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REVIEW

Genetic improvement and agribusiness in Brazil

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ABSTRACT - Genetic plant breeding has significantly contributed to the increase of grain and other products' yield, to reduced investments, and to the incorporation of new areas in Brazil. The performance of the agribusiness over the last decades has reflected this contribution. The main events of participation of improvement are presented here, as well as a discussion on the current tendencies in plant genetics research. Possible consequences of the lack of trained professionals in classical improvement are discussed and the deficiency of funds in this area. Emphasis is given to the exigency that progress in molecular biology must not occur in detriment of classical improvement, but rather in perfect harmony of both, for a sustained success of Brazil's agribusiness.

Key-words: genetics, contribution of improvement, soybean, maize, grain yield

INTRODUCTION

The importance of agribusiness for Brazil is becoming the longer the more evident. It is the sector that generates most employment, and that also allows surplus in the balance of payment. This importance has existed since shortly after the discovery, but has only recently been acknowledged by the means of communication and, consequently, by urban Brazil. With the growing world population, the demand for agricultural products will greatly increase (Pingali 1999). Brazil is one of the few countries that has the conditions of supplying this additional demand (Borlaugh 1999). In this light, it is to be expected that the importance of agribusiness will become even more substantial in the future.

Down through the years, genetic plant breeding has provided new cultivars adapted to the country's different ecological niches and is one of the directly responsible factors for the successful agribusiness. The reason is that new cultivars do not only contribute to a greater yield per area, but also increase the tolerance and/or resistance to biotic and abiotic factors, contributing to a greater profitability in agricultural exploitation.

The aim of this revision is to compile evidence on the importance of genetic improvement for agricultural development. Annual grain producing species are brought into focus, but the points discussed here can certainly be extrapolated to perennial species that produce fruit, wood, grass, and other products. Moreover, some strategies how genetic improvement can continue contributing to society are looked at.

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500 YEARS OF AGRICULTURE IN BRAZIL

Soon after the discovery, the expeditions that arrived in Brazil introduced some important cultivated plant species. There are reports, for instance, that wheat and sugarcane were introduced as early as 1532 (Table 1) in Capitania of São Vicente, nowadays State of São Paulo. Coffee came later, in 1727, to the northern region of Brazil.

Due to the genotypes x environments interaction, which is presently well-documented, the adaptation of the introduced cultivars was not immediate. The persistence of the first immigrant farmers was the starting point so that some years later these species do not only provide for the internal consumption demand, but for exportations as well. It is frequently believed that the gold exports during the three centuries of Portuguese domination were the main source of the country's wealth. However, there are reports that the devises from sugarcane were a lot more meaningful. The value of the Brazilian production of this product is estimated at 300 million pound Sterling, while that of minerals was less than 200 million during the period of the Portuguese colonization (FAPESP 2000). Later, with the comedown of sugarcane, the entrance of resources into the country was maintained by the ascension of rubber, cacao and, mainly, coffee. The migration of coffee to the southeastern region led to the emergence of new towns and cities, instigated railway constructions and generated, above all, income. It came to the point that during several years about 70% of the Brazilian export revenue was generated by coffee (Agroanalysis 2002, page 5).

Deep changes set in at the end of the 19th century. The vision of Dom Pedro II, who proved to be an exceptional statesman, is worth mentioning. He anticipated that the country would only be able to develop by science, technology, and education. Among his most momentous deeds are the creation of the Agronomical Station of Campinas, which gave rise to the Agronomical Institute (IAC), and of the first school of Agriculture and Veterinary Medicine in Rio de Janeiro. Other important institutions of higher education were founded at the onset of the 20th century (Table 1). They were followed by several others, which doubtlessly play and have played a vitally important role in the actual success of agribusiness.

Besides the IAC, some other research institutions were founded at the very beginning of the 20th century. Among them was the Serviço Nacional de Pesquisa Agrícola in 1940 (Table 1), which coordinated agricultural research in the country for some years. By and by, this organ was substituted by others, until it was replaced by Embrapa in 1974. This public enterprise modified the research philosophy and intensified the process of training researchers.

For the support of research in all areas, the foundation of the Conselho Nacional de Pesquisa (CNPq) in 1951 was fundamental. It was backed up by other research furtherance institutions, among them the state research foundations.

The implantation of post-graduation courses in 1963 is worthy of note. Table 2 displays the record of agronomy post-graduation courses with main field of activity in Genetics and Plant Breeding. Currently, there are 460 scientists with a PhD's degree in the area. Besides developing research, these programs allowed a speedy qualification of a large contingent of new professors and researchers. Consequently, the sector of Genetics and Plant Breeding has made enormous progress in the last 40 years. This was fundamental to make Brazil a world reference in tropical agriculture.

Table 1. Milestones for the development of agriculture in Brazil

Event	Year
Introduction of wheat and sugarcane	1532
Introduction of coffee	1727
Foundation of the Agronomical Station in Campinas – IAC	1887
First College of Agriculture and Veterinary Medicine	1898
Advanced Agricultural School Luiz de Queiroz – ESALQ	1901
College of Agriculture Lavras – UFLA	1908
College of Agriculture Viçosa – UFV	1927
Agronomical Institute of Minas Gerais	1930
Creation of the first seed company in Brazil – AGROCERES	1938
National Service of Agricultural Research – SNPA	1940
National Research Council – CNPq	1951
Initiation of Post-Graduation courses – ESALQ	1963
Creation of the State Research Foundation – FAPESP	1962
Creation of the Brazilian Seed Producers Association – ABRASEM	1971
Brazilian Agricultural Research Corporation – Embrapa	1974

Table 2. Relation of Agronomy courses/faculties with main focus on Genetics and Plant Breeding

Post-Graduation Course	Institution	Local	Year of introduction		Number of Breeders	
			MSc.	PhD	MSc.	PhD
Genetics and Plant Breeding	ESALQ	Piracicaba	1964	1970	384 [1]	278 [1]
Genetics and Plant Breeding	UFV	Viçosa	1976	1979	293 [1]	125 [1]
Genetics and Plant Breeding	UFLA	Lavras	1986	1995	143 [1]	38 [1]
Plant Breeding	UFG	Goiânia	1985	1985	76	15
Genetics and Plant Breeding	UNESP	Jaboticabal	1985	1996	92	5
Genetics and Breeding	UEL	Londrina	1989	-	79	-
Plant Breeding	UEM	Maringá	1995	1999	-	-
Plant Genetic Resources	UFSC	Florianópolis	1996	-	46 [1]	-
Plant Breeding	IAC	Campinas	1998	-	12 [1]	-

[1]Data of 2001

POPULATION GROWTH AND GRAIN YIELD IN THE LAST 40 YEARS

The population growth rate in Brazil in the last century was expressive. Between 1960 and 2000, for example, the increase was 2.42 fold (Table 3). This fact called for enormous efforts in food production to supply the internal market and the exportations.

Data of grain yield and the cultivated area from 1980 on are presented in Figure 1. This period was chosen, since it shows the result of some of the events listed in Table 1; that is, the result of the work of the country's first qualified breeders and six years after the foundation of Embrapa. Note that the cultivated area remained practically the same in this period, while the grain yield increased spectacularly. Of course, several factors led to this expressive increase, as for example: the endeavor of the Brazilian farmers and the service of rural assistance by public and private companies. Besides, novel cultivars, released nearly every year and substituting the earlier favorably, were decisive.

GENETIC PROGRESS BY CLASSICAL IMPROVEMENT IN BRAZIL

There are countless reports on the powerful genetic progress in nearly all cultivated species in Brazil. Vencovsky and Ramalho (2000) described some of the obtained contributions. The case of soybean is cited as example. Figure 2 presents the production of this leguminous. Note that until 1960, the production was rather irrelevant. The cultivation was concentrated in southern Brazil. Forty years later, soybean has become the grain producing species with the greatest cultivated area and is the main export product.

To explain these facts, it is important to emphasize that soybean originally comes from China and was domesticated a long time after the principal cereals (Evans 1998). It was brought to the USA in 1804 and not cultivated in vast areas for a long time because of its restricted adaptation. First references of extensive cultivation date back to 1930. In Brazil, the situation was similar. There are reports on its introduction in 1882, where cultivation was restricted to the southern states until 1960 (Sediyama et al. 1999).

Table 3. Brazilian population from 1960 to 2000

Years[1]	Millions of inhabitants	%
1960	70.07	100
1970	91.14	130
1980	119.00	170
1991	146.82	209
1996	157.07	224
2000	169.79	242

[1]www.ibge.gov.br

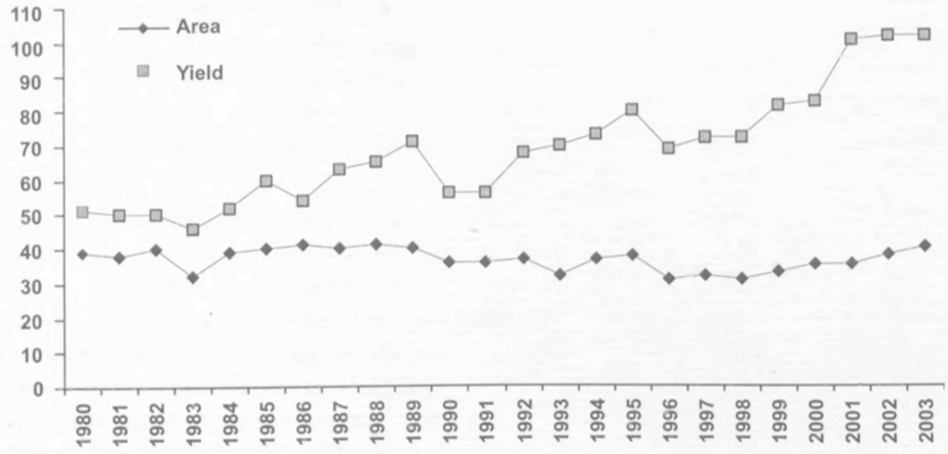

Figure 1. Grain yield and cultivated area in Brazil from 1980 to 2003

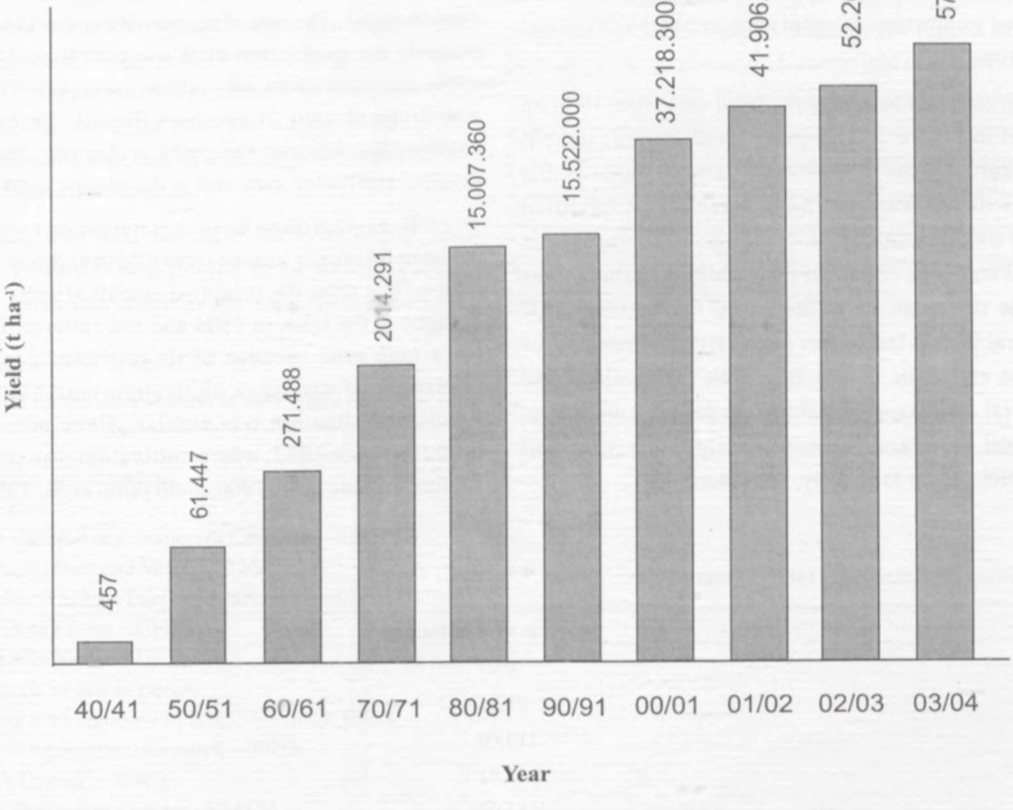

Figure 2. Evolution of the soybean grain yield in Brazil from 1940/41 to 2003/04

The primitive soybean cultivars were adapted to conditions of high latitude. When grown in lower latitudes, where the photoperiodic amplitude is smaller, i.e., the variations between the shortest and longest day are very small, flowering sets in earlier and, consequently, the growth period is shorter. As a result, the plants grow and produce little. This was the limiting factor for an expansion of the soybean crop in the savannah of Brazil, the central west and northern regions of the country.

To solve the problem, it was necessary to develop plants without sensitivity to the length of the day. Soybean has a development phase known as juvenile period. Flowering is only induced in the plant after completing this phase. In cultivars with a long juvenile period, the flowering sets in later enabling economical soybean cultivation in low latitude regions. Breeders introduced alleles of a long juvenile period from imported germplasm into existing Brazilian cultivars. This process was quite fast and efficient, since the genetic control of this trait is rather simple (Bonato 1989, Moro et al. 1993).

The success of the expansion of the crop, however, did not depend only on this trait. It was necessary to obtain plants that were more tolerant to heat and to conditions of soil fertility prevalent in regions under savannah vegetation. In this last case, the selection work realized with *Rhizobium* stirps adapted to cultivation conditions in savannah soils is worth mentioning. The interaction *Rhizobium* x soybean x environment was broadly documented and as upshot, nitrogen fertilizer is presently not used in soybean crop. Such an effect of research on agribusiness is enormous. It is estimated that for a soybean yield of 18 million hectares in the crop year 2003/2004, Brazil saved nearly 1.4 billion dollars - the value of at least 3.6 million tons of nitrogen fertilizer (Furtado 2004).

More recently, with intensified cultivation, problems of biotic stress, especially pathogens, are growing, but the results by obtaining resistant cultivars to these pathogens have been very satisfactory. Genetic improvement is doubtlessly one of the chief responsible for the growth of soybean cultivation (Figure 2).

FUTURE OF IMPROVEMENT IN BRAZIL

Although the birth rate in Brazil has been strongly declining, it is still high and goes hand in hand with the increased average life expectancy of the population. For the next years, the population is expected to cross the 200 million line. This fact together with the expectation of an increased *per capta* income will require an even greater grain yield than in the past. Is this possible? Yes, certainly. Firstly, it can be argued that this is perfectly feasible, expanding the cultivated area. Brazil still has over 100 million hectares fit for agriculture and animal husbandry, a worldwide unrivalled situation. It must, however, be made it clear that it would be possible to meet the grain demand without having to incorporate new areas, that is, without pushing the agricultural frontier any further, since, despite the great success in agribusiness, the grain productivity of most species in Brazil is still low. The technology is available to raise productivity greatly. Some aspects, discussed in the following, should be taken into consideration.

The agrarian structure in Brazil is very diversified, but can be grouped in plantation, family, and other systems. Regarding the area coverage, the plantation system covers 68%, families 30%, and others 2%. In the production value, 61% come from the plantation, 38% from the family, and 1% from other systems. Of all farmers, 11% are plantations, 86% families, and 3% other groups (Agroanalysis 2003). There is growth potential for productivity in all these classes, particularly in the family system. There are some reasons for this expectation of increase, among them the little use of improved seeds by farmers in family systems (Table 4). Simply by facilitating the access to improved seeds of all species, the grain yield would certainly rise tremendously.

Taking maize as reference, there is a tendency to increase the use of single-cross hybrids (Table 5) but, nevertheless, the adoption of this kind of hybrid is still very low, well below its use in other countries. In the USA, for example, since some decades, 100% of the farmers use single-

Table 4. Utilization of controlled seeds of some species cultivated in Brazil in 2002

Species[1]	Percentage of utilization
Cotton	90
Rice	40
Common bean	10
Maize	80
Soybean	85
Wheat	90

[1]www.abrasem.com.br

Table 5. Percentage of the different seed types of maize cultivars sold in Brazil

	Crop year				
Types[1]	**1998/99**	**1999/2000**	**2000/01**	**2001/02**	**Mean**
Single-cross hybrid	20.39	27.94	30.16	33.70	28.05
Triple-cross hybrid	27.62	25.00	27.20	24.62	26.11
Double-cross hybrid	42.81	38.66	34.20	34.20	37.47
Variety	9.18	8.44	8.44	7.47	8.37

[1]Lobato (2003)

cross hybrid seeds. The expectation is that the utilization of this hybrid type in Brazil will double in the short term, which will certainly lead to increases in productivity. The greatest problem is that 30% of the farmers that do not use any hybrid seed type. For most of them, the cost of the seed is insurmountable. In this case, the public sector should have more efficient programs for hybrid seed production. These programs could feed small or medium Brazilian seed companies. This is the way Embrapa has been working, but should be adopted, furthermore, by state companies and universities.

The large companies of the maize sector are market-present all over the country. In spite of their size, their net of experimentation is insufficient to cope with the continental dimensions of a country like Brazil. The focus of public programs and of microcompanies should be the generation of cultivars for particular regions, market niches, in which the experiments could be intensively realized in these regions capitalizing on the genotype-environment interaction. This strategy would certainly induce a greater competition on the maize seed market in Brazil, as it became apparent when Embrapa Maize and Sorghum released its first hybrid, BR 201, to the market. Not only can the seed price be reduced with this competition, but what is more important, the pressure will stimulate the achievement of ever-enhancing cultivars.

Along with the need to regionalize improvement programs of public and microcompanies, producers ought to be involved in the different stages of improvement programs. There are no longer so much human and financial sources available that the help of the producers could be missed out. A structure of participatory improvement must be created, along the lines described by Dias and Resende (2001) for perennial crops, where part of the tasks are realized by the farmers. These tasks could include production and evaluation assays. This kind of approach brings farmers and breeders closer together, awakens the active participation of the producer when he sees the differences between genotypes in an assay, and ensures that the producer will not reject the program's end product.

The situation of seed production is more critical in subsistence crops, such as the common bean. In this case, the companies are not interested in improvement programs. It is necessary that the public sector produce, frequently, new lines that favorably replace the existing. The availability of these new cultivars should, furthermore, be as flexible as possible. Private seed companies could then produce and distribute them across the country. As it is, only part of the success of improvement is useful, simply because the improved seeds do not get to the farmers.

Compared to temperate regions, the environments of cultivation in Brazil are much more adverse (Paterniani 2000). Rainfall precipitations are more unpredictable, the days shorter, the soils more subjected to erosion, and the pest and disease incidence is greater. To obtain cultivars with a greater stability of production, these have to be identified in experiments carried out within the greatest possible environmental range. For the most part of the cultivated species, the decisions on which cultivar(s) is/are to be recommended, is based on a very small number of environments. It is known that the competition trials of new cultivars is the part that requires most resources and dedication of breeders. The trials are not more intensely realized owing to the scarce resources earmarked for classical improvement in Brazil. The number of breeders, for example, who work with species whose cultivated area covers over 3.0 million hectares, and, therefore, with a great economical impact, is very small. In most cases, there are less than 20 breeders. Comparing to the maize crop again, the number of breeders in the USA rose from 250 to 550 in the period from 1980 to 1990 (Duvick and Cassman 1999). These professionals carry out experiments at approximately 1000 sites and evaluate 3.000.000 of plots annually. In Brazil, the area cultivated with maize is over 12 million hectares, and the number of breeders is possibly less than 10% of the referred group of north American breeders. In many other species, the contingent of breeders is yet smaller and with, in most cases, partial dedication, mainly because the private companies have no interest to produce seeds of these species.

There is an evident reduction in the number of trained professionals in classical breeding. Even in the genetics and improvement courses, most of the students are headed for the area of molecular biology. It is necessary to make clear that the demand for professionals with formation in classical improvement is in the rise lately. It is possible to state, moreover, that the demand for professionals with this qualification does not supply the existing offer. A concern was expressed by Jones and Cassels (1995) regarding the training in classical improvement in the developed countries. According to these authors, "in the 90s, research for the development of cultivars at European and north American universities has been, predominantly, based on molecular biology and genetic transformation. Therefore, the number of universities that offer training in classic genetics and improvement, at graduation and post-graduation levels, has diminished in the developed countries, with serious consequences for society".

In an attempt to valorize the work in the area of molecular biology and, consequently, raise funds, some specialists argue that classical genetic improvement is very slow and costly and that there is no more genetic variability. Ferreira (2003), for example, mentions that the development of a new rice cultivar takes 6 to 8 years, with an average cost of some millions of Reais. If the cost were in fact so high, the expenses to obtain a new cultivar could probably only be raised for few species like coffee and soybean. Any breeder knows that the cost to achieve a novel cultivar is well below the cited 'millions of Reais'.

The aspect time to create new cultivars is relative. Once a program is installed, it is possible to establish a new cultivar every year. This happens routinely, in most improvement programs. The process is only more time-consuming if some new problem turns up, such as the occurrence of an unknown pathogen, for instance. This fact would slow down the process, since resistance sources would have to be sought and the work begun specifically for this trait. Nevertheless, this would happen anyway, even when one of the currently available techniques of molecular biology were being used.

The new biotechnological techniques should offer an enormous contribution to achieve novel cultivars. Besides offering basic information regarding the mode of genes action and thus making the classical improvement more efficient, active participation in the achievement of new cultivars, as for example, using the technologies of recombinant DNA is also possible. However, Duvick (1996) and Knight (2003) claim that it would not be a good idea to reduce or shut down the programs of conventional improvement in favor of biotechnology. Mutual support would be a lot more intelligent. We repeat once more that both areas must complement each other. In the practice, this is not happening and the lack of human, financial, and infrastructure resources for conventional improvement tends to aggravate the problem. Should this picture remain unchanged, Brazil's agriculture is going to be affected by the consequences in the medium term.

Since the promulgation of the law for cultivar protection on April 25, 1997, germplasm exchange has suffered restrictions. This fact is particularly alarming, since it involves public institutions also. It is important to highlight that nearly all species cultivated in Brazil are originally from other countries. A restriction of the germplasm flow will hamper genetic improvement in Brazil.

One of the main qualities of a breeder must be persistency. Only who dedicates his life to the solution of problems of a certain species will be fully successful. Genetic improvement is an accumulation of advantages (Rasmusson and Phillips 1997). There are no miracles; there is, however, the need of persistence to go on accumulating favorable alleles.

More than ever, breeders should be heedful to what is happening in agriculture. Knowing all about the species with which one works is fundamental. There is, however, more to it; it is necessary to evaluate the national and international market and the actual concerns of farmers and of consumers. Opposite to the developed countries, where agricultural products are subsidized and the level of improvement is already very high, Brazil of the 21st century needs to increase the productivity of its cultivated species more than ever. This increase should be attained by a reduction of the use of agricultural input, especially agricultural defensives, due to the pressure of the environmentalists. In an environment as this, is possible to anticipate that, if Brazil has a good staff of breeders who are granted resources for intensive evaluations and who know the real needs of farmers and consumers, it will be possible to generate new cultivars that allow the agribusiness to go on as the main driving force of Brazilian economy.

Melhoramento genético e agronegócio no Brasil

RESUMO - *O melhoramento genético de plantas tem contribuído significativamente para o incremento da produção de grãos e outros produtos, para redução dos investimentos e para a incorporação de novas áreas no Brasil. O desempenho do* *agronegócio nas últimas décadas reflete essa contribuição. Os principais eventos da participação do melhoramento são apresentados, tanto quanto a discussão das tendências atuais na pesquisa em genética vegetal. As possíveis conseqüências da escassez de profissionais treinados em melhoramento clássico e de financiamentos para essa área são também discutidas. Enfatiza-se que o progresso em biologia molecular não precisa ocorrer em detrimento do melhoramento clássico. Ao contrário, a perfeita harmonia entre ambos assegurará o sucesso sustentado do agronegócio brasileiro.*

Palavras-chave : genética, contribuição do melhoramento, soja, milho, produção de grãos

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