting barley;
Summer crops (cereal): rice (under irrigation), maize and sorghum in dry lands.
(Oil crops): soybean and sunflower.
Soybean has grown its area from some 9.000 hectares in 1999/2000 to 578.000 hectares in 2008/2009, and 863.000 in the 2009/2010 season (Anuario Estadístico Agropecuario 2010, DIEA, MGAP).

Among fruit and horticultural crops: citrus (for external market), grapes, apples, pears, peaches, plums, quinces are the most important for fruit production, although an important area of olives has been planted in the country in the last years, and some novel fruit crops like blueberries and kiwis have also been established. Among horticultural crops, potatoes, sweet potatoes, onions, tomatoes and carrots are the most important ones. Nevertheless, several other horticultural and fruit tree crops are grown for consumption.

Forestry has increased dramatically its area, occupying 676.000 has in 2004, mainly with *Eucalyptus* and *Pinus* species.

Commercial crops, both, for consumption or for external markets are produced mainly based on national or introduced modern cultivars, although local varieties are still used in a few crops.

In relation to pastures and improved grassland areas, main species used are *Lotus corniculatus*, *Trifolium repens, Trifolium pratense*, *Lolium multiflorum*, *Festuca arundinacea* and *Avena byzantina.*

CHAPTER 2. NATIONAL AGRICULTURAL RESEARCH SYSTEM

The National Agricultural Research System in Uruguay has been mainly funded by the public sector, being established in the early 1900's. Being Uruguay an agricultural country, the research system is mainly based on agricultural research. Plant breeding has been one of the most important areas, beginning back in 1912, when the government hired the German scientist, Dr. Alberto Boerger. In 1914 the first Experimental Station was founded: the "Instituto Fitotécnico y Semillero Nacional", established at La Estanzuela, Colonia, for breeding and seed production purposes.

2.1. Plant Breeding programs in Uruguay

Plant breeding began with wheat breeding, based on the germplasm of local adapted varieties, with very good disease resistance, which had been introduced into the country and used since the time of the colony. In the early years of the last century, seed distribution to the farmers was one of the main objectives of the research station.

Plant breeding activities in different crops were added through the years: oats, flax, maize, sunflower, forage crops (red and white clover, ryegrass), most of them based on local adapted varieties, but with strong germplasm exchange with the region, mainly with Argentina. Later, soybean and sorghum were also included.

In 1935, La Estanzuela established a program on Industrial and Forage Plants, as well as an Official Seed Distribution Service, under the scope of the Ministry of Livestock and Agriculture. The main objective was multiplication and distribution of seed to the farmers. In the following period, research was also carried out in different areas of the agricultural production in several research stations located around the country.

In 1961, all the public research projects and programs (with the exception of the work carried out by the academic sector) were reorganized in an Agricultural Research Center: "Centro de Investigaciones Agrícolas "Alberto Boerger" (CIAAB), with five research stations covering the country and the different productions In most of main crops, plant breeding was highly supported during the 60's and early 70's. Consequently, the Seed Certification Program was also a very strong one. During the 80's, many of the plant breeding programs in extensive crops began to decrease their activities, (flax, oat, soybeans, maize, sorghum, sunflower) or were closed, mainly in cross pollinated crops.

In horticultural crops, breeding activities were emphasized since the 70's at CIAAB, including seed production in onion, garlic, potato, sweet potato (with CG support), and grain legumes (mainly beans and peanuts).

In 1989, following a new re-organization, the National Agricultural Research Institute (INIA) was created, a public non-state institution, with an Executive Board composed by two representatives of the government (eventually with double vote, that gives them majority), appointed by the Livestock, Agriculture and Fishery Ministry (MGAP in Spanish), and two representatives from farmers organizations. One of MGAP delegates is INIA's president. Its particularity is that although is a public institution, all activities regarding accounting, personnel and contracts are regulated by private law.

All the research activity was reinforced after the creation of INIA, as well as most of plant breeding programs. Some new breeding programs were installed, like in some forest tree species (Eucalyptus, Pinus). In horticultural crops, strawberry breeding program began toward the 90's and tomato toward the 2000.

The academic sector (University of the Republic, Faculty of Agronomy) also has carried out plant breeding work since mid 60's in different crops (barley, maize, citrus, onion, carrot, eucalyptus and pinus) and domestication programs on native forage and fruit tree species.

Actually, in Uruguay, most of the formal plant breeding activities are being carried out by the public sector, being the most important breeding institutions INIA and the Faculty of Agronomy. Some breeding activities have been carried out by a few private companies since the 80's, and some new ones have been incorporated into this area in the last years.

The main goal of the national plant breeding program is to create cultivars to be grown for internal consumption or for industrial and/or exportation requirements. The main objectives of Plant Breeding Programs (PBP) are productivity increase, industrial quality of the product and biotic stresses resistance (mainly fungal diseases) in crops, adding characteristics like persistence and seasonal productivity in forage crops.

In winter crops, the varieties grown in the country are mainly a product of the national PBP, although introduced cultivars from public and private PBPs of the region have also appeared in the last years. In wheat, local adaptability of varieties has been an objective of the utmost importance in the PBP. For barley, the main source of varieties has been introduced germplasm, although lately several superior lines have been released by the national PBP, as a result of an interesting integration of public and private sector in the last decades through the National Barley Board. In oats, most of the cultivars used in production are national, and local adapted varieties have been very important basis for the PBP.

In summer crops, several changes have occurred in the last 30 years. National PBP of sunflower (which began in the 30's), sorghum and soybean (began in the 60's) have progressively disappeared since the 90's. Some maize breeding is actually being carried out, mainly for forage purposes in INIA, and based on local varieties in the Faculty of Agronomy. (A very interesting National Collection of more than 800 local varieties is hold in the Long Term Storage Facility of INIA). In maize for grain, most of the seed used for production is introduced and of hybrid origin, with more than 60% of the area planted with GMO materials (carrying the MON 810 and BT11 events). Actually, in sorghum (both for grain and forage) and sunflower, most of the seed is introduced. The soybean production is carried out with introduced GMO varieties (tolerant to Glyphosate). Actually, INIA is beginning again a PBP for this crop. Also, the rice breeding program at INIA is now one of the strongest PBP at the institution and in the country as well.

In forage crops, (ryegrass, oat, fescue, red and white clover, lucerne, D*actylis, Phalaris, Lotus*), most of the cultivated seed is from public varieties developed in the 60's and the 70's, and based on local adapted varieties. Plant breeding activities in some new forage species have begun in the last years: *Lotus subbiflorus, Lotus uliginosus, Ornithopus compressus,* and three cultivars of *Bromus auleticus* have been released.

In horticultural crops, the situation is variable. In those crops where PBP were developed, seed production is also done in the country (onion, sweet potato, strawberry). In a few crops, seed from local varieties are used; in others, the seed is mainly imported. It is remarkable that since the 70's aspects related to seed production, mainly in vegetative propagated species have been studied, as well as the development of production systems and adapted varieties for those systems. Besides, in those crops, techniques for virus free plant production and accelerated multiplication by tissue culture were also adapted. Support by projects from FAO and the International Potato Center during the 90's have been very important in the potato and sweet potato crop development.

A minimal climatic differentiation and an unfavorable rainfall regime for seed production of the country for most of these horticultural crops have been compensated using adapted varieties as well as novel multiplication systems. Most of this effort has been developed by public institutions, being these species recently introduced into the productions systems. The use of open pollinated varieties, due to its practicality and lower production costs, as well as the improvement of varieties in vegetative propagated species -with resistance to systemic diseases- facilitates its multiplication and use by farmers. It must be taken into consideration that in these crops almost one third of the production cost is associated to the seed. Besides, most farmers are small and family farmers that do not have access to protected varieties in vegetative propagated species. It must be remarked the difference with today's situation, where multiplication of improved local varieties by the own farmer predominates, opposed to a previous situation where local populations, with disease and commercialization deficiencies predominated.

In fruit tree production, the situation is also variable, with the co-existance of national and introduced germplasm. Since the 70's, public research PBP have done introduction, evaluation and release of varieties in some species (like peaches), rootstocks in several species, and also the characterization of Tannat and other vine clone varieties. In the last years, evaluation and selection activities in olives have also begun, adding to the traditional breeding in peaches. Research in management of blue berries and other berries is also on its way. The domestication process of a few native species, like *Acca sellowiana* (guayabo del país) mainly, but also in *Psidium cattleianum* (arazá) has also been started in the public institutions in the recent years.

For most forest tree species, seed is imported, although seed of improved varieties are now also produced in the country by INIA.

Mainly in forage and horticultural crops, a new trend has been the increasing participation of farmers in the breeding, evaluation and selection process.

Plant breeding in the private sector was not important in Uruguay during most of the last century, although programs in some crops have been established on the last years.

2.2. Trends in the near future and government policies for agriculture

In order to achieve the goal of a productive country, the Livestock, Agriculture and Fishery Ministry, has proposed several objectives:

1. Sustainable use of natural resources, through a rational use of soil and water elements.
2. Production increase assuring social inclusion and equity.
3. Strengthening of agro industrial boards or chains, (in barley, wheat, and rice have been established several years ago), that are the basis of the economy. In order to do that, the identification of main issues of each sector is of the upmost importance, as well as maintaining the actual external markets and searching for new opportunities to diversify or assure the demand.
4. Support the productivity and competitivity of the agro industrial chains, based on added value to the primary natural resources, and meeting international requirements in product quality, sanitary condition, food safety, through appropriate measures.
5. Increasing inputs in research and capacity building in the related areas, as well as technical training and qualification.
6. Establishment of different types of measures to decrease risk production: ex: insurances, emergency previsions, financing mechanisms.
7. Special attention to small farmer production through a differential general approach and improvement of rural salaried worker condition. (Since more than 60% are small farmers).
8. Increasing role of MGAP and related institutes, through reorganization and progressive decentralization of functions, in order to improve technical training and access of farmers to the different services. Strengthening the coordination between institutions in order to improve the use of available resources.
9. Co-existence of MGO, being approved every new event through an interinstitutional commission that evaluates the risk of any new solicitude for introduction (CERV in Spanish).

CHAPTER 3. DESCRIPTION AND INTERPRETATION OF THE DATA FROM EACH QUESTIONNAIRE

PUBLIC SECTOR

National Agricultural Research Institute (INIA)

The National Agricultural Research Institute (INIA) is a legal person within the non-state private law, created in 1989, that followed the research lines developed at the CIAAB (Alberto Boerger Agricultural Research Center), created in 1961, as a part of the Ministry of Livestock and Agriculture. CIAAB was created based on the existing La Estanzuela National Plant Breeding and Seed Institute, founded in 1914. Nowadays, INIA is integrated by a total of five research stations, located at the most important and representative productive areas in the country. They carried out research activities in livestock, agriculture and forestry.

Plant breeding

Taking into consideration the institutional continuity of the actual INIA, this public national research system has carried out plant breeding activities in the country for almost one hundred years.

Number and educational level of scientists involved in plant breeding (Question 4):

INIA is the most important plant breeding institution in Uruguay, with an actual dedication of 20,4 Full Time Equivalent (FTE) plant breeders, being the organization that has the highest number of plant breeders in the country (Table 3.1 y Figure 3.1a). Analyzing the evolution from 1985 to the first years of the 90's, the number of plant breeders decreased, since several plant breeding programs were closed (dry-land crops), and the researchers were reassigned to other activities. Since later in that decade to now, a constant increase in plant breeding dedication at the institution is observed. In relation to the educational level of scientists involved in plant breeding, an increasing number of masters and PhD level is observed, mainly during the last years. It must be noted that not all the researchers are full time and exclusive to plant breeding, developing in those cases other research activities.

Table 3.1. FTE (full time equivalent) evolution de INIA since 1985 to 2008, according to educational level of plant breeders and biotechnologists.

Research Area	Year	B.Sc.	%	M.Sc.	%	Ph.D.	%	Total	%
Plant Breeders	1985	11,0	64,7	6.0	35,3	0,0	0,0	17,0	100
	1990	8,0	51,0	6,7	42,7	1,0	6,3	15,7	100
	1995	10,0	58,5	5,1	29,8	2,0	11,7	17,1	100
	2000	6,0	31,4	9,1	47,6	4,0	20,9	19,1	100
	2004	6,0	29,9	10,1	50,2	4,0	19,9	20,1	100
	2008	5,7	27,9	8,6	42,2	6,1	29,9	20,4	100
Biotechnologists	1985	1,0	100,0	0,0	0,0	0,0	0,0	1,0	100
	1990	1,0	100,0	0,0	0,0	0,0	0,0	1,0	100
	1995	4,0	66,6	1,0	16,6	1,0	16,6	6,0	100
	2000	2,0	28,6	3,0	42,8	2,0	28,6	7,0	100
	2004	1,0	14,4	3,0	42,8	3,0	42,8	7,0	100
	2008	2,0	18,7	5,0	46,7	3,7	34,6	10,7	100

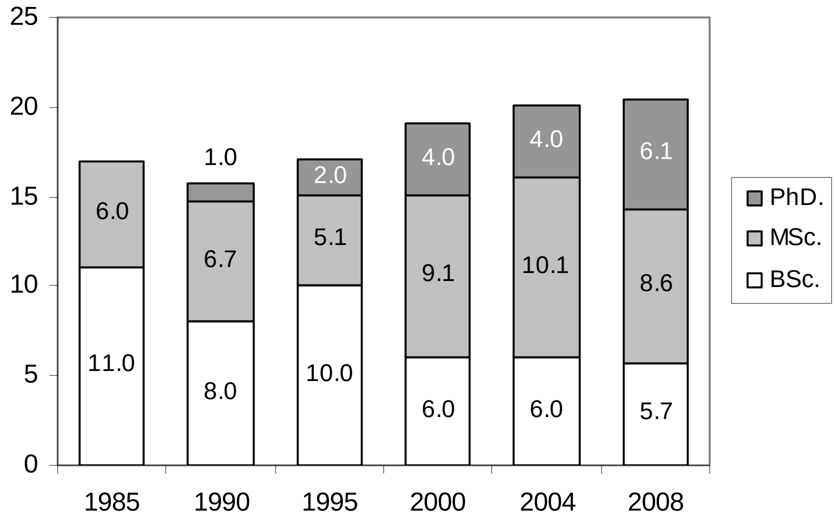


Figure 3.1a. Distribution of plant breeders between 1985 and 2008, according to their educational level.

Number and educational level of scientists involved in biotechnology

Although the Biotechnology Unit, located at INIA Las Brujas (Canelones), was created in 1989, the institution had begun with activities in the area some years earlier.

Following the same pattern of plant breeding, time of researchers devoted to biotechnological activities increased during the last part of the period (Table 3.1 y Figure 3.1b). The educational level of the researchers has also improved, as reflected by the number of researchers with postgraduate studies.

The specialized biotechnological areas developed at INIA are: molecular characterization, tissue culture, double haploid breeding, marker-assisted selection, wide crosses and crosses with wild materials. Work is done also in the area of genomic information and biostatistics' and computer information as support to the identification of candidate genes for assisted selection (Question 10).

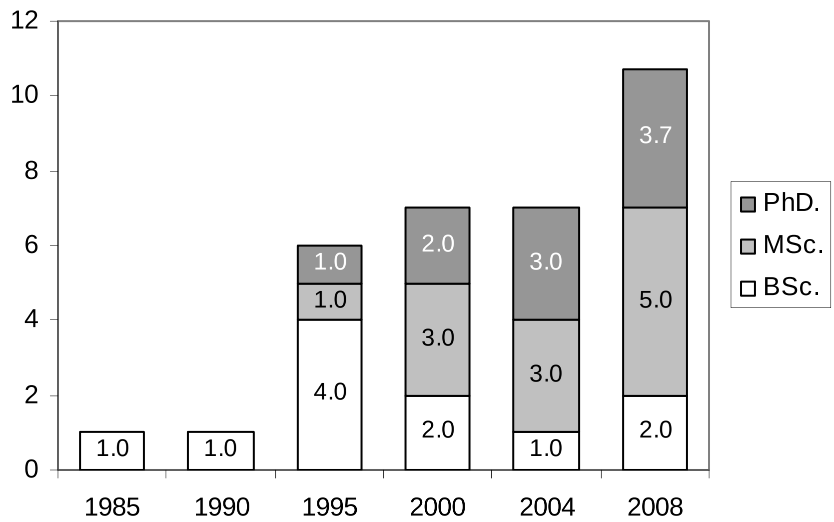


Figure 3.1b. Distribution of biotechnologists between 1985 and 2008, according to their educational level.

Organization's total budget and proportion allocated to plant breeding activities in the period 1985 to 2008 (Question 5):

The information on the total research budget, budget devoted to plant research and plant breeding budget are presented in Tables 3.2 and 3.3. The budget of INIA originates from the revenue of an additional tax of 4 o/oo (four by thousands), as a maximum to Agricultural Goods Alienation and the contribution (matching fund) that the Executive Power annually assigns, that is at least equivalent to the one established by the mentioned additional tax. For that reason, there is a close relationship between the amount that the institution receives and the national agricultural production. Although in 2008 occurred a very important increase of the budget, due to the exceptional productive conditions of the year, there is also a distorting factor present in the 2008 estimation, since the estimation process changed, now including structural costs not included in the previous years. Anyway, in both tables the percentage devoted to plant breeding increased during the period in study.

Table 3.2. Budget dedicated to Plant Breeding Activities, compared to the Total Research Budget. (Uruguayan Pesos).

Financial Resources	2000	2004	2008
Total Research Budget	195.253.041	311.434.961	529.807.786
Plant Breeding budget	26.824.820	51.029.809	94.953.181
%	13.7	16.3	17.9

Table 3.3. Budget dedicated to Plant Breeding Activities, compared to the Total Plant Research Budget (Uruguayan Pesos).

Financial Resources	2000	2004	2008
Total Budget for plant research	125.470.685	181.716.579	316.895.260
Plant Breeding budget	26.824.820	51.029.804	94.953.181
%	21,4	28,1	30.0

Organization's resource allocation (human and financial) for plant breeding activities. Percentage distribution by crop and/or crops-group. (Question 6):

The most important PBPs of INIA are, in crops: wheat, barley, oats, rice, maize and sunflower; in forages: white clover, lotus, fescue, ryegrass, lucerne and red clover. In addition, the genera *Ornithopus* and *Lotononis* are being developed for extensive production systems, (although there is an evaluation of a much more extensive number of species); in horticultural species: potato, sweet potato, and other like onion, tomato, garlic and strawberry; in fruit tree species: apple, pear, plum and citrus; in forest tree species: *Eucalyptus* and *Pinus*, and work is beginning in native forest and fruit tree species.

Percentage distribution by crop and/or crops-group of the total resource allocation, and its evolution is presented in Table 3.4 and Figure 3.2.a, b and c.

Table 3.4. Percentage of the budget used in each of the breeding programs by crop or group of crops between 2000 and 2008.

Crops	2000	2004	2008
Wheat	17.4	14.6	14.0
Barley	12.7	10.3	10.1
Forage Oats	1.1	1.7	1.0
Rice	25.1	22.0	16.7
Maize	1.5	1.8	3.3
Sunflower	1.2	1.5	3.3
Forage crops	9.8	15.3	13.9
Roots and tubers	2.6	2.7	8.1
Vegetables&Fruits	6.8	5.8	14.6
Forest species	21.8	24.3	15.0
Total	100	100	100

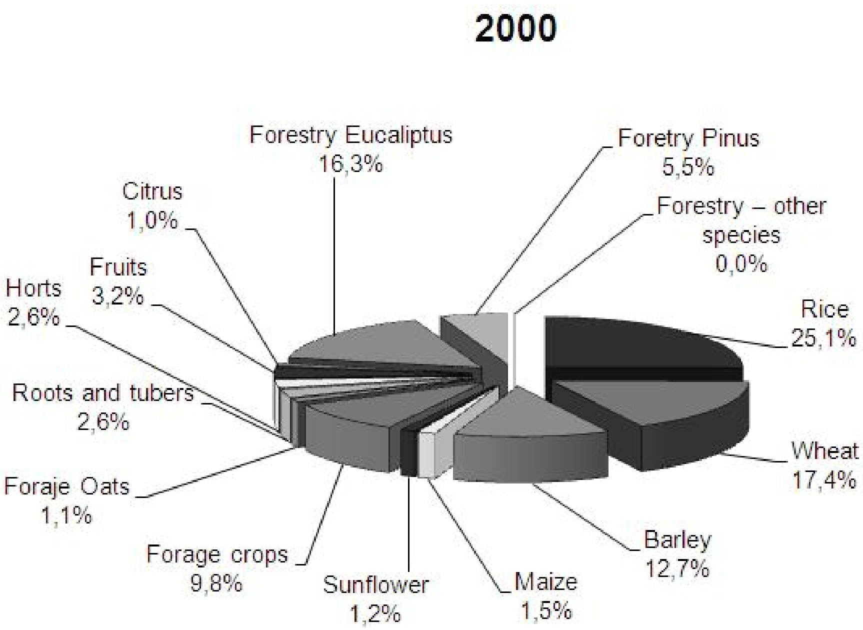


Figure 3.2.a. Budget % allocated to the different breeding programs at INIA. 2000.

2004

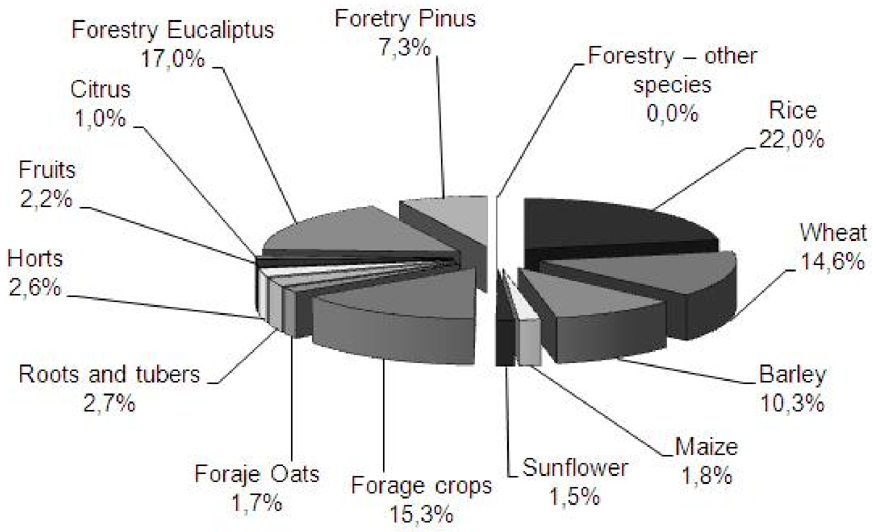


Figure 3.2.b. Budget % allocated to the different breeding programs at INIA 2004.

2008

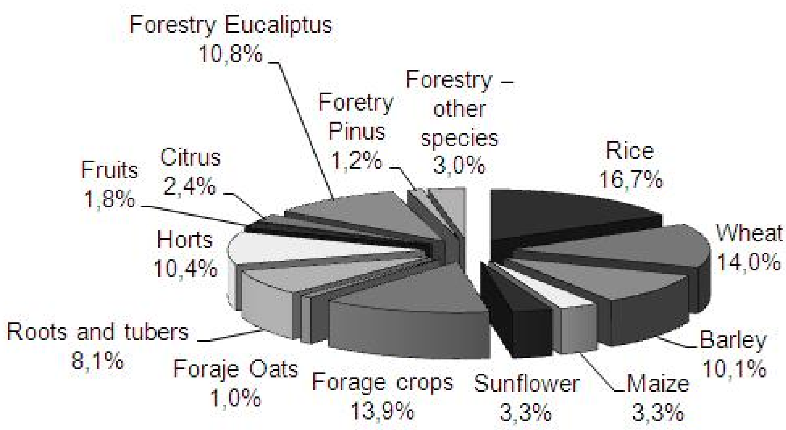


Figure 3.2.c. Budget % allocated to the different breeding programs at INIA. 2008.

Wheat breeding has been the program that historically received more support, but between 2000 and 2004 the rice breeding program received the highest budget, being this program in close relationship with the private sector (the National Rice Growers Association or ACA). The importance of this crop has increased in the country, and the crop area has also increased significantly. The rice production is mainly for the external market (90%), and it contributed to the 10% of the Gross Production Value of the agricultural activity in 2004.

The wheat breeding program, the oldest one in Uruguay as mentioned before, has traditionally been the most relevant plant breeding program, reflecting the adoption of the crop by farmers in the country. The area devoted to wheat has fluctuated in the last thirty years, reaching a maximum close to half a million hectares in some years with 476.000 hectares planted in the 2008/2009 season. The breeding program also works in close relationship with the private sector through the Wheat National Board. In barley, a crop which main objective is malting barley for the external market, the breeding work is done jointly with the Faculty of Agronomy and the private sector through the Barley National Board.

The *Eucalyptus* (*E. grandis* y *E. globulus*) breeding program followed the same pattern of the crop area, which has been dramatically increased in the last years, mainly since the 90's, following a particularly special governmental support to the forestry sector. In the last years, the relative budget allocated to forest trees breeding (*Eucalyptus y Pinus)*, has decreased, and some breeding work was also started in other forest tree species.

The total allocated budget to forage breeding was significantly increased toward 2004, but it must be taken into consideration that important projects with international financing support were executed during this period. In oat, used basically as a forage crop in Uruguay, the program maintains its importance during all the considered period.

At 2008, although with some variations, tendencies were maintained. A relative increase in the budget was observed for vegetables and fruits, due mainly to horticultural crops including potato and sweet potato. This fact should be analyzed taking into consideration that no private plant breeding activities are developed in the country for these species. And it needs to be mentioned that in the case of horticultural crops, that budget is not all devoted to plant breeding activities. In the 2008's estimation, most of plant breeders are not full time breeders, devoting part of their time to other complementary activities, like seed production, genetic resources, crop management, crop pathology, evaluation, extension activities, etc, and these costs were all included in the breeding budget estimation. In the case of fruits, the program maintains its importance during all the considered period.

Maize and sunflower breeding programs maintain minimum activities when compared to their activity rate during the 70's and 80's. Finally, plant breeding programs of some other crops, like flax, grain sorghum and soybean, that were important ones and with full development from the 60's to the 80's, were closed several years ago (data not presented since that period was not in this survey). Soybean breeding program is now beginning again, since the soy area has had a dramatic increase, reaching 863.000 hectares in the 2009/2010 season.

Taking into consideration the 2000-2008 period, rice, forest tree species, wheat, barley and forage species breeding programs received the highest budget proportion at INIA. Vegetable and fruits also had an important increase in their budget toward the end of the period (increase that occurred mainly in horticultural crops). Part of that budget is not considered regular budget, and may be overestimated, since it comes from national or international projects under execution during the period considered in this survey and that it will finish at the end of the projects.

Type of activity INIA is carrying out at each breeding program. (Question 7):

All INIA's breeding programs carry out genetic enhancement activities, make crosses, evaluate segregating populations, evaluate fixed lines developed by the breeding programs and evaluate fixed lines introduced from other breeding programs (Table 3.5). It can be considered that most of the programs have a high degree of development. Evaluation of genetic material obtained from other breeding programs is a common activity for most of them.

Table 3.5. Activities that carry out the breeding programs at INIA. (2008).

Specify crop(s)	Genetic enhancement activities	Making crosses	Evaluating segregating populations	Evaluating fixed lines	
				developed by the breeding programme	introduced from other breeding programmes
Wheat	X	X	X	X	X
Barley	X	X	X	X	X
Oat	X	X	X	X	X
Rice	X	X	X	X	X
Maize	X	X	X	X	
Sunflower	X	X	X	X	
Forages	X	X	X	X	X
Roots and tubers (1)	X	X	X	X	X
Horticultural crops	X	X	X	X	X
Fruit trees	X	X	X	X	X
Forestry			X	X	
Percentages	100%	100%	100%	100%	64%

1. Potato and sweet potato

<u>Distribution of human and financial resources allocated to germplasm enhancement, line development and line evaluation (Question 8)</u>:

Information on distribution of human and financial resources allocated to germplasm enhancement, line development and line evaluation by crops during 2008 are presented in Figure 3.3 and the tendency for those activities for the same year are presented in Figure 3.4.

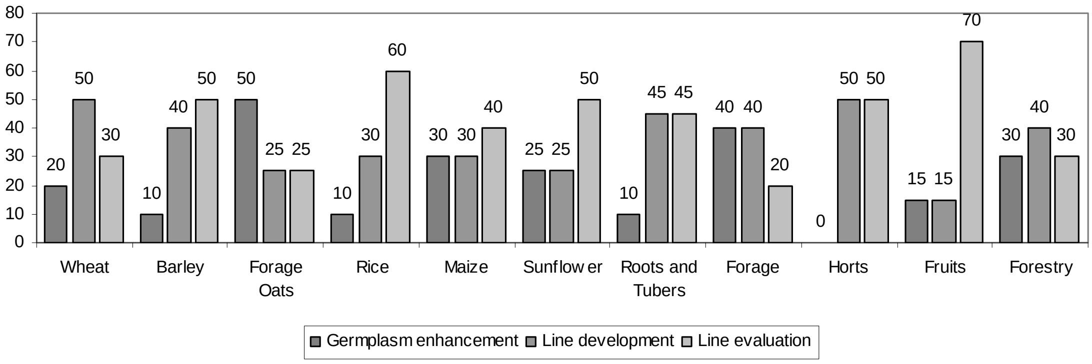


Figure 3.3. Percentage distribution of plant breeding activities in the different crops. 2008.

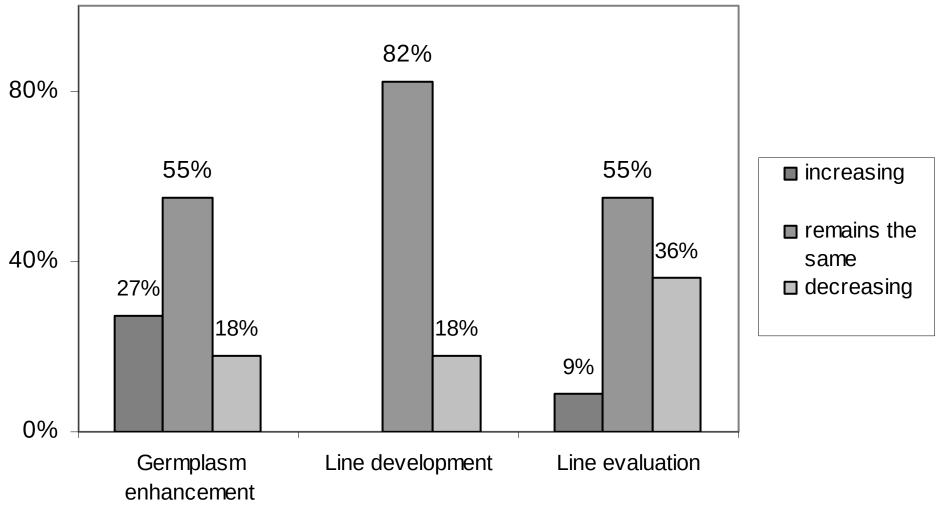


Figure 3.4. Tendencies (% of responses) for the following activities: germplasm enhancement, line development and line evaluation. 2008.

As it is presented in Figure 3.3, line evaluation is one of the most important activities at INIA's breeding programs. It takes at least half of the budget in barley, rice, sunflower, and horticultural and fruit tree species. Line development is a relatively important activity in wheat and horticultural species, and moderately relevant in barley, roots and tubers, forage and forest tree species. For 2008, genetic enhancement is reported as an important activity in forage species, possibly due to the objectives of important international projects that the program is carrying on. Data from Figure 3.4 indicates that approximately one third of the breeding programs are increasing its activity in germplasm enhancement, and half of them maintain its importance. Most of the breeding programs maintain the activities on line development, and approximately half of them reported the same relevance of line evaluation. In 36 % of the programs line evaluation activity decreased.

Budget distribution (%) at INIA for line development and evaluation, germplasm enhancement and biotechnology (Question 9):

Considering the 1995-2008 period, an increasing tendency of germplasm enhancement and plant biotechnology is observed (Table 3.6 and Figure 3.5). Line development and evaluation presents a relative reduction that stabilizes toward 55% of the total budget. Really, the interpretation should be that as biotechnology activities were added in the analysis, plant breeding appears as relatively reduced.

Table 3.6 Proportion of resources assigned to the different research areas. Evolution of human and financial resources distribution for line development and evaluation, plant biotechnology and germplasm enhancement.

Research Area	1995	2000	2004	2008
Line development and evaluation	80	70	60	55
Plant biotechnology	5	10	13	15
Germplasm enhancement	15	20	27	30
Total Distribution (%)	100	100	100	100

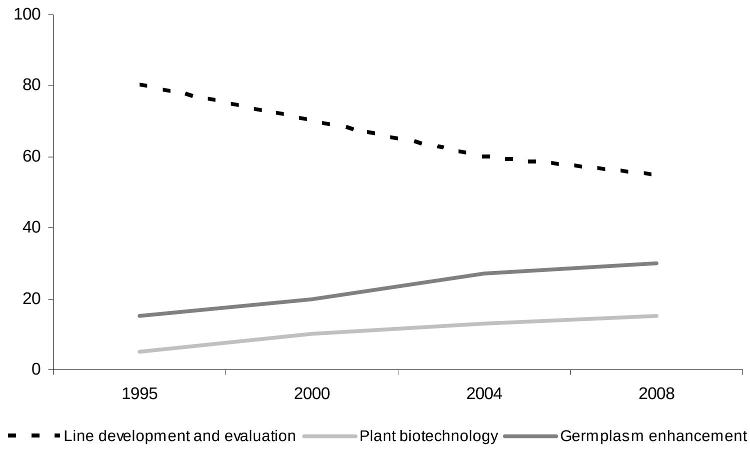


Figure 3.5. Evolution of human and financial resources distribution for line development and evaluation, plant biotechnology and germplasm enhancement.

Biotechnology areas INIA is working on (Question 10):

As it was mentioned, main activities in plant biotechnology are molecular characterization, tissue culture, double haploid breeding, marker-assisted selection, wide crosses and crosses with wild materials.

INIA's breeding programme organization (Question 11):

In Table 3.7, number of crosses made, number of segregating population, number of experimental plots, and number of locations used for field trials are presented. Winter crops (wheat, barley and oat) are the programs that make the higher number of crosses. Crossing is also an important activity for rice, potato, forage species and strawberry. Number of segregating populations and field evaluation present the same trend. The regional evaluation of the species in which INIA works on is variable, reflecting the specific needs in every crop, available resources and management complexity. Anyway, it seems reasonable for the crop area of Uruguay.

Table 3.7. Number of crosses, segregating populations, number of experimental plots and locations used for field trials by INIA's breeding programs.

Crops	2008			
	Number of crosses made	Number of segregating populations	Number of experimental plots	Number of locations used for field trials
Wheat, Barley, Oat	670	13000	25880	4
Rice	130	700	3967	7
Maize	200	800	3500	1
Sunflower	200	800	3000	2
Potato	150	30000		
Sweet potato	30	10000		
Forage species	105	18000	17000	4
Onion + tomato	10	10		
Strawberry	100/	5.000/10000		
Fruit tree	12	10	550	12
Forestry			80	4
TOTAL	1607	150560	53977	

Main sources of germplasm used in the breeding programmes of INIA for each major crop and/or crops-group. (Question 12):

According to the data presented in Table 3.8, the main sources of germplasm used depend on the different breeding program. Wheat, oat, maize, vegetable and fruits and forest tree species mainly use national genetic resources, particularly landraces adapted to the country specific ecological conditions..These species were introduced to the country at least some decades and even centuries ago, especially important is the national collection of maize composed by 852 local varieties, and conserved at the Genetic Resources Unit of INIA. Other programs, like sunflower and most of the forage species actually depend on introduced germplasm. In particular for sunflower this situation has changed substantially since de 80s;, when an important collection of adapted varieties,were released and used in crop production. It also exists an important richness of local varieties for lucerne, lotus, and other forage species for which several collecting expeditions have been made within the country. The remaining breeding programs present intermediate situations.

In horticultural crops, the contribution of local and national germplasm banks is high, but it must be taken into consideration that a high proportion of that germplasm comes from local adapted varieties or landraces. These local varieties had been very successfully used by plant breeding programs, developing improved varieties with high adaptation. In particular, onion first and carrot lately can be cited as very good examples. Germplasm collection and characterization of tomato, sweet pepper, and grain legumes (mainly beans and peanut) has been done. In vegetatively propagated species, garlic has also benefited from the use of local populations. In sweet potato, local varieties are now being used for plant breeding, but the program originated from introduced material. In reference to the use of wild populations, it is remarkable the effort made on characterization and utilization of the wild species *Solanum commersonii* related to cultivated potato as a source to soil borne disease resistance genes. In some of these crops, when local gene bank is mentioned as source of germplasm, it refers to germplasm improved from introduced variability of different types (for example, as progenies in potato, sweet potato and strawberry).

Table 3.8. Main sources (% by crops) of germplasm used in the breeding programs of INIA.

Cultivos	Germplasm source (2008)								
	Local germplasm bank	National germplasm bank	Introduction through bi or multilateral agreements	Introduction through participation in germplasm evaluation networks	CGIAR gene banks	Public organizations in industrialized country	Private sector	Farmers material	Total
Wheat	80			10	10				100
Barley	45		15		5		35		100
Oat		65		20				15	100
Rice	50		40		5	5			100
Maize		50		30		5	5	10	100
Sunflower		10		60		10	20		100
Roots and Tubers	50	5	10		15	20			100
Forage species	10	10	25		20		25	10	100
Horticultural crops	40	5	12,5	0	10	0	22,5	10	100
Fruit trees	45		35	5		10	5		100
Forest trees	70						30		100

Analyzing the distribution of sources of germplasm (%) used by INIA's breeding programs, data from Figure 3.6 indicates that half of the germplasm comes from national Banks (Active and Base Banks).

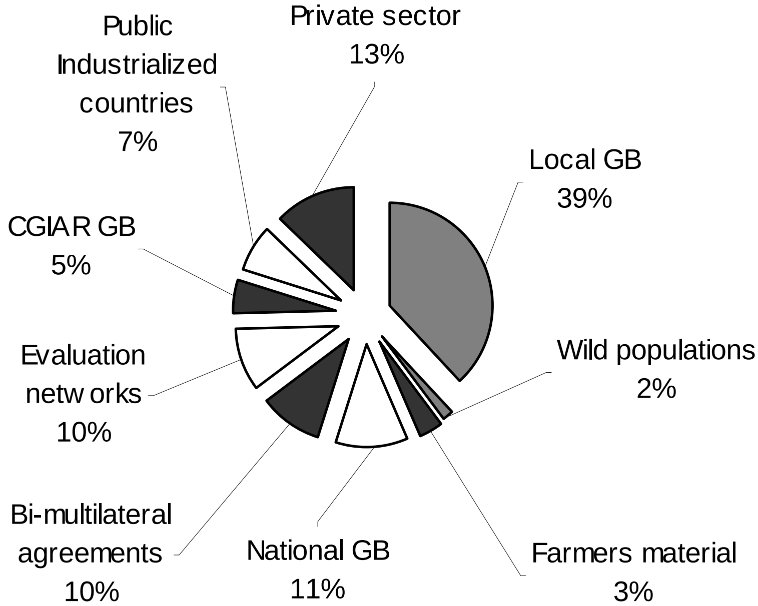


Figure 3.6. Utilization (%) of different sources of germplam at INIA's breeding programs.

<u>Trends in breeding priorities for INIA from 1980 to 2008 in each crop and/or crops-group (Question 13)</u>

Breeders were asked about assigned priorities (high, medium and low) to the following traits or environments: favorable environment, resistance/tolerance to abiotic stresses, resistance/tolerance to biotic stresses, and quality, both at the 80's and nowadays. In Table 3.9 information by crop is presented, and in Table 3.10 percentage that assigned high, medium or low priority to the four traits considered is also presented. An additional column in case the objective was not considered was also included.

Table 3.9. Trends in breeding priorities for INIA from 1980 to 2008.

Crop or crops-group	Traits	Priorities(*)		
		1980	2004	2008
Wheat	Breeding for favorable environment	3	3	3
	Breeding for[1] abiotic stresses	2	2	2
	Breeding for[2] biotic stresses	1	1	1
	Breeding for quality traits	3	2	1
Barley	Breeding for favorable environment			
	Breeding for[1] abiotic stresses			2
	Breeding for[2] biotic stresses	1	1	1
	Breeding for quality traits	1	1	1
Oat	Breeding for favorable environment			
	Breeding for[1] abiotic stresses			
	Breeding for[2] biotic stresses	1	1	1
	Breeding for quality traits	3	3	3
Rice	Breeding for favorable environment	2	2	2
	Breeding for[1] abiotic stresses	1	3	3
	Breeding for[2] biotic stresses	3	1	1
	Breeding for quality traits	3	2	1
Maize	Breeding for favorable environment			
	Breeding for[1] abiotic stresses	1	1	1
	Breeding for[2] biotic stresses			
	Breeding for quality traits			3
Sunflower	Breeding for favorable environment			
	Breeding for[1] abiotic stresses	3	1	2
	Breeding for[2] biotic stresses	1		1
	Breeding for quality traits	2	2	2
Roots and tubers	Breeding for favorable environment			2
	Breeding for[1] abiotic stresses			
	Breeding for[2] biotic stresses	1	1	1
	Breeding for quality traits	2	2	2
Forage species	Breeding for favorable environment	1	1	1
	Breeding for[1] abiotic stresses	2	2	2
	Breeding for[2] biotic stresses	3	1	1
	Breeding for quality traits	2	2	3
Horticultural crops	Breeding for favorable environment			2
	Breeding for[1] abiotic stresses			
	Breeding for[2] biotic stresses	1	1	1
	Breeding for quality traits			2
Fruit tree species	Breeding for favorable environment	1	1	2
	Breeding for1 abiotic stresses	2	1	1
	Breeding for[2] biotic stresses	3	1	1
	Breeding for quality traits		2	2
Forest tree	Breeding for favorable environment		1	1
	Breeding for[1] abiotic stresses		2	2
	Breeding for[2] biotic stresses		1	1
	Breeding for quality traits			

(*)(1 = high priority; 2 = medium priority, 3 = low priority).

[1] Breeding for tolerance/resistance to abiotic stresses

[2] Breeding for tolerance/resistance to biotic stresses

In general a high priority is assigned to resistance/tolerance to biotic stresses (mainly diseases).

Toward the end of the period, half of the breeders assigned medium priority to breeding for resistance/tolerance to abiotic stresses. One third of the programs assigned medium priority to breeding for quality traits and for favorable environments, although it was first priority for some other programs.

In an individual analysis, wheat, barley, sunflower, oat, roots and tubers and horticultural crops (potato, sweet potato, onion and strawberry) have scored first priority breeding for resistance/tolerance to biotic stresses during the whole period, while rice, forage species, fruit trees and *Eucalyptus* prioritized them toward the end of the period. Maize and fruit tree species breeders maintained resistance/tolerance to abiotic stresses as first priority. Breeding for quality traits has been high priority for barley during the whole period, and for wheat and rice toward the last years. Breeding for favorable environments was ranked high priority for forage and forest tree species; in fruit tree species, although was scored as medium priority for 2008, was considered high priority from 1980 to 2004. In general, there was a higher concern for each trait towards the end of the period (Table 3.10).

Table 3.10. Priority assigned to the four considered traits (percentage for each score at 1980 and 2008).

	Breeding for favorable environment		**Breeding for resistance/tolerance to abiotic stresses**		**Breeding for resistance/tolerance to biotic stresses**		**Breeding for quality traits**	
	1980's	2008	1980's	2008	1980's	2008	1980's	2008
High priority	17%	25%	17%	17%	50%	83%	8%	25%
Medium priority	8%	33%	25%	50%	0%	8%	25%	33%
Low priority	8%	8%	8%	8%	25%	0%	25%	25%
Not considered	67%	33%	50%	25%	25%	8%	42%	17%

Breeding for tolerance/resistance to biotic stress was a high priority for 83% of the programs, and 90% or more of the breeding programs indicated it as a medium to high priority. Breeding for quality traits and favorable environment was high priority for one fourth of the programs, and medium or high priority for more than half of them. For 67% of the cases, breeding for resistance/tolerance to abiotic stress was a medium or high priority. Anyway, it needs to be clarified that for abiotic stresses, in most of the cases, evaluation is usually made under field conditions if the stress is present, but seldom specific experiments are set with that purpose.

Opinions about how the international community (FAO, CGIAR Centers, World Bank, IFAD, multilateral or bilateral development agencies, etc) can assist INIA in increasing efficient use of PGRFA (Question 14)

Breeders at INIA indicated the following order of priorities about how the international community could assist INIA in increasing efficient use of PGRFA:

1. Strengthening national programme capacity through investments
2. Facilitating access to new biotechnological tools .
3. Facilitating germplasm exchange
4. Promoting training programmes on biotechnological tools
5. Helping preparing projects for funding

Varieties released by INIA for each crop and/or crops-group (Question 15):

In Table 3.11, number of varieties released by INIA's breeding programs since 1980 is presented. An increase in the number of released varieties in each period is observed, from 15 in the 1980-1984 period to 31 in the 2005-2008 period.

Table 3.11. Varieties released by the breeding programs of INIA for each crop and/or crops-group.

Crops	Number of varieties released						Statistics	
	1980-1984	1985-1989	1990-1994	1995-1999	2000-2004	2005-2008	Total	%
Wheat	2	6	3	4	6	8	29	19.3%
Barley			1		1	1	3	2.0%
Oat			1		1		2	1.3%
Rice		4	2	3	2		11	7.3%
Maize		1	1	1	1	1	5	3.3%
Sunflower	3			1			4	2.7%
Potato				1	1	2	4	2.7%
Sweet potato			4	4	2	1	11	7.3%
Forage species	4	3	4	5	5	5	26	17.3%
Onion(cebolla)	1		1		2	2	6	4.0%
Strawberry				1	2	2	5	3.3%
Fruit trees	8	6	5	5	8	7	39	26.0%
Forest trees (*Eucaliptus*)					3	2	5	3.3%
Totals by year	18	20	22	25	34	31	150	100.0%

Taking into consideration the last twenty years, productivity of the breeding programs in terms of releasing varieties has been important in fruit trees, wheat and forage species, followed by rice, and some horticultural crops like sweet potato and onion.

The contribution of the released varieties to the national production has been variable. In winter crops, varieties used by Uruguayan farmers are mainly a result of the national PBP, although in the last years varieties released by other public and private breeding programs of the region have been used in Uruguay. Adoption by farmers of varieties released by INIA is variable, but they are extensively used: as an example, barley's varieties are planted in 47% of the area, rice varieties in 90% of the area, and wheat varieties occupy 40% of the planting area.

In summer crops, the situation has dramatically changed in the last twenty years, where sorghum and sunflower breeding programs were progressively closed. Today, INIA carries out breeding program in maize, mainly for forage, and some work in sunflower, but with much less emphasis that it did in the 70's and 80's. In maize for grain, most cultivars are imported hybrids, and mainly GMO. In sorghum and sunflower, hybrid seed is imported for commercial production. For soybean although the seed may be produced in the country, transgenic varieties are introduced. The breeding program, that was closed at the beginning of the 90's, is now being reactivated, in response to a dramatic increase in the crop's area.

The varieties of forage species (oat, ryegrass, fescue, dactylis, phalaris, lotus, lucerne, red and white clover) are mainly a result of the national breeding programs. Many of them are public varieties released in the 60's and 70's. Releasing of forage varieties has been very active in the last years, and some private breeding companies have emerged mainly evaluating introduced varieties.

In horticultural crops, the situation is variable. With the exception of potato (where part of the seed is imported), for those species that have national breeding programs the seed is produced locally. The varieties released by the programs predominate at the production level, even in a greater proportion than in extensive crops. Unlike extensive crops, there is no private plant breeding in these groups of species. In species that there is no plant breeding programs at the national level, seed is imported. In fruit trees species, national and imported varieties coexist. In forest tree species, most of the seed is imported.

Referred to perspectives in the near future, horticultural crops and fruit tree sectors are beginning to work toward registering and evaluating varieties by INASE (National Seed Institute), as well as incorporating the private sector into seed production. Fruit tree sector are well organized in this sense, through ANVU (National Nursery Association).

Limiting aspects for the success of the plant breeding programmes at INIA 1980-2008. (Question 16):

In 1980 the following limiting aspects for the success of the plant breeding programmes at CIAAB were identified: 1) Lack of financial resources to carry out field and laboratory experiments, 2) Inadequate availability of laboratory infrastructure to carry out experiments using advanced plant breeding techniques, 3) Lack of knowledge about the use of molecular techniques to support plant breeding programmes, 4) Inadequate number of breeders for each crop and 5) Lack of support from the international community, including organizations like Centres of the CGIAR system, FAO, etc.

In 2008, although an important improvement in available resources and capacity building has occurred at INIA, the first two limiting aspects remained. As third and fourth limiting factors, limited access to national public and/or private genetic resources and limited access to international genetic resources are mentioned. As fifth limiting aspect, inadequate number of breeders for each crop is identified, probably due to an increase in volume and complexity of some breeding activities.

Faculty of Agronomy– University of the Republic, Uruguay

The Faculty of Agronomy (FA) belongs to the public University of the Republic, Uruguay. Its main mandate is teaching in the agronomy area at the undergraduate and graduate level. Its teaching mandate is based on research and extension oriented to give solutions to the most important issues of the agricultural production. It carries out breeding activities in barley, maize, onion, carrot, citrus, forage, fruit trees and forest tree species.

Plant breeding

Number and educational level of scientists involved in plant breeding (Question 4):

At FA, the FTE value has been constant (7,5), from 1985 to 2008 (Table 3.12, Figure 3.7a), although changes in grade structure and in the breeding programs have occurred. This situation can be explained because the FA is an academic institution in which the staff structure is relatively constant.

Referring to age composition, staff has been getting older (66 % older than 40 years and 33% older than 50). Recently, some new personnel has been hired, that allows to think in a restoration of the composition in the age chain within the academic structure of the FA. Referring to educational level, actually the staff is in a better position, (60% with MSc or PhD degree), in relation to 1985, where only 33% had postgraduate studies.

Table 3.12. FTE (full time equivalent) evolution at the Faculty of Agronomy since 1985 to 2008, according to formation of plant breeders and biotechnologists.

Research Area	Year	B.Sc.(1)	%	M.Sc.	%	Ph.D.	%	Total	%
Plant Breeders	1985	5	66,7	2	26,7	0,5	6,7	7,5	100,0
	1990	5	66,7	2	26,7	0,5	6,7	7,5	100,0
	1995	3,5	47,0	3	40,0	1	13,3	7,5	100,0
	2000	2	26,7	4,5	60,0	1	13,3	7,5	100,0
	2008	3	40,0	3	40,0	1,5	20,0	7,5	100,0
Biotechnologists	1986	1,5	60,0	0,5	20,0	0,5	20,0	2,5	100,0
	1990	1,5	60,0	0,5	20,0	0,5	20,0	2,5	100,0
	1995	1	50,0	1	50,0	0	0	2	100,0
	2000	0,5	25,0	1	50,0	0,5	25,0	2	100,0
	2008	0,5	20,0	1,5	60,0	0,5	20,0	2,5	100,0

(1) BSc: (Agronomists and biologists)

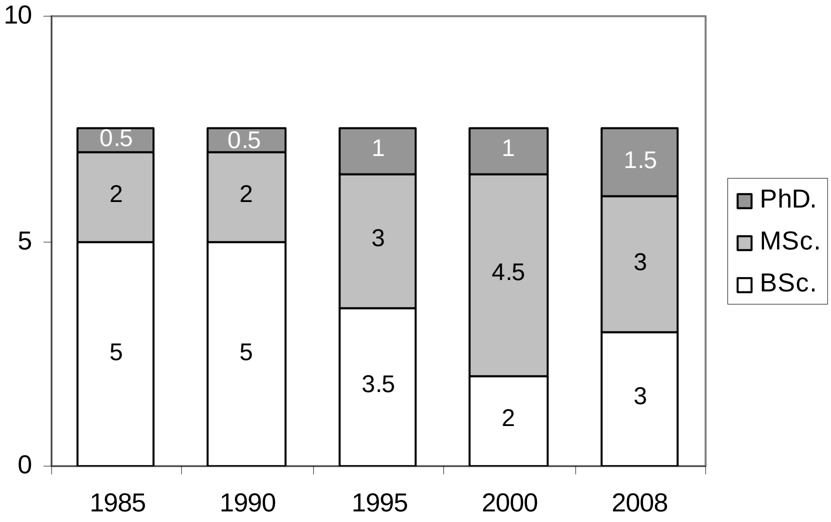


Figure 3.7a. Distribution of plant breeders between 1985 and 2008, according to educational level.

Biotechnology

<u>Number and educational level of scientists involved in biotechnology</u>:

FA began its activities in the biotechnology area in 1986, maintaining its FTE values between 2 y 2.5 (Table 3.11 y Figure 3.7b). As it happened with plant breeders, biotechnologists increased their educational level, (80% with post graduate studies in 2008 in comparison with a 40% in 1985). More than 80% of biotechnologists are older than 40 years, although new younger staff has recently begun to be hired.

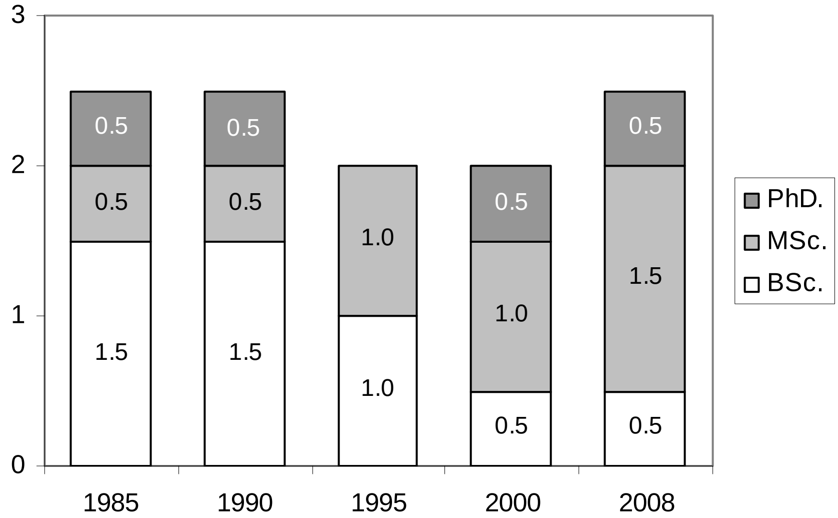


Figure 3.7b. Distribution of biotechnologists between 1985 and 2008, according to educational level.

Organization's total budget and proportion allocated to plant breeding activities in the period 1995 to 2008 (Question 5):

Annual budget allocated to plant breeding, (not including salaries of researchers), is presented in Table 3.13. There are important differences between INIA's and FA's budget estimations, since in INIA, salaries of researchers are included, while as it was stated before, they are not included in FA's estimation. Additionally, in 2008 INIA's budget, all indirect expenses (as infrastructure use, vehicles, tools depreciation) were included, while there were not in FA's estimation.

Although FA's plant breeding budget is not high, compared to the total budget, it seems reasonable, taking into consideration that the institution carries on research in different productive systems (husbandry, dairy cattle, agriculture, forestry, horticulture, fruit tree production, small animals), as well as in different disciplines (biological sciences, plant protection, soils and water management, and social sciences).

In 1985 the country recovered its democratic organization and the university its autonomy. During the dictatorial period, academic development was negatively affected and no international projects existed. It was after 1985 that FA was able to obtain extra-budgetary resources through this type of projects again.

In the budget presented a high percentage of the plant breeding resources are devoted to salaries of research fellows and field assistants, for that reason, "fresh" resources for research are scarce, highly depending upon resources obtained through projects supported with national and international agencies. This situation highly limits plant breeding programs, which are activities with medium to long term projection. For that reason is common to find discontinuity in time, with the corresponding prejudices for those breeding programs. Other aspect that characterizes FA's breeding programs is that as it is an academic institution, most of the projects are related to pre breeding or to basic studies related to plant genetic resources.

Table 3.13. Budget dedicated to Plant Breeding Activities, compared to Total Research Budget (Uruguayan Pesos).

Financial resources	1995	2000	2005
Total research budget	11.905.772	22.218.216	29.592.428
Plant breeding	847.024	1.268.241	2.368.144
%	7.1	5.71	8.0

Organization's resource allocation (human and financial) for plant breeding activities. Percentage distribution by crop and/or crops-group. (Question 6);

FA carries out plant breeding activities in two extensive crops: barley and maize; two native forage species: *Bromus auleticus and Paspalum dilatatum*; two horticultural species: onion and carrot; two forest tree species: *Eucalyptus and Pinus*; and two fruit tree species groups: *Citrus and native fruits* (*Acca sellowiana, Eugenia uniflora, Psidium cattleianum and Myrciantes pungens*) (Table 3.14 and Figure 3.8).

Horticultural and native fruit breeding programs are the youngest ones. Maize and *Bromus auleticus* programs are, at the moment, only evaluating and multiplying genetic material from their own programs. *Paspalum dilatatum* breeding program is still in a pre

breeding stage. Forest tree breeding, opposed to what would be expected has been reduced; (this fact could be explained because private companies are developing their own research and even import their seed). This last trend also occurred at INIA
In the horticultural breeding programs, salaries and capacity building (experimental fields and machinery) are supported by FA, but they receive an extra budgetary contribution from FPTA projects, (Fund for the Promotion of Agriculture Technology) with INIA's support, to carry on the research activities. Barley's breeding program is carried on, among other sources, under the frame of the Barley's National Board agreement, in which also INIA and the private sector take part. In native fruit and citrus programs, main resources are given by FA although some support is also received from INIA. In citrus, joint development is carried out between both institutions.

Table 3.14. Percentage of the Budget used in each of the breeding programs by crop or crops-group between 1985 and 2008.

Crop or Crops- group		1985	1990	1995	2000	2005
Maize	*Zea mays*	13.5	4.9	4.2	6.6	6.4
Barley	*Hordeum vulgare*		14.2	18.7	14.3	13.3
Native forages	*Bromus auleticus, Paspalum dilatatum*	38.4	35.6	30	14.3	13.2
Vegetables and Fruits		29	36.4	43.5	61.9	64.4
Forest trees	*Eucalyptus spp., PInus spp.*	19.1	8.9	3.6	2.9	2.7
Total		100	100	100	100	100

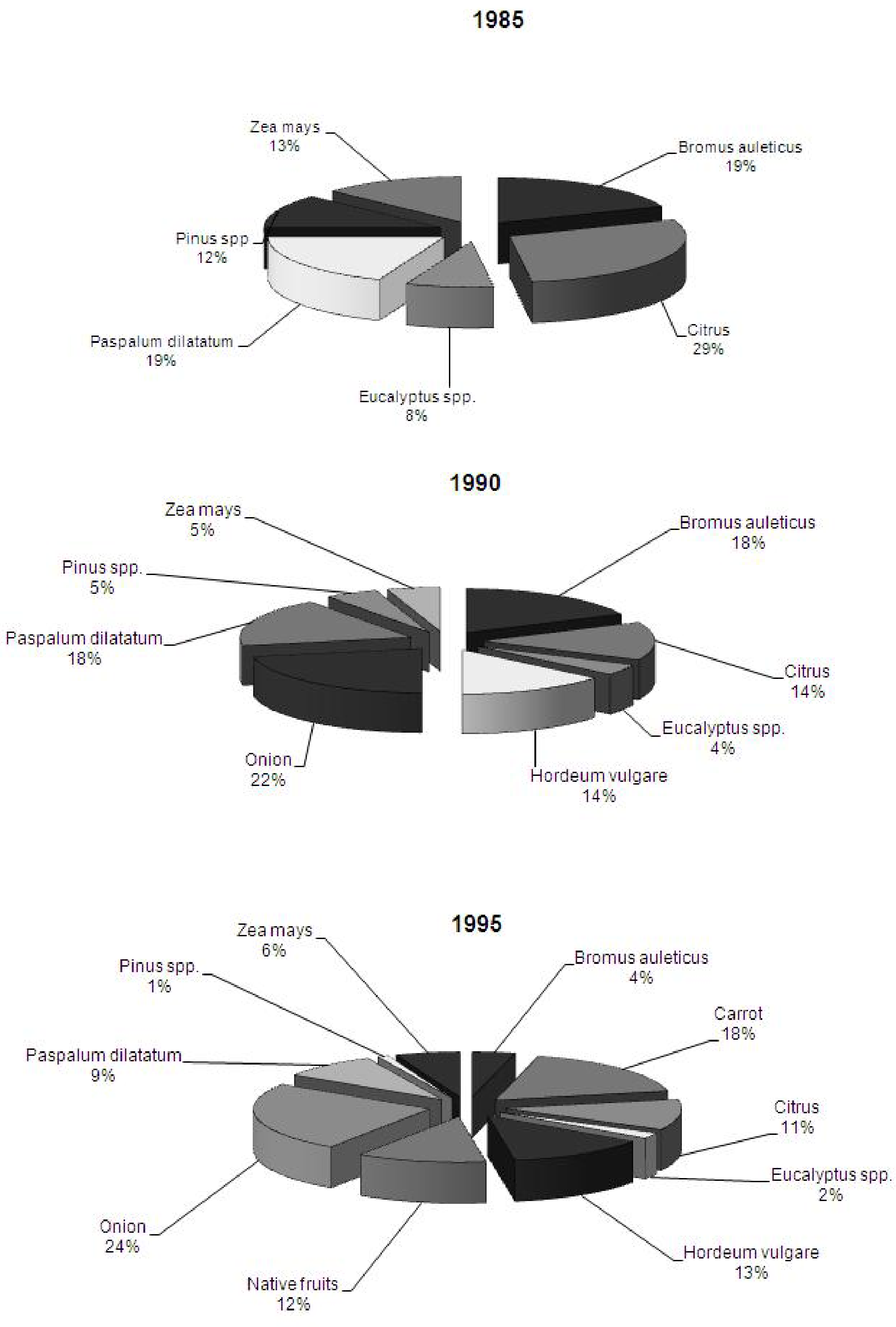
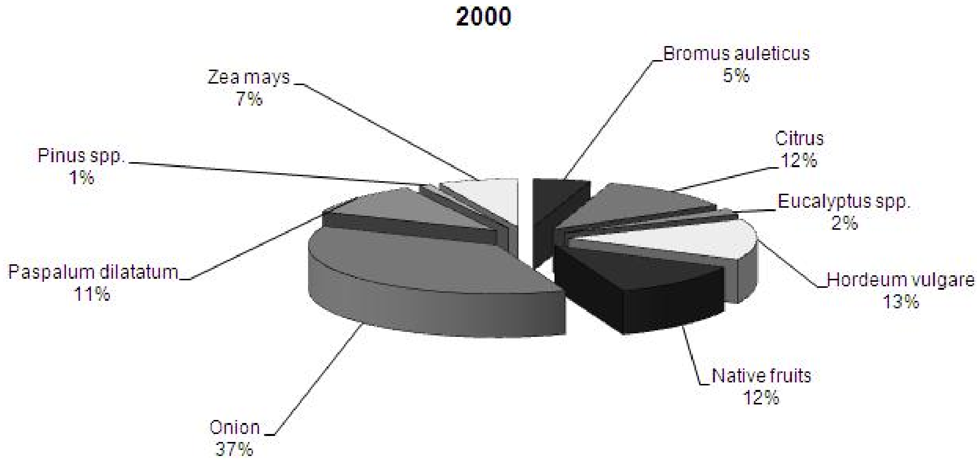


Figure 3.8. Budget % allocated to the different breeding programs at FA. 1985-2008.



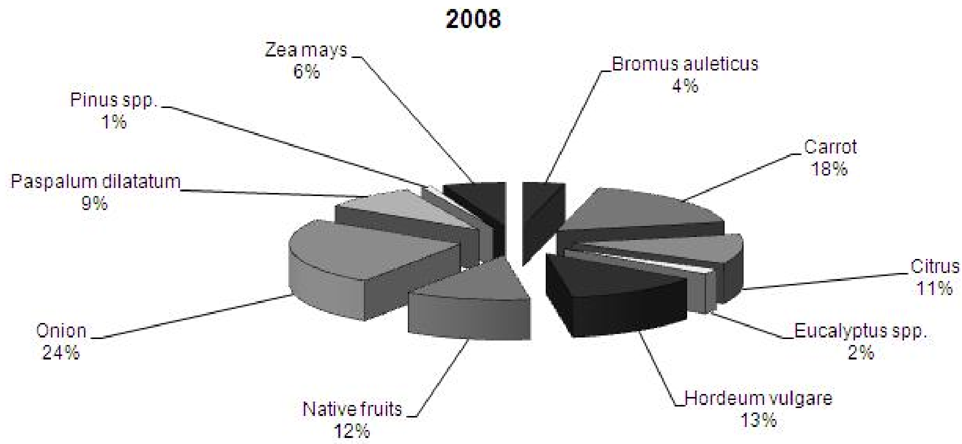


Figure 3.8 cont. Budget % allocated to the different breeding programs at FA. 1985-2008.

Type of activity FA is carrying out at each breeding program. (Question 7):

Plant breeding programs at FA can be grouped into two types: those that make crosses and evaluate segregating populations, like barley, onion, carrot, *Paspalum dilatatum*, citrus and native fruit trees, and those that are based on evaluation and selection from the existing genetic diversity, like maize and *Bromus auleticus*. Forest tree breeding programs are based on the evaluation and progeny selection from different trees without making new artificial crosses. (Table 3.15).

Table 3.15. Activities that carry out the breeding programs at FA (2008).

Crop or Crops-group	Specify crop(s)	Genetic enhan-cement activities	Making crosses	Evaluating segregating populations	Evaluating fixed lines	
					developed by the breeding programme	introduced from other breeding programmes
Maize	*Zea mays*				X	
Barley	*Hordeum vulgare*	X	X	X	X	X
Native forages	*Bromus auleticus*				X	
Native forages	*Paspalum dilatatum*	X	X	X		
Vegetables and fruits		X	X	X	X	
Forest trees	*Eucalyptus and Pinus sp.*	X		X	X	X
	%	70%	60%	80%	90%	30%

Out of ten programs, only barley and forest trees'programs introduce and evaluate materials from other breeding programs. Most of the programs carry on genetic enhancement activities, make crosses, and evaluate segregating populations and lines developed by the breeding program. FA emphasizes utilization of national plant genetic resources (landraces and wild materials), being this aspect one of the main characteristics of the breeding programs.

Distribution of human and financial resources allocated to germplasm enhancement, line development and line evaluation (Question 8):

The trends on germplasm enhancement activities, line development and line evaluation for the breeding programs are presented in Figures 3.9. Due to existing differences among the different programs, tendencies are not clear. The percentages observed for line development activities indicate that some programs are in clear expansion for this area, while others- as it was mentioned earlier- are mainly in the evaluation and advanced material multiplication stage.

In general terms, it could be concluded that tendencies are very specific to each program, and no homogeneous tendencies are identified. Genetic enhancement is emphasized in *Paspalum* and in less proportion in barley, maize and onion. Line evaluation is important in *Bromus* and in forest tree species; and line development is emphasized in native fruit tree species and Citrus.

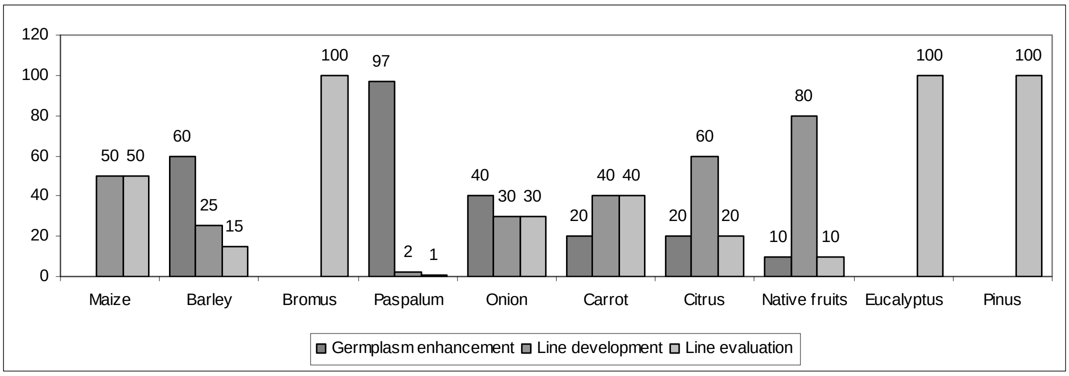


Figure 3.9. Percentage distribution of plant breeding activities en the different crops. 2008.

Budget distribution (%) at FA for line development and evaluation, germplasm enhancement and biotechnology (Question 9):

As presented in Table 3.16 and Figure 3.10 biotechnology activities have clearly been increasing, particularly since 1995. When the data is analyzed jointly with plant breeding activities, the last shows a negative trend. As stated before, germplasm enhancement activities are variable among species, and although there have been increases in several of them, their global volume remains almost constant. Line development and evaluation has shown a decreasing trend, with an approximate value of 50% during the last years. But in a similar analysis to the one made for INIA, the most adequate interpretation seems to be that when biotechnology activities are included in a budget that is partially shared, plant breeding activities appear proportionally reduced.

Table 3.16. Evolution of human and financial resources distribution for line development and evaluation, plant biotechnology and germplasm enhancement.

Research Area	1985	1990	1995	2000	2005
Line development and evaluation	70	60	60	50	50.2
Plant biotechnology		15	8	23	25.8
Germplasm enhancement	30	25	32	27	24
Total allocation (%)	**100**	**100**	**100**	**100**	**100**

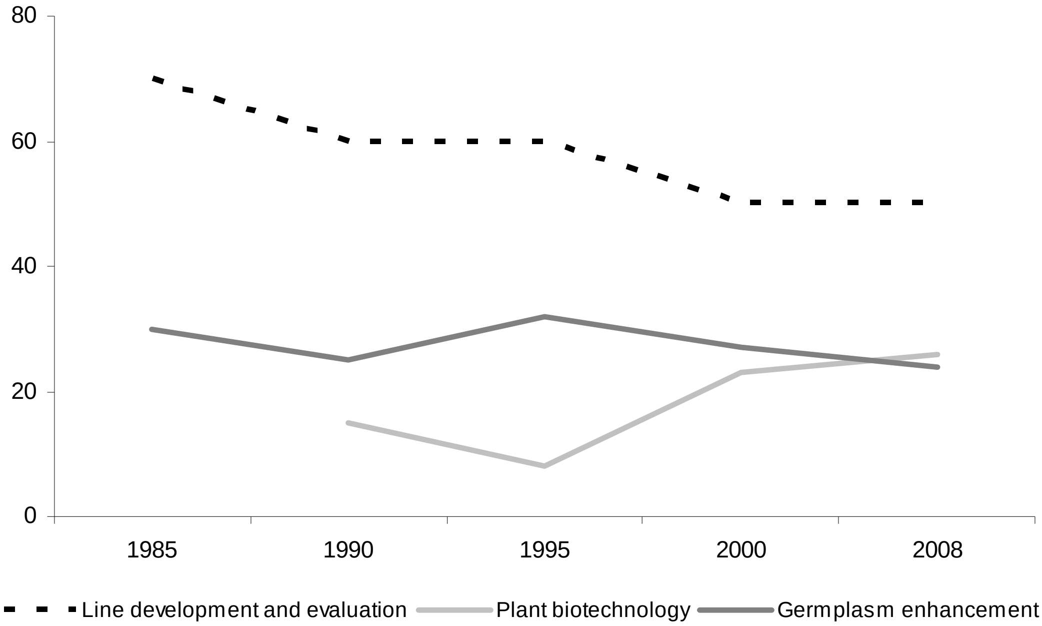


Figure 3.10. Evolution of human and financial resources distribution for line development and evaluation, plant biotechnology and germplasm enhancement.

Biotechnology areas FA is working on (Question 10):

FA develops activities in molecular characterization, tissue culture, marker-assisted selection, genomics, genetic engineering, gene isolation, wide crosses and host-pathogen relationships (molecular and biochemical characterization).

FA's breeding programme organization (Question 11):

As is observed in Table 3.17, barley breeding program presents the highest number of segregating populations. Although workload is not very significant in most of the species, the main objective of the institution is the teaching activity. It can be said that these research lines respond to that main objective, being complementary activities to the teaching role. With this same objective, in most of the species, basic research lines are emphasized. Number of trials and number of locations per year used for field trials are variable, being important in many of the crops, complementing the teaching objective.

Table 3.17. Number of crosses, segregating populations, number of trials and locations used for field trials by FA's breeding programs. 2008

Crop or crops-group	Specify crop(s)	Activity			
		Number of crosses made[1]	Number of segregating populations	Number of trials[3]	Number of locations used for field trials
Maize	*Zea mays*			1	1
Barley	*Hordeum vulgare*	60	2000	14	3
Native forages	*Bromus auleticus, Paspalum dilatatum*	10	3	5	4
Vegetables	Onion, Carrot, Citrus, Native fruits	14	600	43	15
Forest trees	*Eucalyptus and Pinus sp.*			11	3
TOTAL		84	2603	74	

Main sources of germplasm used in the breeding programmes of FA for each major crop and/or crops-group. (Question 12):

In Table 3.18 the data of germplasm by source used at the FA breeding programs is presented. The use of local varieties is outstanding in maize, carrots, onion and also for native fruit trees; it is also remarkable the use of wild populations (Local germplasm bank) in *Bromus, Paspalum* and native fruit tree species. For *Citrus* and barley, ontribution from germplasm banks (local or national) is relevant, and the private sector is important for *Eucalyptus*. In *Pinus,* 100% of the germplasm comes from introductions through bi or multilateral agreements.

Table 3.18. Main sources (% by crops) of germplasm used in the breeding programmes at FA.

Crops or crops-group	Specify crop(s)	Local germplasm bank[1]	National germplasm bank	Introduction through bi or multilateral agreements	Introduction through participation in germplasm evaluation networks	CGIAR gene banks	Public organizations in industrialized country	Private sector	Farmers material	Total
Maize	*Zea mays*								100	100
Barley	*Hordeum vulgare*		40	25		10	10	15		100
Native forages	*Bromus auleticus, Paspalum dilatatum*	100								100
Vegetables	Onion				20		10		70	100
Vegetables	Carrot				10				90	100
Fruits	Citrus	60	20						20	100
Native fruits		40							60	100
Forest trees	*Eucalyptus sp.*	10			10		20	60		100
Forest trees	*Pinus sp*			100						100

Analyzing the distribution (%) of sources of germplasm used by FA's breeding programs, data from Figure 3.11 indicates that the main sources are local varieties (farmer's materials) and wild populations. The second place is occupied by introductions through bi or multilateral agreements.

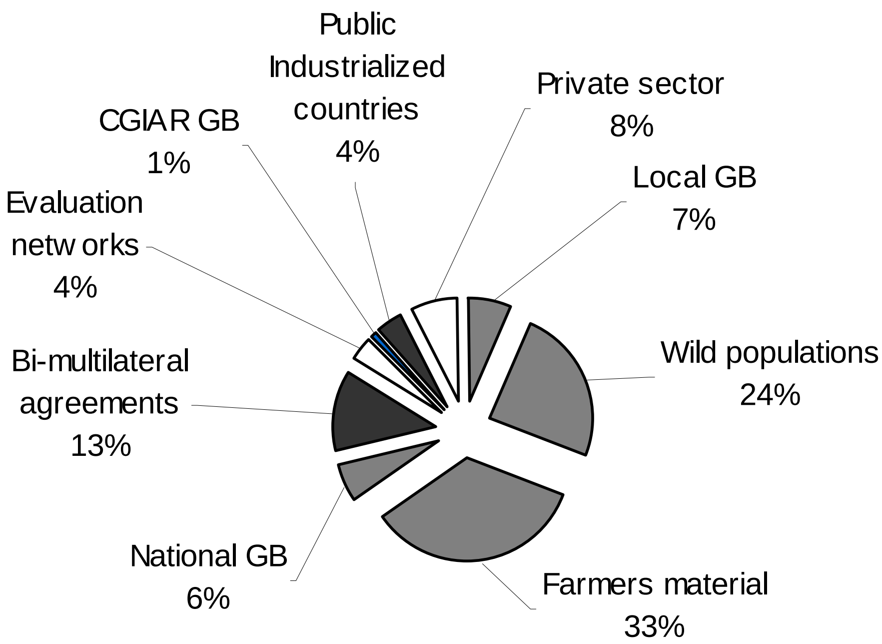


Figure 3.11. Utilization (%) of different sources of germplam at FA's breeding programs.

Trends in breeding priorities for FA from 1980 to 2008 in each crop and/or crops-group (Question 13)

Breeders were asked about assigned priorities (high, medium and low) to the following group of traits or production environments: favorable environment, resistance/tolerance to abiotic stresses, resistance/tolerance to biotic stresses, and quality, both for the 80's and for nowadays. In Table 3.19 the information by crop is presented, and average percentage that assigned high, medium or low priority to the four traits considered is also presented in Table 3.20. An additional column in case the objective was not considered was also included.

Table 3.19. Trends in breeding priorities for FA at 1980 and 2008.

Crop or crops-group	Specify crop(s)	Traits	Priorities(*)	
			1980's	2008
Maize	*Zea mays*	Breeding for favorable environment	3	3
		Breeding for abiotic stresses [1]	1	1
		Breeding for biotic stresses[2]	3	3
		Breeding for quality traits	3	2
Barley	*Hordeum vulgare*---	Breeding for favorable environment	1	1
		Breeding for abiotic stresses	3	3
		Breeding for biotic stresses	1	1
		Breeding for quality traits	2	1
Native forages	*Bromus auleticus, Paspalum dilatatum*---	Breeding for favorable environment	3	3
		Breeding for abiotic stresses	1	1
		Breeding for biotic stresses	2	2
		Breeding for quality traits	3	3
		Breeding for abiotic stresses	1	1
		Breeding for biotic stresses		
		Breeding for quality traits		
Vegetables	onion	Breeding for favorable environment		
		Breeding for abiotic stresses		3
		Breeding for biotic stresses		1
		Breeding for quality traits		1
Vegetables	carrot	Breeding for favorable environment		1
		Breeding for abiotic stresses		3
		Breeding for biotic stresses		3
		Breeding for quality traits		1
Fruits	Citrus	Breeding for favorable environment		
		Breeding for abiotic stresses		
		Breeding for biotic stresses		
		Breeding for quality traits	1	1
Native fruits		Breeding for favorable environment		3
		Breeding for abiotic stresses		2
		Breeding for biotic stresses		2
		Breeding for quality traits		1
Forest trees	*Eucalyptus sp, , Pinus sp.*	Breeding for favorable environment	1	1
		Breeding for abiotic stresses		
		Breeding for biotic stresses	2	2
		Breeding for quality traits	2	2
		Breeding for quality traits	3	3

(*)(1 = high priority; 2 = medium priority, 3 = low priority); [1]Breeding for resistance/ tolerance to abiotic stresses; [2]Breeding for resistance/tolerance to biotic stresses

The priorities assigned were highly dependent on the species under consideration. Breeders considered that resistance/tolerance to abiotic stresses are of high priority for maize and native forage species (*Bromus auleticus* and *Paspalum dilatatum*) breeding programs, being, among them, drought and low soil fertility the most important issues. Quality traits were considered highly relevant during the last years, being high priority for barley, for horticultural and fruit tree species. Breeding for disease resistance was an emphasized objective for barley and onion. Breeding for favorable environment was mentioned as high priority for barley, onion and forest tree species.

Table 3.20. Priority assigned to the four considered traits (percentage for each score at 1980 and 2008).

	Breeding for favorable environment		Breeding for resistance/tolerance to abiotic stresses		Breeding for resistance/tolerance to biotic stresses		Breeding for quality traits	
	1980's	2008	1980's	2008	1980's	2008	1980's	2008
High priority	30%	40%	30%	30%	10%	20%	10%	50%
Medium priority	0%	0%	0%	10%	20%	30%	20%	20%
Low priority	20%	30%	10%	30%	20%	30%	30%	20%
Not considered	50%	40%	60%	30%	50%	20%	40%	10%

Taking into consideration priority assigned to the group of traits it can be concluded that, in general, an increasing priority for each trait was assigned during the last years. Also, an increasing importance being assigned to quality traits is observed, being prioritized by 90% of the breeding programs.

Opinions about how the international community (FAO, CGIAR Centers, World Bank, IFAD, multilateral or bilateral development agencies, etc) can assist FA in increasing efficient use of PGRFA (Question 14)

Breeders at FA indicated the following order of priorities about how the international community could assist INIA in increasing efficient use of PGRFA:

1) Strengthening national programme capacity through investments.
2) Promoting training programmes on conventional breeding methods.
3) Helping preparing projects for funding.
4) Promoting training programmes on biotechnological tools.
5) Facilitating access to new biotechnological tools.

Varieties released by FA for each crop and/or crops-group (Question 15):

As stated in Table 3.21, number of cultivars released by FA has been increased en the last ten years, mainly due to the acquired maturity of the breeding programs.

Table 3.21. Varieties released by the breeding programs of FA for each crop and/or crops-group.

Crop or crops-group	Specify crop(s)	Number of varieties released					
		1980 1984	1985 1989	1990 1994	1995 1999	2000 2004	Total
Maize	*Zea mays*					1	1
Native forages	*Bromus auleticus*				2		2
Vegetables and Fruits	Onion, Citrus	1				7	8
Forest trees	*Eucalyptus sp., Pinus sp*	1					3
Total		4			2	8	14

The market share of these cultivars is variable; while some of them are still in a seed multiplication stage (maize, *Bromus*), others, like the onion variety "Pantanoso del Sauce" are being widely used by farmers, occupying as much as 50% of the production area. A similar situation is found for forest tree species varieties which FA has been commercializing for many years.

Limiting aspects for the success of the plant breeding programmes at FA 1980-2008. (Question 16):

In 1980, the following limiting aspects for the success of the plant breeding programmes at FA were identified: 1) Inadequate (low) number of breeders for each crop, 2) Inadequate availability of laboratory infrastructure to carry out experiments using advanced plant breeding techniques, 3) Lack of financial resources to carry out field and laboratory experiments,4) Inadequate experimental fields conditions, and 5) Lack of support from the international community, including organizations like centers of the CGIAR system, FAO, etc.

In 2008, with the exception of inadequate experimental fields' conditions, the other four restrictions remain, although it changed their order of priority. Main limiting factor is lack of financial resources to carry out field and laboratory experiments. Second limiting factor is inadequate number of breeders for each crop; third one is lack of support from the international community) in fourth place inadequate availability of laboratory infrastructure to carry out experiments using advanced plant breeding techniques is mentioned, and a new restriction is added: inadequate access to recent literature.

PRIVATE SECTOR

The analysis made for the private sector is a global analysis for each company, since privacy restrictions were requested by some of them. Later, in Chapter 4, the data is managed globally in order to make the national analysis and projection. From some fifteen companies contacted, only ten of them answered the survey. From those ten, eight carry out exclusively plant breeding programs; one of them develops activities only in the biotechnology area, and another one carries out both plant breeding and biotechnology activities.

Company 1

This private company began with its plant breeding activities in 1996. The work is carried out by a BSc researcher, age 30-39, with part time dedication to plant breeding activities. (50% FTE).

The total amount of financial resources invested in research is assigned to plant breeding activities. Actually, the company develops plant breeding activities in wheat (50%), foxtail millet (25%) and other forage species (oat and *Lotus corniculatus)* (25%).

In wheat and forage species, the following activities are carried out: genetic enhancement, evaluation of segregating populations (crosses are made abroad), evaluation of lines developed by the breeding program and evaluation of lines introduced from other breeding programs. Fifty percent of the budget is allocated to line evaluation, 30% to line development and 20% to genetic enhancement.

In Setaria (Foxtail millet) only evaluation at one location of introduced materials from other breeding programs is carried out.

Sources of germplasm are: for wheat, 100% private sector; for forage crops, 50% private sector and 50% farmers materials; and for other small grains, 50% CGIAR banks and 50% farmer's materials. Breeding priorities are the same for most of the species, being high priority breeding for resistance/tolerance to biotic stresses and medium priority breeding for quality traits.

In order to efficiently increase the use of PGRFA, the international community should:

1- Promote training programmes on conventional breeding methods
2- Help preparing projects for funding
3- Facilitate germplasm exchange.
4- Promote contact with others companies.

In the 2000 – 2004 period, the company released four varieties: three forage species and one variety of *Setaria italica.*

The most limiting factors for the company's success in plant breeding are, in order of importance:

1- Inadequate number of breeders for each crop
2- Inadequate knowledge level of the general plant breeding strategies
3- Lack of financial resources to carry out field and laboratory experiments.
4- Lack of knowledge about participatory plant breeding techniques
5- Lack of support from the international community, including organizations like Centres of the CGIAR system, FAO, etc

Company 2

This company develops biotechnology activities. It has been working in this area as support to plant breeding companies since 2003 with two researchers, one at M.Sc. level and another at BSc. level.

Taking into consideration the distribution of human and financial resources, a 55% of the total resources are assigned to *in vitro* culture in *Eucalyptus* sp, 15% to blueberries, 15% to rootstock(for apples, peaches and Eucalyptus), 10% to potato and 5% to other berries.

Sources of germplasm for the company are: private sector for potatoes and *Eucalyptus*, and the germplasm banks of INIA (Uruguay) and INTA (Argentina), for the rest of the species.

The international community could help in a more efficient use of PGRFA through:

1- Facilitating germplasm exchange
2- Strengthening national programme capacity through investments.
3- Promoting training programmes on biotechnological tools.

The most limiting factors for the development of this biotech company are:

1- Limited access to international genetic resources.
2- Limited access to national public and/or private genetic resources.

Company 3

This company has worked in plant breeding since 2002. The breeding workload is carried out by a part time MSc (50% FTE), older than 50, and a full time BSc, age 20 to 29. A twenty % it's total annual research budget is devoted to plant breeding.

Twenty percent of total human and financial resources invested in plant breeding are allocated to *Sorghum* and millets, and 80% of the budget to several other forage species (*Cichorium intybus, Setaria italica , Festuca arundinacea, and several species of Trifolium and Lotus).*

The company carries out genetic enhancement activities and evaluation of lines developed by the program for all the species it is working on. The program makes crosses in *Sorghum* and *Setaria,* and evaluation of segregating populations in *Setaria.* For all forage species makes, also, evaluation of lines introduced from other breeding programs. Between 60 and 70% of human and financial resources are assigned to line evaluation, 20% to line development and between 10 and 20% to germplasm enhancement activities. This trend has been sustained since the company foundation.

Referring to sources of germplasm used by the breeding program, main contribution comes from introduction through bi or multilateral agreements (40-60%). Between 20 and 40% of germplasm comes from the private sector, and another 20% comes from farmer's materials. The company installs between two and four trials in one location.

Breeding priorities are the same for all the species, being the highest priority assigned to quality traits, and resistance/tolerance to abiotic stresses. Resistance/tolerance to biotic stresses is set as medium priority.

In the company's opinion, the international community could help in a more efficient use of PGRFA through:

1- Facilitating germplasm exchange.
2- Facilitating access to new biotechnological tools.
3- Promoting training programmes on conventional breeding methods.
4- Promoting training programmes on biotechnological tools.
5- Strengthening national programme capacity through investments.

Since its foundation, the company has released three varieties of sorghum and millet and six varieties of forage species (*Lotus corniculatus, Lotus tenuifolis, Chichorium intibus, Festuca arundinacea* and *Setaria italica).*

The aspects the company has considered the most limiting ones for its success are, in order of priority, the following:

1- Limited access to international genetic resources.
2- Inadequate number of breeders for each crop.
3- Inadequate knowledge level of the general plant breeding strategies.
4- Lack of knowledge about the use of molecular techniques to support plant breeding programmes.
5- Inadequate availability of laboratory infrastructure to carry out experiments using advanced plant breeding techniques.

Company 4

This private company carries out rice breeding activities since 1994. This breeding activity is done by a full time BSc plant breeder, older than 50, and all its research budget is invested in rice breeding.

Crosses, evaluation of segregating populations and evaluation of lines from its own program as well as introduced ones from other breeding programs are made.

Ten percent of total resources are invested in germplasm enhancement activities, 60% in line development and remaining 30% in line evaluation. Germplasm enhancement and line evaluation have decreased their importance toward the end of the period, being increased the budget assigned to line development. Evaluation of genetic material is done in two locations and eight trials. Germplasm used by the program comes from farmer's material. Breeding priority has been mainly quality traits, and resistance/tolerance to abiotic stresses are mentioned as medium priority.

The company expressed that, in order to increase the efficiency in the use of PGRFA the international community could help:

1- Facilitating germplasm exchange.
2- Strengthening national programme capacity through investments.
3- Promoting training programmes on conventional breeding methods.
4- Helping preparing projects for funding.
5- Promoting training programmes on biotechnological tools.

The breeding program has released one variety in the 2000-2004 period.

The aspects the company has considered the most limiting ones for its success are, in order of priority, the following:

1- Limited access to international genetic resources.
2- Limited access to national public and/or private genetic resources.
3- Inadequate number of breeders for each crop.
4- Lack of financial resources to carry out field and laboratory experiments.
5- Lack of knowledge about the use of molecular techniques to support plant breeding programmes.

Company 5

This is a Cooperative that has been working in plant breeding since 1980. Plant breeding responsibility is faced by a full time MSc. researcher, between 30 and 49 years old.

Ninety percent of the budget assigned for research activities is devoted to plant breeding. Relative importance of the different crops has varied during the last fifteen years. Barley breeding was very important during the 90's, decreasing its relevance later. Actually, only line evaluation is made, as a service offered to the malting barley private companies and no research resources are actually allocated to it. Wheat has been increasing its importance since 1990. Actually, a 50% of the total human and financial resources are assigned to wheat, being the second place occupied by oat, with 30% of the budget. Maize receives approximately 10%, and the remaining 10% is allocated to forage species, that have reduced their relative importance in the last ten years.

The cooperative makes evaluation of their own genetic materials in wheat and forage species, and evaluation of genetic materials introduced from other breeding programs for all the species it works with. It does not make crosses, and does not carries out germplasm enhancement activities or use biotechnological tools. In wheat and forage species, 90% of the budget is assigned to line evaluation, and 10% to line development. With the exception of wheat, where line evaluation has been strengthened, all activities in most of the species present a decreasing tendency.
Considering the total resources available in the organization, 100% is assigned to line development and evaluation. An interesting number of evaluation trials, at one location, are installed. Main source of germplasm are: for wheat, 100% comes from the private sector; for maize, 90% from the private sector and 10% from the local gene bank; for barley and oat, 50% from the private sector, 40% are introduced through bi or multilateral agreements and the remaining 10% from the local germplasm bank; for forage species, 50% comes from the private sector, 30% through bi or multilateral agreements and 20% from the local gene bank.

Taking into consideration priorities of the breeding programs, main ones are: breeding for quality traits, breeding for resistance/tolerance to biotic stresses in wheat, barley and oat, and breeding for resistance/tolerance to abiotic stresses in forage species. Breeding for favorable environment is high priority for wheat, and medium priority for barley.

In order to increase the efficient use of PGRFA the international community should help in:

1- Facilitating germplasm exchange
2- Facilitating access to new biotechnological tools
3- Strengthening national programme capacity through investments.
4- Promoting training programmes on biotechnological tools.
5- Helping preparing projects for funding.

Fifteen varieties have been released since 1980, being seven of wheat, three of barley, three of oat, and two of forage species.

Toward the end of the period, the following aspects have been identified as the most important limiting factors for the success of the breeding program:

1- Limited access to international genetic resources.
2- Limited access to national public and/or private genetic resources.

3- Inadequate availability of laboratory infrastructure to carry out experiments using advanced plant breeding techniques.
4- Lack of support from the international community, including organizations like Centres of the CGIAR system, FAO, etc.
5- Inadequate number of breeders for each crop.

Company 6

This is a private company that began plant breeding activities in 1990 with two full time MSc researchers, and by 1995 a full time BSc researcher was added. The same staff remained in 2000. Since 2005, plant breeding tasks are carried out by one full time MSc researcher, age range 40 to 49 years old, and one BSc researcher, age range between 20 and 29.

Actually, the company allocates a 70% of its total research budget to plant breeding, being barley the only specie that is improved. Genetic enhancement activities, crosses, evaluation of segregating populations, evaluation of lines developed by the program and evaluation of introduced lines from other breeding programs are carried out by the program.

Taking into consideration the total human and financial resources allocated to plant breeding, 60% of them are assigned to line development, 30% to line evaluation and 10% to genetic enhancement activities, which is showing a decreasing tendency. Although the company does not develop its own biotech activity, it works in molecular characterization under agreement with other institutions, and develops also double haploids with agreements abroad. (New Zealand).

Some 150 crosses are made, with the corresponding segregating populations, and eight trials in three different locations are managed.

Sources of germplasm have been: national bank, introductions through bi or multilateral agreements, public organizations in industrialized country and farmer's materials.

Main breeding priorities are breeding for quality traits and breeding for resistance/tolerance to biotic stresses. Breeding for favorable environment has been assigned medium priority.

The company has stated the following factors as important ones for increasing the efficient use of PGRFA by the international community:
1- Strengthening national programme capacity through investments.
2- Facilitating germplasm exchange.
3- Helping preparing projects for funding.
4- Facilitating access to new biotechnological tools.
5- Promoting training programmes on conventional breeding methods.

Six varieties have been released by the company between 1995 and 2004.

The aspects the organization considers the most limiting ones for the success of the breeding program are, in order of priorities, the following:
1- Lack of modern machinery (sowing machine and harvester) for the field experiment, as well as micro malting equipment to be able to make the adequate experiments.

2- Inadequate availability of laboratory infrastructure to carry out experiments using advanced plant breeding techniques.
3- Lack of knowledge about the use of molecular techniques to support plant breeding programmes.

Company 7

It is a private company that makes *Eucalyptus* breeding since 1991. It started with one BSc researcher age 30-39 and one PhD researcher age 40-49. In 1995 it had one BSc age 20-29, one BSc age 30-39 and one PhD age 40-49. In 2000 one BSc that turned age 30-39, the other one turned 40-49 and the PhD turned older than 50. In 2005 it had one BSc age 20-29, one MSc age 30-39 and one PhD older than 50.

During the period under consideration, between 66 and 75% of the budget that the company assigns to research is devoted to plant breeding. Breeding activities are carried out in Eucalyptus sp., that include: genetic enhancement, crosses, evaluation of lines developed by the program and evaluation of introduced genetic materials from other breeding programs.

Taking into consideration the total human and financial resources assigned to the breeding activities, 15% of them are invested in germplasm enhancement, activity that is decreasing, some 35% is assigned to line development, and 50% to line evaluation, both, developed by the company's program or introduced from other programs. (Being both increasing activities in the last years). Evaluation is made in six locations.

Public organizations in industrialized countries (70%) are the most important sources of gemplasm, and three other sources contribute 10% each: introduction through bi or multilateral agreements, private sector and farmers materials. Plant breeding main priorities are quality and resistance/tolerance to biotic stresses.

In opinion of the company, the international community could help in a more efficient use of PGRFA through:

1- Facilitating germplasm exchange
2- Strengthening national programme capacity through investments.
3- Promoting training programmes on biotechnological tools.
4- Facilitating access to new biotechnological tools.
5- Helping preparing projects for funding.

A total of seven varieties have been released by this company since 1991.

Taking into consideration the aspects the company considered as limiting factors for the success of its breeding programmes, the following are mentioned: lack of knowledge about the use of molecular techniques to support plant breeding programmes and inadequate availability of laboratory infrastructure to carry out experiments using advanced plant breeding techniques.

Company 8

Is a private company that carries out plant breeding activities since 2005. Its staff has been composed since the beginning by one plant breeder with PhD. degree, older than 50, and two researchers with BSc level, between 40 and 49 years old.

Ninety percent of the research budget is assigned to forage species breeding (oat, birdsfoot, fescue, chicory, red clover, orchargrass, lolium, sudangrass, corn and foxtail).

Plant breeding activities are: genetic enhancement, crosses, evaluation of segregating populations and evaluation of materials developed by the breeding program.

Genetic enhancement takes care of 20% of total human and financial resources (with decreasing tendency), 40% are devoted to line development, and 40% to line evaluation. It carries on evaluation trials in two locations.

Sources of germplasm used to improve forage species, in order of importance, are: 1) introduction through bi or multilateral agreements and farmers materials; 2) private sector and 3) CGIAR gene banks and public organizations in industrialized country.

Resistance/tolerance to biotic and abiotic stresses are of high priority for the breeding program. Quality and selection for favorable environment are medium priority.

The company said that in order to increase the efficiency in the use of PGRFA, the international community should:

1- Strengthen national programme capacity through investments.
2- Facilitate access to new biotechnological tools.
3- Promote training programmes on biotechnological tools.
4- Promote training programmes on conventional breeding methods.
5- Help preparing projects for funding.

Since 2005, two varieties have been released.

Actually, the aspects that the organization considers the most important limiting factors in order for the breeding program to succeed are, in order of importance:

1- Lack of financial resources to carry out field and laboratory experiments.
2- Inadequate availability of laboratory infrastructure to carry out experiments using advanced plant breeding techniques.
3- Lack of support from the international community, including organizations like Centres of the CGIAR system, FAO, etc.
4- Lack of knowledge about the use of molecular techniques to support plant breeding programmes.
5- Limited access to national public and/or private genetic resources.

Company 9

This company has been in the plant breeding business since 1980 and in plant biotechnology activity since 1981.

In 1985, the company had one MSc age 40-49. In 1990 had one MSc age 40-49, one BSc age 30-39 and three BSc age 40-49. In 1995, one BSc age 30-39 and three BSC age 40-49; in 2000, one BSc age 30-39 and three BSc age 40-49. Actually, the plant breeding task is carried out by one MSc plant breeder, age 40 to 49 and four BSc researchers, one age 30-39 and three age 40-49. In the plant biotechnology area, the company has one BSc researcher, age 20 to 29
Budget invested in research has been increased toward 1990, presenting a decreasing tendency after that. Probably, that evolution is due to the required investments at the beginning. Plant breeding activity uses 75% of the total research budget of the company. Until 1990, from the total human and financial resources invested in plant

breeding, beans accounted for 85 to 90% of the resources, and rice breeding for the remaining 10 to 15%. Since 1995 onwards, priority was practically opposite to that: (80-85% to rice breeding and 15-20% to beans breeding).

Genetic enhancement, crosses, evaluation of segregating populations, evaluation of lines developed by the own program and evaluation of lines introduced from other plant breeding programs are activities developed by the breeding program. Evaluation of material is carried out in two environments with a decreasing tendency in both crops. For beans, genetic enhancement and line development decreased in importance toward the end of the period, while in rice, both activities remained stable.

Considering total available resources, in rice, 50% of those resources are allocated to line development and evaluation, 40% to biotechnology activities and the remaining 10% to germplasm enhancement. In beans, 20% are allocated to line development and evaluation, 60% to biotechnology and 20% to germplasm enhancement.

The biotechnology areas in which the company develops activities are: *in vitro* culture and double haploid development.

Sources of germplasm used are: for rice, 80% introduction through bi or multilateral agreements and the remaining 20% from the private sector; and for beans, 70% comes from CGIAR gene banks, 15% comes from introduction through participation in germplasm evaluation networks, 10% from introduction through bi or multilateral agreements and 5% from the private sector.

For rice, breeding priorities are: resistance/tolerance to biotic stresses, quality and development of genotypes for favorable environments. For beans, breeding priorities are quality and improvement of genetic material resistant/tolerant to biotic stresses.

To efficiently increase the use of PGRFA, the international community should, in order of priority:

1- Promote training programmes on conventional breeding methods.
2- Strengthen national programme capacity through investments.
3- Promote training programmes on biotechnological tools.
4- Help preparing projects for funding.
5- Facilitate germplasm exchange.

Related to cultivar release, the most fruitful period has been the 1985-1989 one, having released seven rice and three bean varieties. From 1990 to 2004, some seven more rice varieties have been released.

Taking into consideration the limiting factors that have limited the success of the plant breeding program, they have stated, for 2005, the following ones:

1- Lack of clients.
2- Lack of support from the international community, including organizations like Centres of the CGIAR system, FAO, etc.
3- Lack of financial resources to carry out field and laboratory experiments.
4- Lack of knowledge about the use of molecular techniques to support plant breeding programmes.
5- Limited access to national public and/or private genetic resources.

Company 10

This is a company dedicated to plant breeding since 1969. From 1985 to date, a BSc. researcher between 20 and 49 years old has been assigned to the plant breeding activity.

Actually, 100 % of the research budget is assigned to malting barley. The plant breeding program evaluates segregating populations and introduced lines from other breeding programs. Ninety five % of the budget is allocated to line evaluation and 5% to germplasm enhancement. It does not make plant biotechnology. It works an interesting number of segregating populations, and manages some ten trials in two locations.

The most important source of germplasm is the introduction through bi or multilateral agreements (95-97%), coming the remaining 3 -5% from the national gene bank.

The most relevant breeding priorities are quality and resistance/tolerance to biotic stresses. Medium priority is assigned to resistance/tolerance to abiotic stresses and breeding for favorable environments.

To increase the efficiency in the use of PGRFA, the international community could help in:

1- Promoting training programmes on biotechnological tools.
2- Facilitating access to new biotechnological tools.
3- Strengthening national programme capacity through investments.
4- Facilitating germplasm exchange.
5- Promoting training programmes on conventional breeding methods.

The company has released six varieties in the 1990-2004 period.

Taking into consideration the limiting factors for the plant breeding success, priorities have considerably changed from the 80's to nowadays. In 2005, order of such priorities was:

1- Lack of financial resources to carry out field and laboratory experiments;
2- Inadequate number of support personal;
3- Inadequate availability of laboratory infrastructure to carry out experiments using advanced plant breeding techniques;
4- Lack of knowledge about the use of molecular techniques to support plant breeding programmes;
5- Limited access to international genetic resources.

CHAPTER 4. ASSESSMENT OF THE NATIONAL PLANT BREEDING AND ASSOCIATED BIOTECHNOLOGY CAPACITY

Number and educational level of scientists involved in plant breeding (Question 4):

Taking into consideration the public and private institutions and organizations that carry on plant breeding activities in the country, actual number of plant breeders is 45.9 FTE (Table 4.1), corresponding 62% to the public sector (INIA and FA) and 38% to the private sector (9 companies). In general, a higher number of MSc and PhD level breeders are present in the public sector, while the private sector has actually a higher number of plant breeder that hold a BSc degree.

Table 4.1 Number and percentage of breeders at the public and private sector, according to its academic level. 2008.

	Public Sector	%	Private Sector	%	Total
B Sc.	8.7	42.3	11.5	57.7	20.2
M Sc.	11.6	72.0	4.5	28.0	16.1
Ph.D.	7.6	79.2	2.0	20.8	9.6
Total	27.9		18.0		45.9
%	60.8		39.2		100

Data corresponding to the evolution of number of breeders and its academic level for the country from 1985 to 2008 are presented in Table 4.2.

Table 4.2. Evolution of number of plant breeders and academic level. 1985-2008.

Research Area	Year	B.Sc.	%	M.Sc.	%	Ph.D.	%	Total	Total Pub	Total Priv	% Pub	% Priv
Plant Breeders	1985	17	61.8	10.0	36.3	0.5	1.9	27.5	24.5	3.0	89.0	11.0
	1990	19	55.6	12.7	37.1	2.5	7.3	34.2	23.2	11.0	67.8	32.2
	1995	24	63.0	10.1	26.5	4.0	10.5	38.1	24.6	13.5	64.6	35.4
	2000	17.5	43.6	16.6	41.4	6.0	15.0	40.1	26.6	13.5	66.3	33.6
	2008	20.2	44.0	16.1	35.1	9.6	20.9	45.9	27.9	18.0	60.8	39.2

At the national level, the number of plant breeders has increased since 1985. Plant breeders in the public sector decreased toward 1990, but an important increase is observed in the private sector during the same period. After 1990 constant increase of researchers occurred in the public sector in each period, and the private investment is also increased, mainly toward 2008. While the private industry occupied 11% of total plant breeders in 1985, it occupied 39.2% in 2008.

The increase in number of plant breeders with PhD level is also remarkable (21% in 2008 vs. 2% in 1985). In relation to plant breeders with MSc degree, although there was no variation in the percentage, total number was increased. While postgraduate studies at the MSc level were prioritized during the 70’s and 80’s, PhD level was prioritized during the last decade.

Analyzing individually, INIA is the institution with the highest number of plant breeders (20.4 FTE), followed by FA with 7.5 researchers (FTE) in this area. In the private sector, between 1 and 3 FTE work at each company, presenting a range between 0, 5 and 5.

Analyzing plant breeding in the public sector (Table 4.3), total FTE decreased from 1985 to 1990, due to the discontinuation of plant breeding programs of non-irrigated crops at CIAAB/INIA, but since that moment it has had a continuous increase. This increase observed since 1995 is attributed to INIA, as FA maintained the same dedication in this area. In percentage terms increasing in doctorates is remarkable, as well as a clear reduction in researchers with a BSc degree. This human resources capacity is the one directly assigned to plant breeding activities in most of the cases, but in both institutions, a partial indirect dedication of researchers in different disciplines is also devoted to plant breeding activities, being quite difficult the task of quantifying their actual dedication. In order to do that, researchers doing pre breeding, evaluation/characterization for pathogens, insects, environmental stresses, grain quality, and genetic and botanical studies that support plant breeding activities through different research studies and projects should be added in most cases.

Table 4.3. Summary of plant breeders and their academic level at the public sector (INIA and FA), 1985-2008.

Research Area	Year	B,Sc,	%	M,Sc,	%	Ph,D,	%	Total
Plant Breeders	1985	16.0	65.3	8.0	32.7	0.5	2.0	24.5
	1990	13.0	56.0	8.7	37.5	1.5	6.5	23.2
	1995	13.5	54.9	8.1	32.9	3.0	12.2	24.6
	2000	8.0	30.1	13.6	51.1	5.0	18.8	26.6
	2008	8.7	31.2	11.6	41.6	7.6	27.2	27.9

An analysis of the private sector (9 plant breeding companies) shows also an increase in total number of plant breeders. (Table 4.4 y Figure 4.1).

Table 4.4. Summary of plant breeders and their academic level at the private sector, 1985-2008.

Research Area	Year	B.Sc.	%	M.Sc.	%	Ph.D.	%	Total
Plant Breeders	1985	1.0	33.3	2.0	66.7	0.0	0.0	3.0
	1990	6.0	54.5	4.0	36.4	1.0	9.1	11.0
	1995	10.5	77.8	2.0	14.8	1.0	7.4	13.5
	2000	9.5	70.4	3.0	22.2	1.0	7.4	13.5
	2008	11.5	63.9	4.5	25.0	2.0	11.1	18

This increment can be explained mainly to new companies established during the 90's, with activities in the plant breeding area, mainly devoted to evaluation of introduced genetic materials. These tasks mainly involve university professionals (Ingenieros Agrónomos), although some postgraduate researchers are included in the staff in the last years. An interesting increasing in the number of companies and number of plant breeders occurs toward 2008.

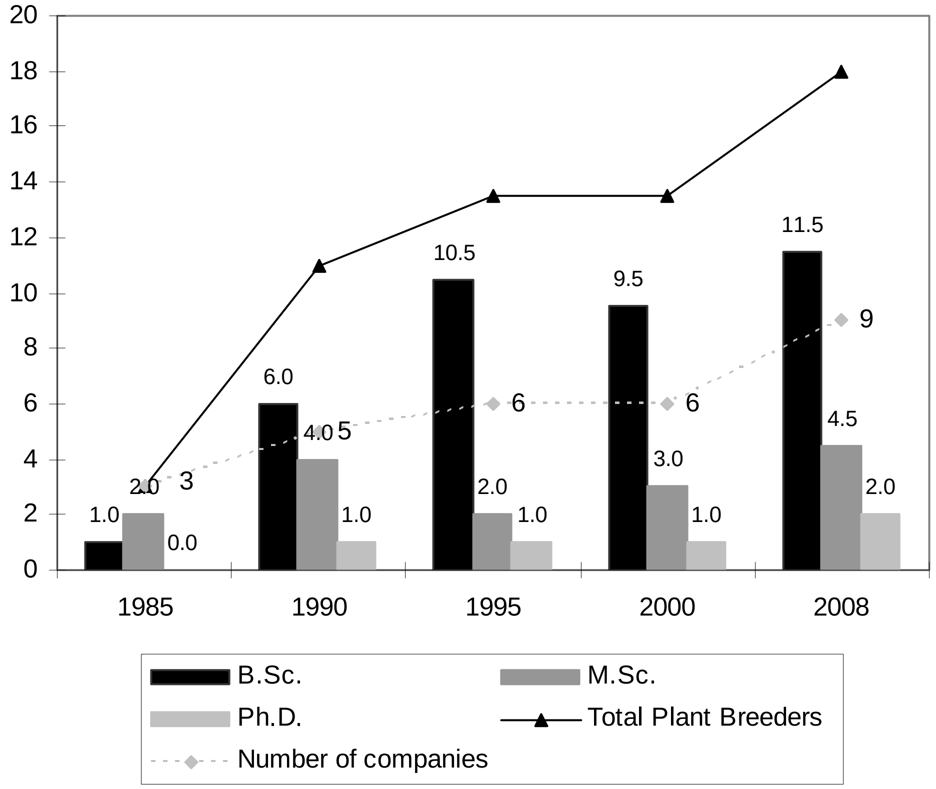


Figure 4.1 Evolution of number of plant breeders and academic level at the private sector. 1985-2008.

Number and educational level of scientists involved in biotechnology (Question 4):

The numbers of biotechnologists that develop activities in support of the plant breeding programs at the national level are presented in Table 4.5. Total number is 16.2 FTE, compared to a 45.9 FTE of plant breeders. This is an area that has basically grown in the public sector, representing 81.5% of the total. Among them, a high percentage has postgraduate studies. The 18.5% figure at the private sector column corresponds to two companies out of the ten that answered the survey, that develop some biotechnological activity.

Table 4.5. Summary of number and percentage of biotechnologists at the national level, both in the public and private sector, according to academic level. 2008.

Academic level	Public sector	%	Private sector	%	Total
B Sc.	2.5	55.6	2.0	44.4	4.5
M Sc.	6.5	86.7	1.0	13.3	7.5
Ph.D.	4.2	100.0	0.0	0.0	4.2
Total	13.2		3.0		16.2
%	81.5		18.5		

In the Table 4.6, evolution of number of biotechnologists and their academic level from 1995 to 2008 are presented. An interesting increase in number, particularly from middle 90's can be observed. A second important increase occurred between 2000 and 2008. Private sector entered in this area in the last years, but still with a very low incidence. Another relevant aspect is the increase in the PhD level occurrence in the public institutions.

Table 4.6. Evolution of number of biotechnologists and their academic level (National data). 1985-2008.

Year	B.Sc.	%	M.Sc.	%	Ph.D.	%	Total	Pub Total	Priv Total	% Pub	% Priv
1985	2.5	71.4	0.5	14.3	0.5	14.3	3.5	3.5	0.0	100	0.0
1990	2.5	71.4	0.5	14.3	0.5	14.3	3.5	3.5	0.0	100	0.0
1995	5.0	62.5	2.0	25.0	1.0	12.5	8.0	8.0	0.0	100	0.0
2000	2.5	27.8	4.0	44.4	2.5	27.8	9.0	9.0	0.0	100	0.0
2008	4.5	28%	7.5	46%	4.2	26%	16.2	13.2	3.0	81.5	18.5

Organization's total budget and proportion allocated to plant breeding activities in the period 19985 to 2008 (Question 5):

In the Table 4.7 the figures for total research budget, budget allocated to plant breeding activities and proportion of the latter related to the former is presented. It includes public institutions and ten private companies that answered the survey. The country invests annually some five million dollars in plant breeding activities, (104.519.285 uruguayan pesos), although as it was stated in Chapter 3, 2008 data from INIA includes structural costs that overestimates total amount directly invested in plant breeding (Tables 3.2 and 3.3). An increase in total research budget has occurred from 1995 to 2008, as well as in plant breeding budget. Proportion of resources allocated to plant breeding in relation to the total research budget has also shown an interesting increase.

Table 4.7. Total budget (public and private sector) allocated to plant breeding in Uruguay Uruguayan pesos

Financial resources	1995	2000	2008
Total Research Budget (INIA, FA, Private Companies)	81.602.413	220.904.817	570.980.149
Plant Breeding Budget	8.917.249	30.813.311	104.519.285
Relationship plant breeding budget/Total research Budget	10,9%	13,9%	18,3%

Considering budget distribution between public and private sector, it is clear that the most important concentration of financial resources is located in the public sector. (Table 4.8). In spite of the increasing volume of resources allocated by the private sector during the considered period (for the companies that answered the survey), its contribution has proportionally diminished.

Table 4.8. Distribution of total plant breeding budget between the public and private sector and its evolution in the 1995-2008 period. Uruguayan pesos

	1995		2000		2008	
	Uruguayan $	%	Uruguayan $	%	Uruguayan $	%
Public sector	7.648.615	85.8%	28.093.061	91.2%	97.321.325	93.1%
Private sector	1.268.634	14.2%	2.720.250	8.8%	7.197.960	6.9%

When analyzing the public sector (Table 4.9) there is a notorious increase in the percentage of the total research budget allocated to plant breeding, from a 9.6% in 1995 to a 17.6 % in 2008. In the public sector, the most important contribution is made by INIA. But again, it needs to be stated that in 2008, INIA's budget includes indirect costs. At FA, salaries of researchers are not included, and only salaries of field and research assistant, as well as direct costs are included.

Table 4.9. Evolution of plant breeding budget at the Public Sector (Uruguayan pesos) 1995-2008.

Financial resources	1995	2000	2008
Total research budget	79.921.679	217.471.257	559.400.214
Plant breeding budget	7.648.615	28.093.061	97.321.325
%	9.6	12.9	17.6

In the private sector (Table 4.10) an increase in financial resources allocated to plant breeding has occurred toward 1990,(data not shown). Later a decline is observed, and a new recovery of the investment toward 2008 occurred, mainly due to the establishment of new plant breeding companies. This estimation may be underestimated, since at least a couple of important private companies did not answer the survey.

In general, proportion of resources allocated by the companies to plant breeding has remained constant. That proportion is higher than in public institutions, due to the fact that the main objective of these companies is plant breeding, while the public institutions develop research and/or teaching activities for the whole agricultural sector.

Table 4.10. Evolution of plant breeding budget in the Private Sector (Uruguayan pesos) 1995-2008.

Financial resources	1995	2000	2008
Total research budget	1.680.734	3.433.560	11.579.934
Plant breeding budget	1.268.634	2.720.250	7.197.960
%	75.5	79.2	62.0

Organization's resource allocation (human and financial) for plant breeding activities. Percentage distribution by crop and/or crops-group. (Question 6)

In Table 4.11, estimated percentages of resources allocated per crop or crops-group at the country level are presented.

Table 4.11. Estimated percentages of resources allocated per crop or crops-group at the country level. 2000 and 2008.

Crop	Details	Sector	2000	2008
Wheat		Private	1.0	0.4
Wheat		Public	15.1	12.7
Barley		Private	0.4	1.9
Barley		Public	11.6	9.5
Rice		Private	0.6	0.3
Rice		Public	21.9	15.2
Sorghum		Private	0.0	0.1
Maize		Private	0.0	0.1
Maize		Public	1.6	3.1
Sunflower		Public	1.0	3.0
Oats		Private	0.4	0.2
Oats		Public	1.0	0.9
Horts		Private	0.1	0.1
Horts		Public	3.8	10.4
Forages		Private	0.4	0.9
Forages		Public	9.1	12.9
Potato and other Tubers		Public	2.3	7.4
Citrus		Public	1.3	2.4
Fruits	**Native fruits**	Public	0.5	0.3
Fruits		Public	2.8	1.6
Forestry	**Eucalyptus**	Private	5.9	3.0
Forestry	**Eucalyptus**	Public	14.3	9.9
Forestry	**Other sp**	Public	0.0	2.7
Forestry	**Pinus**	Public	4.8	1.1

Rice is the only crop that received the most important resource allocation in both years, although some decrease toward the end of the period is appreciated. Wheat follows in order of importance in both years. Forage species have received an important and increasing support, mainly through international projects of large magnitude. Horticultural crops had an outstanding increase in allocated resources from 2000 to 2008, and it is even greater if potato and sweet potato are included. Anyway, as explained in Chapter 3, part of the human and financial resources allocated to plant breeding in these group of crops also carry on some other related activities. An important percentage of the total resources are allocated to forest tree species breeding, and probably this figure could be underestimated in the private sector. Its importance has diminished in the public sector during the period.

For barley breeding, even though the percentage of resources allocated in the public sector decreased, it increased at the private sector. The result is that total national allocation has remained stable. Due to the fact that the Barley National Board partially supports plant breeding activities in the public sector, the figure reported by the private sector could be underestimated. As it was mentioned before, for forage species the relative investment by the public sector is far more important than by the private sector, but it must to be taken into consideration that at least a couple of important private companies did not answered the survey. For eucalyptus, the private sector executes one fourth of the total budget allocated to breeding activities in the specie. The rest of the species represent less than 3% of the breeding budget.

Activities carried out at each breeding program. (Question 7):

The plant breeding programs at INIA carry out all the surveyed activities: genetic enhancement, crossing, segregating populations evaluation, evaluation of lines developed by the institute’s program as well as introduced. This is an institution with a long plant breeding tradition, and, with some exceptions, performs all activities in most of the species (See Chapter 3). At FA, most of the activities are similar to those developed by INIA, although the intensity and the distribution is different according to the species, as is presented in Table 3.15 from Chapter 3.

In the private sector, nine out of ten companies that answered the survey reported plant breeding activities. In this sense, a resume of the answers are presented in Table 4.12.

Forage species and barley are the ones that present more companies in the market, followed by wheat, oat and rice. Most of the companies work in several species, especially those that carry out plant breeding activities in forage crops (four companies).

All private breeding programs evaluate introduced lines from other programs and most of them also evaluate their own breeding lines. Crosses are made by at least one company for barley, rice, beans, forage and/or forest tree species breeding programs, and most of them also evaluate segregating populations.

In relation to genetic enhancement, it seems that the concept was misunderstood, since although most of the companies state that they have these types of activities, no more than two of them would actually develop genetic enhancement activities.

Table 4.12. Plant breeding activities reported by private companies. (Number of companies that carry out each activity).

Crops	Number of Companies that answered on the crop group:	Number of answers reporting:				
		Genetic enhancement activities	Making crosses	Evaluating segregating populations	Evaluating fixed lines developed by the breeding programme	Evaluating fixed lines introduced from other breeding programmes
Wheat	2	1	0	1	2	2
Barley	3	1	1	2	1	3
Oat	2	0	0	0	0	2
Maize	1	0	0	0	0	1
Sorghum Millet	1	1	0	1	0	1
Rice	2	1	2	2	2	2
Others grain legumes	1	1	1	1	1	1
Forages	4	3	2	3	4	3
Forest trees	1	1	1	0	1	1

Distribution of human and financial resources allocated to germplasm enhancement, line development and line evaluation (Question 8):

The distribution of resources allocated to different plant breeding activities by the public and private sector are presented in Table 4.13.

Line evaluation is the most important activity carried out by all plant breeding programs. This is reflected both by the percentage of total allocated resources and by the fact that all the companies assign resources to this activity. Private companies allocate about a 60% of their budget to line evaluation, while institutions from the public sector assign around 45% to that activity.

Line development follows in importance. There is less variation in the relevance of this activity among companies, being allocated between 28 and 34% of their total plant breeding budget.

Germplasm enhancement is the activity that relatively receives fewer resources but is an important activity at INIA as well as at FA. While in the private sector it takes 12.5% of the budget, in FA and INIA takes between 22 and 24,7%.

Table 4.13. Percentage of resources allocated to different plant breeding activities in the public and private sector. 2008.

Sector	Germplasm enhancement	Line development	Line evaluation
	%	%	%
Private companies	12.5	28.3	60.8
FAGRO	22	34	44
INIA	24.7	28.7	46.6

A summary by crops can be appreciated in Table 4.14.

Table 4.14. Percentage of resources by crop allocated to different plant breeding activities.

Crops	Institution	Germplasm Enhancement %	Line Development %	Line Evaluation %
Wheat	**INIA**	20	50	30
	Private Company (2)	20	30	50
			10	90
Barley	**INIA**	10	40	50
	FA	60	25	15
	Private Company(3)			100
		10	60	30
		5		95
Oat	**INIA**	50	25	25
	Private Company(2)	20	30	50
				100
Rice	**INIA**	10	30	60
	Private Company(2)	10	60	30
		50	40	10
Maize	**INIA**	30	30	40
	FA		50	50
	Private Company			100
Sunflower	**INIA**	25	25	50
Potato and Sweet potato	**INIA**	10	45	45
Forage species	**INIA**	40	40	20
	FA	50		50
	Private Company(4)	20	30	50
		11	20	69
			10	90
		20	40	40
Horticultural crops	**INIA**		50	50
	FA	30	35	35
	Private Company	20	60	20
Fruit trees	**INIA**	15	15	70
	FA (Citrus)	20	60	20
Native fruit trees	**FA**	10	80	10
Forest trees	**INIA**	30	40	30
	FA			100
	Private Company	15	35	50

For wheat breeding activities, line development (LD) is important in the public sector and line evaluation (LE) in the private sector. Twenty percent of the general budget is devoted to genetic enhancement (GE).

In barley, GE is mainly done by the Agronomy Faculty; LD is important in most of the breeding programs, as well as LE; in two private companies more than 95% of the budget is allocated to LE.

In rice, in the public sector, LE is the most important activity (60%), although activities are carried out in the remaining ones. In the private sector, about 50% of the budget is used in LE, and one of the companies works mainly in GE.
In oats, GE is important for INIA, while LE is the most important activity for the private sector. Maize breeding is carried out only by the public sector, with emphasis on LE and LD. The private sector introduces and evaluates hybrids used in production from multinational companies.

Also in sunflower, potato and sweet potato, breeding is carried out by the public sector. Emphasis in sunflower is made on LE, while in roots and tubers, 90% of the budget is assigned to LD and LE.

In forage crops, in the public sector, INIA, who works mainly with introduced species, works in the three categories. The Agronomy Faculty, which develops works in native species, in *Bromus* makes LE, in *Paspalum*, GE (50/50 is an average). In the private sector, LE is the most important activity, followed by LD.

In horticultural crops, almost all the breeding work is carried out by the public sector. INIA develops and evaluates lines; the Agronomy Faculty does the three categories, being GE more important in onion. In the private sector, only one company works with beans, mainly developing lines, and decreasing its activity nowadays.

Plant breeding activities for introduced fruit species are only developed by the public sector, mainly in LD and LE. GE is not important. In native fruits, the Agronomy Faculty emphasizes LD, although INIA is also beginning with its breeding program.

In forest trees species, LE is the most important activity for the country, although the three categories are of similar importance for INIA. The Agronomy Faculty evaluates lines, and the private sector emphasizes LE.

Budget distribution (%) at the national level for line development and evaluation, germplasm enhancement and biotechnology (Question 9):

Due to the fact that estimation in some cases was not made in a similar way, data for the public and private sector are analyzed separately.

In Table 4.15 data related to the distribution of human and financial resources over time by the public sector to line development and evaluation, biotechnology and germplasm enhancement are presented. It can be concluded that in the 1995-2008 period line development and evaluation present a relative reduction toward the end of the period, with a value of approximately 53% of the resources, while an increase in the percentage of resources allocated to plant biotechnology and germplasm enhancement occurs in the same period. But, in a similar analysis to that made in Chapter 3, it can be considered as a more adequate interpretation the fact that when biotechnology activities are added to the budget, plant breeding activities are proportionally reduced.

Nonetheless, when absolute figures are compared, resources allocated to line development and line evaluation increased over time.

Table 4.15. Proportion of the total resources allocated to the different research areas. Public Sector. (Average %).

Research Area	1995	2000	2005
Line development[1] and evaluation[1]	70	60	52.6
Plant biotechnology[1]	6.5	16.5	20.4
Germplasm enhancement[1]	23.5	23.5	27
Total allocation (%)	100	100	100

In the private sector, information is presented in a different way, since data is not balanced because not all the companies developed activities in all categories. (See Chapter 3). In Table 4.16, mean value of the budget allocated to the different plant breeding activities are presented.

From Chapter 3, we can conclude that between 1985 and 2008, the number of private plant breeding companies increased from 3 to 9. In biotechnology, one company began activities in 1985, (together with plant breeding activities) and a second one began in 2008, not carrying out plant breeding activities. As a summary, in 2008, from the ten private companies that answered the survey, eight developed exclusively plant breeding activities, one developed exclusively biotech activities and the other one developed both biotechnology and plant breeding activities.

A higher percentage of the resources was allocated to LD and LE, activities that increased from 72.5 to 78.3 in the 1985-2008 period. The assigned relative importance to GE was stable during the same period. The budget proportion allocated to plant biotechnology increased in 2008 due to the fact that a new company was established, developing only biotech activities.

Table 4.16. Mean value of the budgets reported for the different plant breeding activities, private sector.

Activity		Mean	budget	%	
	1985	1990	1995	2000	2008
Germplasm enhancement	15	13	12.7	12.3	13.8
Line development and evaluation	72.5	78	72.8	73.2	78.3
Plant biotechnology	40	40	40	40	70

(Due to different activity composition and no balanced data, in each year data does not add to 100%, being only an indicative trend).

Biotechnology areas developed at the country level (Question 10):

A summary of the biotechnology areas in which national institutes are working on is presented in Table 4.17. In the public sector, work is developed in the following biotech areas: molecular characterization, tissue culture, double haploid breeding, marker-assisted selection, genomics, genetic engineering, gene isolation and wide crosses. Other areas where research is developed are: host-pathogen relationships (Faculty of Agronomy) and genomic information and bioinformatics studies in support to the identification of candidate genes for assisted selection (INIA).

In the private sector, only tissue culture and double haploid production are made. In double haploid production, only one company develops this activity in the country, since another one reports activities but through extra region agreements. This same company reports to do molecular characterization, no directly, but in agreement with other institutions.

Table 4.17. Biotechnology areas developed at the country level.

Activity	Number of Private Companies	INIA	FAGRO
Molecular characterization	1	X	X
Tissue culture	2	X	X
Double haploid breeding	2	X	
Marker-assisted selection		X	X
Genomics			X
Genetic engineering			X
Gene isolation			X
Wide crosses		X	X
Other (specify)			Host-pathogen interaction

Organization of the breeding programs (Question 11):

In Table 4.18 information on number of crosses made by the breeding programs, number of segregating populations, number of trials and number of locations used for field trials are presented.

Workload of the breeding programs follows the importance of the crop in the country (with the exception of soybean, where, as mentioned before, the breeding program was closed and is now being reopened). In some self pollinated crops, number of crosses and segregating populations are very interesting. According to workload, the highest volume is carried out by the public sector, mainly INIA. However, plant breeding activities developed by FA in some species are also important. In the private sector, *Eucalyptus* and barley are the species where the major input is made.

Cuadro 4.18. Numbers of crosses, segregating populations, number of experimental plots, number of trials and locations managed for every crop and/or crop-group.

Crops	Institution		Number of crosses made	Number of segr. pops.	Number of experimental plots	Number of trials	Number of locations used for field trials
Small Grains	INIA (wh,ba,oa)*		670	13000	25880		4
	FA (ba)		60	2000		14	3
	Private companies	wh,oa				1	1
		wh,ba, oa		10	90	20	1
		ba	150	150		8	3
		ba		100/ 200		10	2
Rice	INIA		130	700	3967		7
	Private companies		20	100		8	2
			30	120		2	2
Maize	INIA		200	800	3500		1
	FA					1	1
	Private companies					10	1
Sunflower	INIA		200	800	3000		2
Potato	INIA		150	30000			
Sweet potato	INIA		30	10000			
Forage species	INIA		105	18000	17000		4
	FA (*Bromus*)					3	3
	FA(*Paspalum*)		10	3		2	1
	Private companies					1	1
			20			4	1
			20			2	1
						10	1
			20	30		30	2
Hort crops	INIA(on+tom)		10	10	50		
	INIA(strawberry)		100	5000/ 10000			
	FA(on)		10	300		6	2
	FA(carrot)		4	300		20	5
	Private companies, beans			20000		2	2
Fruits	INIA		12	10	550		12
	FA					15	6
Native fruits	FA					2	2
Forest tree species	INIA				80		4
	FA(*Eucalyptus*)					6	2
	FA(*Pinus*)					5	1
	Private companies		350				6

*wh;wheat; oa:oats;ba:barley;on;onion:tom:tomato

Main sources of germplasm used in the breeding programmes (Question 12):

Main sources of germplasm used in the breeding programs in the country are presented in Table 4.19.

In general, main source of germplasm for INIA are local gene banks, followed, with a similar contribution, by the national gene bank, and in smaller proportion by introductions through bi or multilateral agreements, private sector and by participation in germplasm evaluation networks. The same comment made in Chapter 3 refers to the fact that in many cases, like some horticultural crops, local gene banks include farmer's materials or adapted materials being its origin introduced germplasm. The most important sources for FA are farmer's materials and local germplasm bank, followed by introductions through bi or multilateral agreements. In the private sector, main source of germplasm comes from the own sector (private), followed by bi or multilateral agreements and farmer's seed. In general, and with a few exceptions, contribution of CGIAR banks to the public plant breeding programs is not relevant.

In Table 4.20, relative importance of different sources of germplasm for each crop or crop-groups is presented. In some crops, 100% of the germplasm used comes from one source, while in others the origin is distributed among different sources.

Table 4.19. Main sources of germplasm used by the public and private plant breeding programs in Uruguay. (%).

	Local germplasm bank	National germplasm bank	Introduction through bi or multilateral agreements	Introduction through participation in germplasm evaluation networks	CGIAR gene banks	Public organizations in industrialized country	Private sector	Farmers material
INIA	40	11,2	10,4	9,6	5,4	7,3	12,7	3,5
FAGRO	31.0	6.0	12.5	4.0	1.0	4.0	7.5	34.0
Private sector	2.13	3.0	20.9	1.0	7.0	6.6	39.9	19.3

Cuadro 4.20. Main sources of germplasm used in the breeding programms by crops or crops-group. 2008.

Crops	Institution	Local gene Bank	National gene Bank	Introduction through bi or multilateral agreements	Introduction through participation in germplasm evaluation networks	CGIAR gene banks	Public organizations in industrialized country	Private sector	Farmers Materials
Wheat	INIA	80			10	10			
	Private companies							100	
								100	
Barley	INIA	45		15		5		35	
	FA		40	25		10	10	15	
	Private companies	10		40				50	
			30	20			20		30
		3 - 5		95- 97					
Oat	INIA		65		20				15
	Private comp							50	50
		10		40				50	
Rice	INIA	50		40		5	5		
	Private companies								100
				80				20	
Maize	INIA		50		30		5	5	10
	FA								100
	Private companies	10						90	
Sunflower	INIA		10		60		10	20	
Potato	INIA	50		10		10	30		
Sweet potato	INIA	50		10	10	0	20	10	0
Forage species	INIA	10	10	25		20		25	10
	FA	100							
	Private companies					25		25	50
				51				29	20
		2,5	15	32,5				50	
				30		10	10	20	30
Horticultural crops	INIA Onion	70						20	10
	INIA Strawberry	50					25	25	
	FA				15		5		80
	Private companies			10	15	70		5	
Fruit	INIA	55	45						
	FA	60	20						20
Native fruits	FA	40							60
Forest tree species	INIA	70						30	
	FA	5		50	5		10	30	
	Private companies			10			70	10	10

In wheat, at the public sector, germplasm mainly comes from local gene bank, while for the private plant breeding programs, it comes from the own sector.

In barley, for public plant breeding programs, main sources of germplasm are local and national gene banks, while for the private sector, situation is variable: while for some companies, main source is their own sector, for some others, introductions through bi or multilateral agreements are the most relevant ones.

In oats, most important source of germplasm for INIA is the national gene bank and farmer's materials and the own sector for private companies. (The gene bank at INIA has also an important collection of farmer's materials).

In rice, INIA mainly uses germplasm coming from the local gene bank, followed by introductions through bi or multilateral agreements. This last source was also mentioned as very important for one of the private plant breeding companies, being farmer's materials, main source of germplasm for another one.

At FA, farmer's materials are the most important source of variability for the maize breeding program, while for INIA it comes from the national gene bank. In the private companies, germplasm comes from the sector. In sunflower, INIA introduces genetic material through participation in germplasm evaluation networks.

In forage species, wild populations (under local gene bank) are the source of germplasm for FA, since it works with native species (*Bromus* and *Paspalum*). At INIA, which works mainly with introduced species that have developed adaptation to the country conditions, there is a similar contribution of different sources, being the most important ones: introductions through bi or multilateral agreements, private sector and CG gene banks. It receives, also, some contribution from the national gene bank, farmer's materials and wild populations (local gene bank). In the private plant breeding companies, situation is variable: the most relevant ones are introductions through bi or multilateral agreements, farmer's materials and the own sector.

In horticultural crops, there is variation among species. In potato and sweet potato, the biggest germplasm provider is the local gene bank, followed by germplasm that comes from public organizations in industrialized countries. In onion and strawberry, local gene bank is the main provider for INIA, while farmer's materials are for FA; for the private sector (one company that works with beans), the CG Banks. In the case of INIA, local gene bank may include farmers material in some crops (like onion), and/or improved germplasm obtained from introduced variability (like in potato, sweet potato and strawberry).

In native fruit species, germplasm comes mainly from farmer's materials followed by wild populations (local gene bank). In introduced fruit tree species, INIA gets its material from the local and national banks.

Finally, in forest tree species, major source of germplasm for INIA is the local gene bank; for FA, introductions through bi or multilateral agreements, and for the private sector, materials from public organizations in industrialized countries.

Trends in breeding priorities: 1980 – 2008 (Question 13):

A summary on breeding priorities and their trends in the 1980-2008 period by institution is presented in Table 4.21 and by crops in Table 4.22.

Table 4.21. Plant breeding priorities. Public and private sectors. 1980 and 2008.

INSTITUTION	CROP	Breeding for favorable environment		Breeding for resistance/tolerance to abiotic stresses		Breeding for resistance/tolerance to biotic stresses		Breeding for Quality traits	
		1980	2008	1980	2008	1980	2008	1980	2008
Public Sector									
INIA	**Wheat**	3[1]	3	2	2	1	1	3	1
	Barley				2	1	1	1	1
	Oat					1	1	3	3
	Rice	2	2	1	3	3	1	3	1
	Maize			1	1				3
	Sunflower			3	2	1	1	2	2
	Potato and sweet potato		2			1	1	2	2
	Forage species	1	1	2	2	3	1	2	3
	Onion and strawberry		2			1	1		2
	Fruit trees	1	2	2	1	3	1		2
	Eucalyptus		1		2		1		
	Pinus		1		2		2		
Faculty of Agronomy	**Maize**	3	3	1	1	3	3	3	2
	Barley	1	1	3	3	1	1	2	1
	Bromus	3	3	1	1	2	2	3	3
	Paspalum			1	1				
	Onion				3		1		1
	Carrot		1		3		3		1
	Citrus							1	1
	Native Fruits		3		2		2		1
	Eucalyptus	1	1			3	3	2	2
	Pinus	1	1			2	2	3	3
Private Sector									
Company 1	**Wheat**						1		2
	Forage				3		1		2
Company 3	**Sorghum**				1		2		1
	Forage				1		2		1
Company 4	**Rice**				2				1
Company 5	**Wheat**	1	1		2	1	1		1
	Corn								1
	Barley	2	2			1	1	1	1
	Oats					1	1	1	1
	Forage (diferences among species)			2	1			2	1
Company 6	**Barley**		2				1		1
Company 7	***Eucalyptus***						1		1
Company 8	**Forages**		2		1		1		2
Company 9	**Rice**	2	1	1	3	1	1	1	1
	Beans					1		1	
Company 10	**Barley**	2	2	2	2	1	1	1	1

[1] (1 = high priority; 2 = medium priority, 3 = low priority).

Analysis by crops for each institution was made in Chapter 3. The analysis in this chapter tries to highlight the most relevant general factors for each institution or sector. In general, there is more concern on all the considered traits or environments toward 2008. At INIA, emphasis is made mainly on breeding for biotic stresses, especially breeding for disease resistance. Also grain quality is relevant in many species in the last years. At FA, breeding for quality traits is emphasized. In the private sector, breeding for quality is highly relevant in most of the surveyed companies, followed by breeding for biotic stresses.

At the public sector, breeding for favorable environments is high priority during the whole period for introduced forage species; and breeders highlighted the importance of breeding for resistance to abiotic stresses for native forage species. Also for forage species, at the private sector, breeding for quality and abiotic stresses are emphasized as important traits.

In both public institutions, breeding for favorable environments is high priority in forest tree species.

Breeding for resistance to biotic stresses are emphasized toward the end of the period for wheat, barley, rice, oat, potato, sweet potato and onion. This trait always has been a high priority objective of the national breeding programs particularly in wheat, barley, sunflower and oats. Toward 2008, also breeding for quality traits is of high priority for barley, rice, sorghum, onion and carrot. Breeding for resistance to abiotic stresses has always been reported as an important trait to improve in maize and native forage species. Finally, breeding for favorable environments has been emphasized in forest tree species in the surveyed institutions.

Table 4.22. Trends in breeding priorities by crops at the country level. 1980 and 2008.

CROP	Company	Breeding for favorable environment		Breeding for resistance/ tolerance to abiotic stresses		Breeding for resistance/ tolerance to biotic stresses		Breeding for quality traits	
		1980	2008	1980	2008	1980	2008	1980	2008
Wheat	**Private**	1[1]	1		2	1	1 1		2 1
	INIA	3	3	2	2	1	1	3	1
Barley	**Private**	2 2	2 2 2	2	2	1 1	1 1 1	1 1	1 1 1
	FA	1	1	3	3	1	1	2	1
	INIA				2	1	1	1	1
Rice	**Private**	2	1	1	2 3	1	1	1	1 1
	INIA	2	2	1	3	3	1	3	1
Sorghum	**Private**				1		2		1
Sunflower	**INIA**			3	2	1	1	2	2
Maize	**Private**								1
	FA	3	3	1	1	3	3	3	2
	INIA			1	1				3
Oats	**Private**					1	1	1	1
	INIA					1	1	3	3
Horts Beans	**Private**					1		1	
Horts	**INIA**		2			1	1		2
Roots and tubers	**INIA**		2			1	1	2	2
Carrot	**FA**		1		3		3		1
Onion	**FA**				3		1		1
Forage	**Private**		2	2	3 1 1 1		1 2 1	2	2 1 2 1
Forage: Bromus	**FA**	3	3	1	1	2	2	3	3
Paspalum	**FA**			1	1				
	INIA	1	1	2	2	3	1	2	3
Fruits Citrus	**FA**							1	1
	FA		3		2		2		1
	INIA	1	2	2	1	3	1		2
Eucalyptus	**Private**						1		1
	FA	1	1			3	3	2	2
	INIA		1		2		1		
Pinus	**FA**	1	1			2	2	3	3
	INIA		1		2		2		

[1] (1 = high priority; 2 = medium priority, 3 = low priority).

Opinions about how the international community can assist the country in increasing efficient use of PGRFA (Question 14)

Opinions of different national institutions about how the international community (FAO, CGIAR Centers, World Bank, IFAD, multilateral or bilateral development agencies, etc) could assist the country in increasing efficient use of PGRFA are presented in Table 4.23.

Cuadro 4. 23. Possible assistance from the international community. 2008.

ASPECTS	INIA	FAGRO	Private company									
			1	2	3	4	5	6	7	8	9	10
Strengthening national programme capacity through investments	1	1		2	5	2	3	1	2	1	2	3
Facilitating access to new biotechnological tools	2	5			2		2	4	4	2		2
Facilitating germplasm exchange	3		3	1	1	1	1	2	1		5	4
Promoting training programmes on biotechnological tools	4	4		3	4	5	4		3	3	3	1
Helping preparing projects for funding	5	3	2			4	5	3	5	5	4	
Promoting training programmes on conventional breeding methods		2	1		3	3		5		4	1	5
Promoting contact with other companies			4									

Strengthening national program capacity through investments is number one priority for the national public sector, being also first priority for some private companies and second one for others. Facilitating germplasm exchange is important for several private plant breeding companies, followed by promotion of training programs on conventional breeding methods. Facilitating access to new biotechnological tools is also scored second place for several companies.

Varieties released by the national breeding programs (Question 15):

As presented in Table 4.24, from a total of 200 cultivars released from 1980 to 2004, approximately two thirds of them were released by the public sector, and one third from the private plant breeding programs. A constant increase in the number of varieties released is observed. Total number of varieties obtained from national breeding programs is underestimated, for two reasons: neither cultivars released during the 2005-2008 period are included (where only INIA has released 31 cultivars), nor varieties released from some important private companies that did not answer the survey. Among them there are several companies that release introduced cultivar but without having breeding program in the country.

Table 4.24 Number of varieties released in Uruguay by the public and private plant breeding programs. 1980-2004.

Class	1980-1984	1985-1989	1990-1994	1995-1999	2000-2004	Total	%
Private companies		15	9	17	26	67	33.5%
Public sector	22	20	22	27	42	133	66.5%
Total	22	35	29	42	66	200	100.0%

Number of varieties released in Uruguay by the public sector is presented in Table 4.25. INIA contributes with approximately 90% of the released cultivars, and FA the remaining 10 %. There has been a constant increase in this activity at INIA during the considered period.

Table 4.25. Number of varieties released in Uruguay by the de public institutions. 1980-2004.

Class	1980-1984	1985-1989	1990-1994	1995-1999	2000-2004	Total	
INIA	18	20	22	25	34	119	89.5%
FA	4			2	8	14	10.5%

Number of released varieties by crop is presented in Table 4.26. Releasing of varieties in fruit tree and forage species toward the end of the period is remarkable. In both cases, several species are included. As individual crops, releasing of varieties in wheat and rice is outstanding, in coincidence with the importance assigned to those plant breeding programs in the country.

Table 4.26. Number of varieties released in Uruguay by crop. 1980-2004.

Cultivos	1980-1984	1985-1989	1990-1994	1995-1999	2000-2004	Totals	%
Wheat	2	8	4	6	8	28	14.0%
Barley		1	4	8	4	17	8.5%
Oat			2	2	1	5	2.5%
Others small grains		3			4	7	3.5%
Rice		11	4	6	5	26	13.0%
Maize		1	1	1	2	5	2.5%
Sunflower	3			1		4	2.0%
Roots and tuber (potato)			4	5	3	12	6.0%
Onion	1		1	1	6	9	4.5%
Forage species	4	5	4	7	16	36	18.0%
Fruit tree species	9	6	5	5	13	38	19.0%
Eucaliptus	3		2	2	6	13	6.5%
Total	22	35	31	44	68	200	

Number of varieties released in Uruguay by private plant breeding companies, in different species, are presented in Table 4.27.

Table 4.27. Number of varieties released in Uruguay by the private sector. 1980-2004.

Crop or crops-group	Specify crop(s)	1980-1984	1985-1989	1990-1994	1995-1999	2000-2004	Total
Rice			7	2	3	3	15
Wheat			2	1	2	2	7
Barley			1	3	8	3	15
Others small grains	***Setaria italica***					1	1
Oat				1	2		3
Sorghum and Millet						3	3
Others grain legumes	**Beans**		3				3
Forage species			2			11	13
Forest trees				2	2	3	7
Total			15	9	17	26	67

The most important releasing of varieties occurs in rice, barley and forage species (several species included), followed by wheat and *Eucaliptus*.

Limiting aspects for the success of the plant breeding programmes at the national level 1980-2008. (Question 16):

A summary of the most important limiting aspects identified by the different institutions/organizations/companies for the success of the plant breeding programs at the national level are presented in Table 4.28. Only data for 2008 is summarized, since there is partial data from the previous years.

Table 4.28. Limiting aspects for the success of the plant breeding programmes. 2008.

ASPECTS	INIA	FAGRO	Com1	Com2	Com3	Com4	Com5	Com6	Com7	Com8	Com9	Com10
Inadequate number of breeders for each crop	5	2	1		2	3	5					
Inadequate experimental fields conditions												
Inadequate access to recent literature		5										4
Inadequate knowledge level of the general plant breeding strategies			2		3							3
Limited access to international genetic resources	4			1	1	1	1					2
Limited access to national public and/or private genetic resources	3			2		2	2			5	5	
Lack of knowledge about participatory plant breeding techniques			4									5
Lack of knowledge about the use of molecular techniques to support plant breeding programmes					4	5		3	1	4	4	
Inadequate availability of laboratory infrastructure to carry out experiments using advanced plant breeding techniques	2	4			5		3	2	2	2		
Lack of financial resources to carry out field and laboratory experiments	1	1	3			4				1	3	1

Cont. Table 4.28. Limiting aspects for the success of the plant breeding programmes. 2008.

ASPECTS	INIA	FAGRO	Com1	Com2	Com3	Com4	Com5	Com6	Com7	Com8	Com9	Com10
Lack of support from the international community, including organizations like Centres of the CGIAR system, FAO, etc		3	5				4			3	2	
Lack of connection with adequate seed delivery systems												
Other (specify)		Brain drain						Lack of equipment			Lack of clients	
Other (specify)		Low salaries										

Lack of financial resources to carry out field and laboratory experiments was identified as the most important limiting factor by the public institutions as well as by a couple of private companies. Limited access to international genetic resources was the most important limiting factor identified by private companies, and limited access to national public and/or private genetic resources was scored first place by three private companies. The rest of the factors fluctuated among the different institutions.

CHAPTER 5. <u>CONCLUSIONS AND RECOMMENDATIONS</u>

Conclusions

Plant breeding of some important crops in Uruguay has historically occupied a prioritized place in the agricultural research area. Some of them, like the wheat breeding program is almost one hundred years old. Plant breeding is mainly developed at the public sector, being INIA the main institution that carries on this activity. Faculty of Agronomy, belonging to the University of the Republic, is the other public institution that carries out plant breeding work in several species. The private sector has developed breeding activities also in malting barley and rice. In both crops, activities are developed in association with and partially funded by the industrial and exporting sector. In the last years, some private companies started to invest in plant breeding activities in forage and forest tree species, mainly in *Eucaly*

Number of plant breeders was, in 2008, 45.9 Full Time Equivalent, (FTE), compared to 27.5 FTE in 1985, most of them belonging to the public sector (62%). Importance attributed by the private sector to plant breeding activities has been growing toward the end of the period, increasing its human resources proportionally from 11.0% to 39.2%. Educational level of plant breeders has also remarkably increased during the last years, mainly in the public sector, where 41.6% of them have got MSc degree and 27.2% of them PhD degree.

The biotechnology sector associated to plant breeding activities has grown in the last years, especially in the public sector, where the number of biotechnologists increased from 3.5 FTE in the middle 90's up to 16.2 FTE in 2008.

Private sector works basically in the tissue culture area and is beginning activities in the double haploids area. Educational level of biotechnologists has followed a similar figure to that of plant breeders.

Total budget allocated to agricultural research has been increased since 1995. This growth has mainly occurred in the public sector, and in particular at INIA. An increasing in the budget assigned to plant breeding activities has also occurred, as well as a percentage increasing in the resources allocated to plant breeding in relation to the total budget for agricultural research, which is positioned at 18,3% toward the end of the period (while it was at 10,9% in 1995).

According to the surveyed information, rice, wheat and forage species programs are the ones that receive the most important support in financial resources, followed by horticultural crops, included potato and sweet potato, forest tree species and barley. However, it needs to be taken into consideration that not all the private forest tree companies answered the survey, and that in some cases, basic studies done under international funded projects, like in forage species, are included in the plant breeding budget. Toward the end of the 80's, several plant breeding programs were closed or decreased its importance (soybean, flax, sorghum, sunflower and maize). In those crops, national varieties obtained by public national programs were substituted by imported cultivars. Is particularly remarkable the case of soybean, where although a very valuable national breeding program existed until 1990, it was completely closed. Today, with a changed situation, the soy plant breeding program is beginning again its activity. Domestication and breeding of native species (forage and fruit tree species) are carried out basically at FA, although INIA has increased its budget in these species in the last years.

In the institutions of the public sector, all surveyed breeding activities are developed: (genetic enhancement, crosses, evaluation of segregating populations, and evaluation of lines from the program as well as introduced ones from other programs). Line evaluation, both, introduced or developed by the own program are the prioritized activities in the private companies. Germplasm enhancement has begun to be a relevant activity, mainly in the public sector, following the increasing activities in plant biotechnology toward the end of the period.

Workload in the national plant breeding programs is variable. In some self pollinated crops, like wheat, rice, barley, number of crosses as well as segregating populations managed by the programs shows a very interesting figure. Similarly to other parameters, public sector accounts for most of the breeding work at the country level, being INIA the institution with the biggest workload. However, breeding activities developed by FA are very relevant in some species, mainly native ones.

Although variable among species, local gene banks (active banks), that includes farmers and some introduced materials, are the main source of germplasm for INIA , farmer's materials and wild populations are for FA, and the own sector is the main source for the private plant breeding companies. In general, in cultivated species which have developed adaptation to the specific national conditions, plant breeding programs combine such characteristics with some specific trait identified in introduced genetic material (like in wheat). In some other species, like onion, local varieties are the most important source of germplasm for plant breeding programs, and in native species, germplasm is exclusively national. For crops recently adopted in the country, work is mainly based on introduced germplasm.

Main objectives of the plant breeding programs in the country are improving characteristics of yield potential, quality, and pest and disease resistance. Quality is an objective that has been incorporated in most of the programs, and in the last period, also breeding for favorable environments has been added.

In reference to cultivars used in crop production, situation differs among crops. In winter crops (wheat, barley, oat), varieties used are mainly products of the national plant breeding programs, although during the last years, seed of cultivars released by public and private nurseries of the region had entered into the Uruguayan market. In summer crops, situation has radically changed in the last twenty years. Due to the fact that national plant breeding programs of cross pollinated crops (maize, sunflower, and sorghum) have reduced its relative importance or have been closed, imported hybrid seed is used in most of the area, existing an extraordinary number of importing seed companies in relation to the production area. In maize and sunflower, there is some availability of national seed of varieties released by public national breeding programs. In maize, genetically modified cultivars are planted in more than 60% of the area. In soybeans, in which the breeding program was also closed, although today high proportion of the seed used in commercial crops is produced in the country, cultivars were developed abroad and are genetically modified (RR).

Most of forage seed (ryegrass, oat, fescue, dactylis, phalaris, lotus, red and white clover, lucerne) is mainly a product of national breeding programs. It is remarkable the fact that public varieties released in the 60's and 70's are still used by farmers. Germplasm used by breeding programs are, in some cases, based on local adapted populations (ej. *Lotus corniculatus*, *Avena* sp), and in other cases, on introduced germplasm. Domestication activities of native forage species have been mainly developed at the Faculty of Agronomy, although also INIA has begun to work in this group of species in the last years.

Referring to seed of horticultural species, situation is variable. In the case of those species that have a breeding program, (except potato), seed production of national cultivars is made in the country (onion, sweet potato, as example), and adapted varieties released by the programs predominate at the production level, even in greater proportion than in traditional crops like winter crops or forage species. In other cases, production is based on seed from local varieties, produced by the own farmer. Finally, there is another group of species for which seed is mainly imported, since they do not have breeding programs at the national level. In general, origin, adaptation and even genetic quality of those materials are unknown. It must be remarked that in forage as well as in horticultural species, there is an increasing tendency to farmers' involvement in the breeding process, including evaluation and selection of promising germplasm.

Although clone reproduction is done at the national level in deciduous fruit trees as well as in citrus species, national and imported varieties coexist. In the particular case of Guayabo del país (Pineapple Guava, *Acca sellowiana*), species for which Uruguay is a primary center of diversity, and is grown in several countries around the world, Faculty of Agronomy and INIA are working in its domestication. Also some work has begun in some other native fruit species like *Psidium cattleianum*,(arazá), *Eugenia uniflora* (pitanga) and *Myrcianthes pungens* (guaviyú).

For forest species, most of the seed is imported. National breeding programs use introduced as well as adapted materials, with the objective of producing varieties, and more recently with the objective of producing cloned materials.

During the last twenty years some two hundred varieties have been released at the national level, corresponding two third of those releasing to the public sector, and being INIA the major breeder institution. Most of the released varieties are from wheat and rice.

In reference to opinions about how the international community could help with plant breeding activity in the country, the following ones were mentioned as first and second priority by the public sector: strengthening national program capacity through investments, facilitating access to new biotechnological tools and promoting training programs on conventional breeding methods. At the private sector, both first priorities are shared, adding also, facilitating germplasm exchange.

For 2008, lack of financial resources to carry out field and laboratory experiments, inadequate availability of laboratory infrastructure to carry out experiments using advanced plant breeding techniques and inadequate number of breeders for each crop were main limitations for the success of plant breeding programs for the public sector. Private companies expressed their concern about limited access to genetic resources and lack of financial resources to carry out field and laboratory experiments as their main limiting factors.

Recommendations

Uruguay has an excellent potential for the development of effective plant breeding programs, mainly due to the high qualification of its breeders and related disciplines (pathologists, entomologists, nutritionists, statistics, etc), which are closely integrated to the breeding programs in most of the cases.

Main plant breeding programs in the country are those of extensive crops, especially winter crops. Growth and consolidation of horticultural species breeding programs has occurred in the last years, which should be extended to fruit and forest tree species. In forage species- of high importance for the country- situation is some kind of ambivalent, since important resources are allocated to this area, but number of plant breeders is relatively low for the number of species in what the programs are working on.

A main recommendation from this report is the need to strengthen plant breeding programs, in human as well as in financial resources. National policies for medium and long term periods must be discussed, designed and implemented, in order to maintain and give continuity to the breeding programs as well as to germplasm conservation, management and utilization. Also domestication activities of native valuable genetic resources should be supported.

Continuity of breeding programs is essential, even although important variation in planted area of the crop may occur. In systems that have demonstrated to be so dynamic, with changes in planted area that can be so dramatic, discontinuity of breeding programs can cost the country many years to retake its strategic position in order not to depend completely on imported seed or genetics. Such a national policies must be designed with wide participation of different involved actors (governmental and nongovernmental organizations, universities, local governments and communities, farmers, industrial sector, etc), Prioritization of breeding activities in selected crops must be made by its economic importance as well as from a food security and social importance point of view, and taking into consideration demands and needs of small farmers, especially small family farmers.

It is considered strategic to maintain national plant breeding programs that allow the development of improved cultivars, adapted to the specific conditions of the country, in species cultivated today, as well as in underutilized ones and in native species, among whom there are several ones with excellent potential (forage, fruits, timber, ornamental, medicinal species, etc.). There is need for resources in order to have a characterization (in the wide sense) of local genetic resources, and its utilization in pre-breeding activities.

Breeding activities, either developed by public or private institutions must be strengthen in a sustained way at the national level. Due to the fact that in Uruguay, plant breeding task mainly depends on public research and teaching institutions, these must dispose required resources that assure the continuity of the programs, and not rely on projects that normally have duration of two to three years, limiting funds to that period. Anyway, model used in some crops, like National Board by crops to do public-private collaborative research (or integrated work with agro industrial chain, like in rice) could be extended to other species.

International support is basic in order for developing countries to give the necessary continuity to their plant breeding programs, since their limited capacity to maintain those programs puts their gene pool at risk. That diversity that national programs collaborate to maintain may play an important role for agriculture in other parts of the world, and the best way to maintain that gene pool and its variability, is to do so in the place where they were adapted and selected, both, by nature or by man. Similar situation occurs with achievements obtained by those national programs.

If developing countries do not have continuous and strong plant breeding programs, utilization of germplasm by those countries will decrease more and more and the breach between developed and developing countries will continue growing. Facilitating and regulating access to germplasm will be of little use if there is not a real utilization of germplasm by the global community, and not only by the strongest breeding programs. If that equitable utilization is not promoted, the global system in general, as well as the Multilateral System agreed under the International Treaty on Plant Genetic Resources for Food and Agriculture will lack content.

Identification of strategic alliances with different countries, institutions and organizations that have similar visions of the topic, regional as well as international ones is of the utmost importance for our country. It is especially important to capitalize regional capacities through participation in regional programs that allow for joint methodological developments and research projects.

For the private sector in Uruguay, facilitating access to germplasm is of high priority, as well as promoting training programms on conventional breeding methods; facilitating access to new biotechnological tools is also prioritized.

Facilitating germplasm exchange is very important for the country, being with CG Centers or other organizations or institutions, keeping reciprocity relationships with them, and maintaining capacity to work and co-participate in the research teams that develop the exchanged germplasm. Close collaboration with programs and centers in other countries are desired. CG centers could also collaborate through new methodologies and techniques, in particular molecular ones. Uruguay could collaborate with adapted germplasm of food crops for other developing countries. Access to genetic resources must be done under the frame and regulations of Convention on Biological Diversity and the corresponding access to genetic resources legislation. Effective utilization and development of genetic resources that are conserved at national banks must be made, as well as use of local germplasm must be maximized.

Another relevant recommendation refers to the need for harmonizing genetic enhancement and biotechnology developments in a way that do not negatively affect plant breeding activities. Academic and technological development have a high impact on institutions and researchers decision of getting involved in projects which main objectives are genetic enhancement and biotech activities. These objectives are highly desirable, but can not be developed from a reduction in human and financial resources allocated to conventional breeding, since at the end, it is from conventional plant breeding programs that new cultivars for production are obtained and released.

In general, need of releasing cultivars in the least possible time makes difficult the use of basic germplasm by plant breeding programs, due to the time and costs that takes pre-breeding process. In order to improve utilization of germplasm is essential to characterize and properly document information on the collections, making that information friendly accessible through an adequate data base. Also the necessary interfaces between germplasm collections and their utilization by plant breeding programs through the new available tools, like biotechnology and bioinformatics need to be developed. Capacitating breeders and biotechnologists to effectively implement this interface is essential. International support is needed in all this process.

From the point of view of food security and sustainability of productive systems, the country must introduce new species in its production systems. That measure will permit to face in a better situation climate change risks. In order to do that, domestication and breeding of native species is a tool that the country must use and capitalize as a differential element. Important and continuous support for the characterization and evaluation of the new species are required, as well as basic studies: reproductive biology, seed physiology, propagation methods, etc. These aspects are indispensable for its cultivation and posterior inclusion in the production systems of the country.

A greater diversification will contribute as well to give sustainability and new productive alternatives to small and family farmers, contributing to their food security and a better quality of life. A better exploitation of the richness that the country still has on local varieties of introduced and native species will also contribute to give better alternatives to small farmers, as well as to face eventual extreme climatic events. Even although in many zones local varieties have been substituted by introduced cultivars, they still can be rescued, in order to restore productive systems in several regions of the country with these types of varieties with wide adaptation. A higher participation of farmers through participative breeding will also assure to obtain cultivars that respond to their interests, needs and requirements. This process must also be matched with the development of programs directed to add value to the products result of a participatory breeding process, through work around marketing issues, quality labels or stamps, etc.

It is very important to reaffirm and support human resources development and capacitating process, including creation and consolidation of collective instances that allow for national breeders to exchange knowledge, opinions and different visions. In this sense, different *fora* must be implemented at different technical and political levels of decision, including different governmental authorities, in order to introduce, disclose and spread the relevance of having national plant breeding programs in support to national production.

CHAPTER 6. SHORT DOCUMENT TO POLICY-MAKERS

Main recommendations arising from an analysis of the surveys answered by public institutions and private companies that carry out plant breeding activities in the country are the following:

- It is considered strategic to maintain national plant breeding programs that allow development of improved cultivars, adapted to the specific conditions of the country, in cultivated species of economic interest as well as in species important for food security and small and family farmer agriculture. Such national policies must be designed with wide participation of different involved actors (governmental and non governmental organizations, universities, farmers, industrial sector, etc),

- From the point of view of food security and sustainability of productive systems, the country must diversify its production through the introduction of new species and utilization of greater genetic diversity. Diversification will contribute to decrease diseases and pests risks, as well as to adapt to and diminish climate change effects.

- A greater crop diversification also will contribute to the generation of new productive alternatives for small family farmers, contributing to their food security, food sovereignty and a better quality of life. More farmers' involvement in participative breeding programs is an interesting tool to assure obtaining cultivars that respond to their interests and needs.

- Domestication and breeding of native species is a tool that the country must use and capitalize as a differential element. It is recommended widening and strengthening breeding programs in these species, being among them several ones with high potential (forage, fruit trees, forest trees, ornamental, medicinal

- An important element to take into consideration is that closing plant breeding programs when reduction in area occurs, as it happened during the 90’s with the soybean breeding program must be analyzed carefully. The cost that later could cause the country could be very high. Breeding activities are cumulative, and its closing can cause many years of delay. Similar situations have occurred in other crops, where also the country depends almost totally on imported seed or genetics.

- Plant breeding activities carried out by public and private national institutions must be strengthening in a sustainable way. Due to the fact that plant breeding activities in Uruguay mostly depends on public research and teaching institutions, they must have resources that assure continuity of such programs instead of depending on short or medium term projects.

- In order to strengthen plant breeding programs a national policy that guaranty their continuity and growth must be developed. This policy should also contemplate that national agencies of research and innovation include the thematic in their calls for project proposals.

- Identification of strategic alliances with different countries, institutions and organizations that have similar visions of the thematic is of utmost importance for our country. These alliances could be at a regional as well as the international level. It is especially important to capitalize regional capacities through participation in regional programs that allow for joint methodological developments and research projects. International support to give continuity to national plant breeding projects is basic.

- In a national policy of strengthening of its plant breeding programs, the capacity to retain, increase and capacitate its human resources is vital. To support and reaffirm national capacitating programs, as well as obtaining scholarships that facilitate utilization of regional and international programs, will permit growth, development and improvement of Uruguayan plant breeder’s capacity.

- As part of this strategy, a collective of plant breeders, like an Uruguayan society of plant breeders or similar figure is seen as necessary, in order to facilitate periodic exchange of opinions among them at different level. Also in this sense, different *fora* must be implemented at different technical and political levels of audience and decision, including different governmental authorities, in order to introduce, disclose and spread the relevance of having national plant breeding programs in support to national production.

- Use of new biotechnological tools as support of plant breeding programs and multiplication of cultivars should be extended and intensified. Integrated capacitating approach of both biotechnologists and plant breeders is essential in order to improve the integration of both disciplines to potentiate its use and capacity.

- Utilization of local genetic resources as well as germplasm conserved in the local and national gene banks by plant breeding program is necessary. Also is of the utmost importance to concrete a national legal frame that regulate access to national genetic resources and associated knowledge, innovations and practices that give sense and value to those genetic resources and its use. Such a legal frame will implement mechanisms to regulate access and participation in benefits derived from its utilization.

- In order to improve the utilization of available germplasm of national banks, characterization and documentation of collections is basic. That information should be in a friendly accessible way through an adequate data base. Also the necessary interfaces between germplasm collections and their utilization by plant breeding programs through the new available tools, like biotechnology and bioinformatics need to be developed. Capacitating breeders and biotechnologists to effectively implement this interface is essential. International support is needed in all this process.

- Close collaboration with programs and centers in other countries are desired. CG centers could also collaborate through new methodologies and techniques, in particular molecular ones, and in training activities.

- Facilitating germplasm exchange is very important for the country, being with CG Centers or other organizations or institutions, keeping reciprocity relationships with them, and maintaining capacity to work and co-participate in the research teams that develop the exchanged germplasm.

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