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Plant breeding at Instituto Agronômico do Paraná – IAPAR

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Abstract – *The plant breeding program at IAPAR started in 1972, soon after its foundation, and has as main objective the development of superior cultivars with high yield potential, genetic resistance to major biotic and abiotic adverse factors and good nutritional and technological quality. Over these forty years, IAPAR has made available to farmers 184 cultivars of different species, resulting in an increase in the productivity, greater availability of food, decrease in environmental impacts, addition of value to agricultural properties and life improvement of farmers and consumers. Thus, the institution fulfills its mission of generating technology, contributing to the development of agriculture in Paraná and in other parts of Brazil, since many of the cultivars developed are used in different regions of the country.*

Key words: *Cultivars yield potential, disease resistance, tolerance to edaphoclimatic adverse factors, technological and nutritional quality.*

INTRODUCTION

Genetic improvement at IAPAR began soon after its foundation, which occurred on June 29th, 1972, and it was oriented to the cultures of social and economic importance for the State of Paraná. To initiate these studies, experienced researchers were recruited, with attractive salaries, especially those from the Instituto Agronômico de Campinas - IAC. Besides all technical and scientific knowledge, these researchers brought genetic resources, which are fundamental to the development of new cultivars. These collections were subsequently enriched and used for breeding programs, which have as main objective the development of superior cultivars with high yield potential, genetic resistance to major adverse biotic and abiotic factors and good nutritional quality and technology. The improved cultivars are undoubtedly one of the most important technologies generated by IAPAR, which is easily transferred to and adopted by farmers and incorporated in different production systems.

Since 1980, when it started registers of cultivars releases, IAPAR has made available to farmers 184 cultivars of several species such as beans, wheat, coffee, corn, rice, potato,

cassava, temperate and tropical fruit, fibrous plants, green manure and forrage. It makes up an average of about six new cultivars released a year, which resulted in an increase in productivity, greater availability of food, decrease in environmental impacts, addition of value to agricultural properties and life improvement of farmers and consumers. In studies conducted by the IAPAR Socioeconomics Area, the varieties developed by this institution, since 1980, have consistently participated with substantial proportion on the occupied areas for agricultural production in the state. Paraná stands in the national agricultural scenario as the main producer of beans, wheat, oats and barley. An estimate of the contribution of IAPAR varieties in the production of the state reveals that approximately 60% of the area planted with beans in the state is occupied by cultivars developed by IAPAR. Thus, the institution fulfills its mission of generating technology, contributing to the development of agriculture in Paraná and in other parts of Brazil, since many of the cultivars developed are extensively used in different regions of the country.

The following is a brief history of the major programs, emphasizing the objectives and main results.

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Bean

The bean breeding program at IAPAR began in 1973 and has greatly contributed to the genetic gain in productivity. The main objective of this program is to develop varieties for the domestic and foreign markets with high yield potential, wide adaptation, yield stability, early maturity, upright plants and grains with good nutritional and technological characteristics. Recurrent selection, modified bulk, pedigree and mass selection methods have been employed. The recurrent selection has been used since 1998, mainly in the development of Carioca cultivars, aiming to widen the genetic basis of these cultivars and enabling the combination of desirable characteristics found in different genomic pool. Biotechnology tools have been developed or improved in order to further improve the efficiency of selection, especially for traits with low heritability or in which phenotypic evaluation demands much time or is costly, such as tolerance to edaphoclimatic adverse factors and grain nutritional quality among others. Currently, the bean AGB consists of 7480 accessions introduced from IAC, Universidade Federal de Viçosa, Centro Internacional de Agricultura Tropical (CIAT), Embrapa Arroz e Feijão and by the American Universities of Michigan, Nebraska, Wisconsin and North Dakota States. Up to now, IAPAR has made available to farmers 35 bean cultivars, and the cultivars IAPAR 81 (1997), IPR Uirapuru (2000), IPR Juriti (2002), IPR Graúna (2002), IPR Chopim (2004), IPR Colibri (2004), IPR Tiziu (2007), IPR Gralha (2007), IPR Eldorado (2007), IPR Siriri (2007), IPR Garça (2008), IPR Tangará (2008), IPR 139 (2009), IPR Tuiuiú (2010) and IPR Campos Gerais (2011) are in complete seed production by IAPAR partners from the states of RS, SC, PR, SP, MG, GO, MS and MT. The total number of basic seed of these cultivars marketed by IAPAR during the period January 2009 to August 2012 was 341,492 kg, whereas the cultivars IPR Tangará, IPR Tuiuiú, IPR Gralha e IPR Uirapuru contributed approximately with 50% of the total sales. IAPAR 81, released in 1997 and still in use by farmers, is distinguished for being upright, presenting excellent grain quality and tolerance to drought and heat, being the first upright cultivar of carioca group which exceeded the yield of Carioca cultivar. The cultivar IPR Tangará, also from carioca group, has gained significant growing areas due to the excellent market quality of the grain and resistance to diseases, especially to those in which genetic resistance is the most effective way of control, such as bacterial wilt, fusarium wilt and common bacterial blight.

Bean cultivars developed by IAPAR besides having good agronomic performance, providing increased yields and yield stability for farmers, has also brought benefits

to the consumer. One of the major contributions is the reduction of cooking time. The cultivar IPR Campos Gerais, from carioca group, which was indicated for cultivation in 2011, presents average cooking time of 22 minutes; IPR Uirapuru, 18 minutes; and IPR Tuiuiú, 17 minutes. IPR Uirapuru, besides being the bean cultivar of the black bean group which is most cultivated in the country, and being an upright plant tolerant to drought and heat, it is currently used as a standard of grain quality. Another advantage to the consumer is the nutritional quality of grains, for which it has been developed cultivars with higher protein and mineral content in grains, especially iron and zinc. The cultivars IPR Juriti, from carioca group, and IPR Tuiuiú, from black bean group, have become known for presenting average levels of iron in grains higher than other cultivars.

Winter cereals

The breeding program of wheat (*Triticum aestivum* L.) at IAPAR began in 1973 with the introduction of 5,000 genotypes from the IAC – Estação Experimental de Capão Bonito - SP and the extinct Instituto de Pesquisa Agrícola Meridional - IPEAME, located in the city of Colombo-PR. The first artificial hybridizations were performed in 1977. The breeding methods used has been the Single Seed Descendent (SSD) and modified bulk. Yield preliminary trials are conducted in Londrina (North), Ponta Grossa (South) and Cascavel (West), in the State of Paraná. VCU trials are conducted at 20 locations in four states (Paraná, Santa Catarina, São Paulo and Mato Grosso do Sul), in collaboration with the Fundação Meridional de Apoio a Pesquisa Agropecuária. The main objectives of the program are: to increase grain yield, to improve nutritional and industrial quality, to develop cultivars which are resistant to major foliar and ear diseases and tolerance to environmental stress factors, and to emphasize favorable agronomic and adaptive traits.

Nowadays, the germplasm used is of Brazilian origin and also genotypes introduced from the Centro Internacional de Melhoramento de Milho e Trigo – CIMMYT. The Active Germplasm Bank (AGB) of Winter Cereals accounts with the current availability of 3,500 accessions. Up to now, as a result of the works that have been carried out, 33 new cultivars of wheat have been released, the main ones are: IAPAR 1-Mitacoré (1980); IAPAR 6-Tapejara (1982); IAPAR 17-Caeté (1986); IAPAR 29-Cacatú (1988); IAPAR 53 (1992); IAPAR 78 (1996); IPR 85 (1999); IPR 110 (2003); IPR 118 (2004); IPR 130 (2008); IPR 144 (2009) and IPR Catuara TM (2011).

In addition, five cultivars of triticale have been released (X *Triticosecale Wittmack*), which is a cereal originated from a cross between wheat and rye, being IAPAR 23-Arapoti and IPR 111 the most important cultivars; and IPR Afrodite oat cultivar (*Avena sativa L.*) was released in 2012.

Coffee

Coffee breeding program at IAPAR began in 1972 and has achieved several goals during these 40 years of existence, as the viability of dense coffee crop with high yield compact cultivars, resistant to diseases and nematodes and different maturation groups. These cultivars were important for increasing producer income, reducing production costs and improving the quality of coffee. The viability of coffee cultivation in areas infested with nematodes by developing resistant Arabica coffee cultivars was another goal achieved by IAPAR, which presented great impact for the region of “Arenito Caiuá” in Paraná, and potential benefit to the rest of Brazil. The improvement was mainly based on the Arabic coffee germplasm Catuaí, Mundo Novo, Icatu, Sarchimor, Catucaí and Etiópia. Coffee trees carrying genes of *C. canephora*, *C. racemosa*, *C. dewevrei*, *C. liberica* e *C. eugenioides* species were also used in the breeding program of *C. arabica*.

Currently, coffee breeding at IAPAR has a germplasm bank with high genetic diversity and coffee trees with different characteristics. There are over 3,500 selections of Arabica coffee from different origins, different generations of selfing, 144 accessions of *C. arabica* from Ethiopia, around 55 cultivars and 20 botanical varieties of *C. arabica*, 60 genotypes *C. canephora*, rust races differential genotypes, ten species of coffee and six interspecific hybrids. Up to now, 13 coffee cultivars have been registered. Out of these, IAPAR 59, IPR 98, IPR 99, IPR 100, IPR 103 and IPR 107 have been released, which are widely grown in the state of Paraná. Soon, the cultivars IPR 102 (resistant to bacterial blight) and IPR 106 (resistant to nematodes and ring spot virus) will be released. In 2012, ‘IPR 100’ was released, which is considered the first cultivar of Arabica coffee (without grafting) resistant to *Meloidogyne paranaensis* and *M. incognita*.

Nowadays, coffee breeding at IAPAR aims to obtain coffee plants that present: a) high yield; b) resistance to diseases like rust, Phoma, bacterial blight, ring spot virus, necrosis and mummification of fruits; c) resistance to insects: leaf miner and berry borer d) resistance to nematodes; e) tolerance to abiotic factors such as drought, cold and poor soils; f) different fruit maturation for harvest scheduling (very early, early, semi-early, medium, semi-late, late and

very late); g) differentiated quality of beverage. Improvement methodologies have been developed to reduce the time in obtaining cultivars from 35 years to 15-20 years. The program develops joint projects with biotechnology for the development of molecular markers, marker assisted selection and transgenesis. IAPAR also develops F₁ hybrids cultivars for cloning.

Corn

The project of IAPAR, following the techniques described for the improvement of outcrossing plants, has two basic activities, which are: 1 - Improvement of populations and 2 - Development of hybrid lines.

Improvement of population uses different Recurrent Selection techniques. This activity aims at the gradual and continuous improvement of agronomic traits of populations, seeking greater adaptation, resistance to biotic and abiotic stresses, nutritional quality and yield. Initially, these populations were introduced from IAC, Escola Superior de Agricultura “Luiz de Queiroz” (ESALQ), Embrapa Milho e Sorgo and Centro Internacional de Pesquisa de Milho e Trigo (CIMMYT), or collected from farms. Currently, the formation of compounds and synthetics within the project is the main source of populations for breeding purposes. Therefore, the activity does a continuous analysis of the performance of commercial hybrids and evaluates diallel or top crosses involving varieties, hybrids and inbred lines. Improved populations are useful for obtaining lines as well as for commercial puposes, like open pollinated varieties, which today represents an alternative for some segments of agriculture and small farmers, seasons or cultivation condition of greatest risk, where hybrids cannot express their genetic potential, and organic agriculture. Since the beginning of the program, the following varieties have been released: IAPAR 15, IAPAR 26, IAPAR 50 and IAPAR 51. Currently, the varieties IPR 114 and IPR 164 are marketed. For multiplication of these cultivars, IAPAR has partners in the states of Mato Grosso do Sul, São Paulo, Paraná and Santa Catarina.

The development of corn hybrid lines began in the 1986/87 harvest, aiming at obtaining corn hybrids with superior agronomic traits and which met the needs and demands of the seed market of this culture. The main goal was to provide basic germplasm to commercial seed companies, especially for those who did not have their own breeding program. The germplasm consisted of initial compounds and improved varieties that have comprised the active bank of IAPAR Corn Program, which had been introduced especially from IAC, ESALQ, Embrapa Milho e Sorgo and

CIMMYT. In subsequent years, commercial hybrids began to be explored as a source for extracting lines, besides new compounds formed by the breeding program. As the main results, the following commercially hybrids were released: IPR 115 - simple hybrid of yellow grains; franchised to COODETEC in 2002; IPR 119 - double hybrid of white grain, franchised to several small businesses in 2003; and IPR 127 - simple hybrid of white grains, also franchised to several companies in 2005.

Rice

The breeding of upland rice began in 1975, with some segregating populations introduced from IAC, in 1976/1977, in the F₄ generation, of which it was selected some promising lines, highlighting L50, which was recommended in 1983 as 'IAPAR 9'. The program's main objective has always been high yield potential, resistance to drought and disease and technological quality of grain. In the last twenty years there has been a noticeable decrease in rice planted area in the State. This fact is related to depletion of pastures or clearing areas where rice preceded the soybean crop. From 2010, there has been a decrease in the activities of rice breeding program due to the retirement of researchers responsible for conducting the activities. In all, IAPAR has released 11 rice cultivars, highlighting IAPAR 9, which was donated 20 years ago to the Chinese government, during the ECO-92, being used by Chinese farmers until today. It presents high yield potential, around 10 t ha⁻¹, wide adaption and moderate resistance to rice blast fungus. It is important to mention 'IAPAR 63', the first upland rice variety with fine long grains, and resistant to rice blast fungus, and IAPAR 64', which presents excellent cuisine quality. Currently, with the restriction of the use of wetlands, high costs and availability of water for irrigation, rice production will increasingly depend on the production of upland rice. Three lines of early cycle (average of 90 days) are in pre-registration in the RNC/MAPA, which will facilitate the inclusion of rice in different production systems.

Potato

Potato breeding started in 1985 with the introduction of clonal families originated from the Centro Internacional de la Papa (CIP), in Peru, intermediated by Embrapa Vegetables. These populations originated from two cultivars, IAPAR 82 - Araucaria, released in 1997, and the clone PHO 15, which is in pre-registration in RNC/ MAPA, under the name of IAPAR Cristina. Both are resistant to foliar diseases; therefore, they are adapted to the organic system. IAPAR has a partnership agreement with Embrapa Clima Temperado for introduction of clonal populations for regional selection,

and it has been receiving annually from 6 to 12 thousand minitubers of crosses made in Pelotas, Brazil, since 1999, in which selection is made aiming commercial aspects, hardiness, productivity and dual purpose (fresh consumption and industry). Of the approximately 120,000 clones which have been released, it was selected the clone PCD AG03-11, which has been registered and protected in RNC and SNPC/MAPA, for a joint release with Embrapa, under the name of BRSIPR Bel.

Cassava

Cassava breeding program began in 1982 with the introduction of materials from IAC, Embrapa Mandioca e Fruticultura, Empresa de Pesquisa Agropecuária e Extensão Rural de Santa Catarina (EPAGRI), and especially with the collection of materials from farmers of Paraná. The program's objectives are: a) the development of table and industry cultivars resistant to major diseases such as bacterial blight (*Xanthomonas campestris* pv *manihotis*), anthracnose (*Colletotrichum manihotis* e *Glomerella manihotis*) and superelongation (*Sphaceloma manihoticola*); b) the development of cultivars with high yield for industry, presenting high production of dry matter / ha and good quality starch; c) the development of table cultivars with high yield, low hydrocyanic acid, good cooking standard and high levels of beta carotene; d) aboveground that facilitates mechanized planting and cultural practices. In 1986 IAPAR released IAPAR 19 - Pioneira, which has as main characteristic the reduced cooking time, it is well-cooked during the whole year, it shows excellent standard of cooked pasta and it can be fried without prior cooking. Two new varieties are in pre-registration phase, one table and one industry cultivar.

Temperate and tropical fruit

Breeding works with temperate fruit species began in 1972 at IAPAR, mainly including the following species: apple, pear, peach, nectarine and diploid plum tree. The main objectives that guided this study were: a) environmental adaptation - due to the presence of winter in most part of Paraná, but with insufficient chill hours to meet the physiological demands of the main commercial varieties. It was necessary to develop varieties with low demand in cold, becoming this the main objective of the breeding program of temperate fruits of IAPAR; b) resistance to diseases: scab, leaf spot and apple powdery mildew, bacterial blight, rust and plum scald are the major diseases of these two species whose genetic resistance have been identified and incorporated into the development process of commercial cultivars at IAPAR c) time of production - selection of

plants with different flowering periods and different cycles of flowering and maturation, aimed at developing cultivars for better exploitation of the environment of the state, whose fruit offer tends to be between the States in the north (early) and in the south (late) and d) modification of tree size and yield - the study of modification of plant architecture has been applied in the development of cultivars of apple, peach and plum, as well as in the selection of rootstocks that have similar effects in these species. Seven cultivars of temperate fruits have been released and registered on the Registro Nacional de Cultivares - RNC/MAPA: one of peach (IAPAR 48 Ouro), one of plum (IAPAR 49 Irati) and five of apple, including the most important, IAPAR 75 Eva and IPR 137 Julieta cultivars, both with low chill time, presenting early maturation and high yield. These characteristics favor the cultivation in some regions of Paraná, in the southern and southeastern Brazil, where the available cultivars, which demand a lot of cold, are little adapted.

Another study of relevance was developed by IAPAR with citrus crop, which did not count with a proper breeding program, in which hundreds of clones and canopy cultivars and rootstocks have been evaluated, having as primary objective the selection of materials less susceptible to citrus canker due to its endemic occurrence in the state of Paraná. Another objective was to select cultivars associated with better adaptation to the ecological conditions of the state. This work, which began in 1979, has selected 32 citrus cultivars, among canopy and rootstocks, which are registered on the Registro Nacional de Cultivares – RNC/MAPA.

FIBER PLANTS

Cotton

The improvement in cotton at IAPAR began in 1974 with the introduction of a collection of genotypes from IPEAME. In order to enlarge the genetic variability, introductions were made from IAC, from the United States Department of Agriculture (USDA) and from the Universidade de Auburn - EUA.

The objectives of the breeding program are oriented to increasing yield, reducing risks and costs, increasing profit and preservation of environment and human health. It works focusing on the development of cotton cultivars adapted to different production systems and regional characteristics of the cotton industry of Paraná, prioritizing high yield potential, percentage of balance and technological characteristics of fiber, and multiple resistance to major diseases that occur in Paraná. It seeks to harmonize more than twenty-five desirable characteristics in a genotype, several of them negatively

correlated with each other, which explains the high degree of difficulty in obtaining superior genotypes in this species.

Throughout this period, IAPAR has released nine cotton cultivars: IAPAR 4 – Paraná1, IAPAR 45 – Paraná 2, IAPAR 71, IPR 94, IPR 95, IPR 96, IPR 120, IPR 140 and IPR JATAI. Although all of them have had considerable success in cultivation, some of them have had outstanding participation, providing support to the State, so that Paraná remained as the main producer of cotton for nineteen consecutive years.

Aiming at developing cultivars with greater disease resistance, the IAPAR Cotton Program emphasized the studies of inheritance involving major crop diseases. In such studies, it has been identified genes that influence in the complete resistance to four diseases. The latest study, done with *Ramularia areola*, the most important disease of cotton in Brazil - whose control has required an average of seven applications of fungicides – it was identified two genes with complete dominance. The pyramiding of these genes is at an advanced stage, and may solve a major economic and environmental problem of cotton production in the country. The next stage of this work is the identification of molecular markers closely linked to these genes.

Over the years, cotton breeding at IAPAR has consolidated formal scientific cooperation with IAC, Agência Rural (EMATER- GO) and Instituto Mato-Grossense do Algodão, and it maintains informal partnerships with several other research institutions in the country.

Ramie

In 1976, IAPAR made a partnership with the local industry of ramie fiber processing, Toyo Sen I of Brazil, starting several research lines involving the various technological aspects of the culture, including the improvement of culture in order to obtain cultivars with higher yield potential and better quality to meet the demand of producers and textile industries. As a result of this work, IAPAR has released two varieties of ramie: IAPAR 10 - TPA and IAPAR 11 – Yamamori, both obtained from populations of plants grown from seeds of Miyazaki, the most widely grown in the state at that time, through the process of individual plant selection. The main characteristics obtained in the selection were: high fiber fineness, for IAPAR 10 – TPA, and high yield capacity, for IAPAR 11 - Yamamori

Paraná was the main national producer of ramie, estimating that 100% of the product offering were from Northern region of the State. The planted area with this culture in the agricultural year 1982/83 was approximately 4,100 ha, result-

ing from a reduction in area that occurred due to problems with prices and to yield decrease, which occurred from the lack of adequate technology and cultivars. With the shortage of the product at that time, the culture presented a new cycle, marked by a new expansion area, accompanied by an improvement in yield and fiber quality, using new technologies. Cultivars released after that period have represented an important finding for this new cycle.

Currently, the production of ramie is restricted to a small region of Londrina - PR for making strings, due to problems with labor (rural exodus and labor laws), and especially for the difficulty of mechanization, like shredding operation. Currently, due to little cultivation in the state, the released cultivars, especially IAPAR 11 - Yamamori, have been used for research in animal feeding.

Melhoramento genético de plantas no Instituto Agronômico do Paraná - IAPAR

Resumo – *O programa de melhoramento de plantas no IAPAR iniciou-se em 1972, logo após sua fundação, e tem como objetivo principal o desenvolvimento de cultivares superiores, com alto potencial de rendimento, resistência genética aos principais fatores bióticos e abióticos adversos e boa qualidade nutricional e tecnológica. Ao longo desses quarenta anos o IAPAR tem disponibilizado para os agricultores 184 cultivares de diferentes espécies, resultando em aumento de produtividade, maior disponibilidade de alimentos, redução dos impactos ambientais, agregação de valor para as propriedades agrícolas e melhoria de vida dos agricultores e consumidores. A instituição cumpre assim com sua missão de gerar tecnologia contribuindo para o desenvolvimento da agropecuária paranaense e nacional, uma vez que muitas das cultivares desenvolvidas são utilizadas em diferentes regiões produtoras do país.*

Palavras-chave: *Cultivares, potencial produtivo, resistência a doenças, tolerância a fatores edafoclimáticos adversos, qualidade nutricional e tecnológica.*