Twenty Six Years of Wheat Breeding Activities at IAPAR

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ABSTRACT

The description of the IAPAR wheat breeding program in its 26th years of existence aims at presenting its major achievements giving an idea of the program size, breeding objectives and methodology. A germplasm flow chart will show the steps by which the populations have to follow starting either from crosses or from introductions until an advanced inbred line can be evaluated and elected as a new cultivar. A list of 23 wheat cultivars released by the program along with their pedigrees is presented as a special contribution. From the recent developed cultivars, data on grain yield, agronomic characteristics, technological quality and kernel properties are presented. The pedigree description for IAPAR 53 and the development of IPR 85 are presented in some detail. New biotechnological tools to help wheat breeding become more efficient are discussed.

KEY WORDS: *Triticum aestivum*, Breeding, Grain yield, Quality, Germplasm.

INTRODUCTION

Wheat (*Triticum aestivum* L.) is one of the largest consumed cereal by human kind, representing approximately 32% of the world grain production. Its unique combination of proteins and capacity to produce light leavened and tasty products makes it very attractive to the consumers. It was probably the first cereal to be domesticated and cultivated favored by the possibility of long term storage.

In Brazil, wheat has an important participation in the population diet and the consumption has increased with the urbanization process. Although the country has extensive areas suitable for the wheat production, it is the second largest importer of the cereal in the world. Nowadays we are import 75% of our consumption which totals 9.5 million tons. This makes us dependent on this important staple food that needs to be produced in other countries. With the creation of MERCOSUL, wheat has become a trade issue with other countries, especially with Argentina. Our economy has been strongly affected by this reality. Good part of the capital spent with importation could be used to stimulate regional economy (Hubner, 1999).

The state of Paraná is the largest wheat producer of Brazil, contributing with 60-70% of the total production. The average yields range from 1.7 to 1.9 tons.ha^{-1}. The IAPAR Wheat Program nowadays known as the Winter Cereals Program, started in 1973 with the introduction of nearly 5,000 genetic entries, development and selection of hybrid populations and carrying out yield trials to obtain adapted cultivars to the varying climatic and soils conditions of Paraná state. In 1976, the Wheat Program was expanded by a partnership with Embrapa Trigo and COODETEC (before CNPTrigo/Embrapa and OCEPAR, respectively). This new partnership gave rise to the Integrated Plan of Wheat Research in Paraná, from which resulted in an annual indication of several cultivars, sowing dates, and subsidies for the new wheat crop regionalization in the state (IAPAR, 1984).

Since then, several technologies have been developed for soil management, the establishment of criteria for tolerance to acid soils as a parameter for cultivar indication, the integrated management of diseases and insects, adequate sowing dates, rational use of fertilizers, and crop rotation. The continual development of new technologies according with actual needs has also been emphasized. The state cultivar evaluation through

the regional yield trials network is still done in cooperation with the partnership mentioned earlier. Although, the breeding programs are conducted separately by each institution.

The process of developing cultivars is long and costly, taking approximately 10-12 years to breed and disseminate a new cultivar. The use of new biotechnologies such as molecular markers (Riede and Anderson, 1996) and the production of double-haploids (Scheeren et al., 1999) might contribute to increase the efficiency and reduce the time for new developments.

IAPAR´s research program has made 23 wheat cultivars available to farmers which are appropriate to different regions in Paraná and also to some regions in Mato Grosso do Sul and São Paulo.

BREEDING PROGRAM

The IAPAR wheat breeding program, in its 26th years of existence, makes annually hundreds of crosses between adapted cultivars and sources of necessary traits for the cultivation and industrialization of the new wheat. The state of Paraná is located in a transitional zone as far as climate and soil properties are concerned. This makes the breeding tasks more difficult, requiring sometimes the development of more regionally adapted cultivars in order to be more competitive and superior to the ones being presently used.

In the last years, quality has become paramount and dependent on the segment, which is involved in the production. To the farmer, superior quality is represented by desirable agronomic characteristics such as high yield potential with good hectoliter weight, good resistance to diseases, which results in economic profitability. To the miller, however, quality means uniform kernels with high flour extraction, and low ash levels. As for the baker, the flour must have high water absorption, good mixing tolerance, average gluten strength and high protein content, which represent balanced factors with potential to produce bread with good rheologycal characteristics. Finally, to the consumer, the last element in the production chain, the concept of quality embraces a larger issue in which palatability and appearance of the elaborated products are fundamental. In each case, it is expected that the desirable wheat will produce a bread with high volume, adequate external and internal texture and high nutritional value.

Breeding for technological quality is an important objective of any project aiming at developing new cultivars suitable for the milling and baking industry as well as at supplying flour suitable for other products such as pasta, crackers and cookies.

RESEARCH OBJECTIVES

The major objectives of wheat breeding for the state of Paraná are listed below:

1. Breeding for yield increase
   - Yield components (heads/m^2; kernels/ head; kernel weight; etc)
   - Yield stability and wide adaptation

2. Breeding for quality
   - Selection for grain filling, hardness and color
   - Evaluation of gluten strength in early generations through the MS-SDS

   Sedimentation test.
   - Rheologycal evaluation to indicate industrial uses of advanced breeding lines
   - Determination of falling number which indicates levels of preharvest field sprouting
   - Determination of amount and quality of proteins
3. Disease resistance
   - Foliar diseases: mildew, leaf rust, leaf blight and bydv
   - Head disease: fusarium head blight

4. Soil toxicity and nutrient efficiency
   - Tolerance to Al and Mn toxicities
   - Efficiency of P extraction system

5. Environmental stresses
   - Tolerance to drought, heat and frost
   - Resistance to preharvest field sprouting

6. Agronomic traits
   - Semi dwarf plant height and good straw strength
   - Early to intermediate maturity (120-130 days)
   - Good tillering capacity
   - Shattering resistance

BREEDING METHODOLOGIES

Breeding methodologies such as "pedigree", "modified pedigree" or "modified bulk" have been used in the research program, with selections in both acid and non-acid soils. Selection of plants and breeding lines followed by Preliminary yield trials have been carried out in Londrina (Region 6 – North), in Palotina (Region 7 – West), and Ponta Grossa (Region 8 – South) of the state of Paraná. A network team has evaluated recommended and potential new cultivars in approximately 10 locations on different seeding dates.

Every year a Crossing Block is established in which the potential parental genotypes are grouped according to their major traits. 120 entries, approximately, are grouped in the following major sub-blocks: 1) Yield potential; 2) Aluminum tolerance; 3) Technological quality; 4) Preharvest sprouting resistance; 5) Sources of leaf rust resistance; 6) Sources of mildew resistance; 7) Sources of leaf blight resistance; 8) Sources of fusarium head blight.

Either individual plant or bulk selections are performed on outstanding populations (within and between families) until homozygosity is achieved. Homozygosity increases by 50% in each inbreeding generation as wheat is a self-pollinated crop. Advanced lines are nominated as follows: lines IA are obtained from germplasm introductions; lines LD are lines originated from crosses and/or segregating generations selected in Londrina; and lines PG are lines developed in Ponta Grossa. The germplasm flow in the breeding program can be seen in the diagram named Germplasm Flow Chart (Figure 1) which illustrates all the major steps of a particular cross or selection until the advanced lines can be cut and evaluated in yield trials. Quality tests and seed increase are performed according to the stage the lines have reached in the program.

RECENT CULTIVARS

Yield comparison of the major recent cultivars indicated and adapted for cultivation in regions 6 (North), 7 (Central-West) and 8 (South) of Paraná in the four last years can be visualized in Figures 2 to 4. The recent cultivars are moderately tolerant to soil aluminum toxicity, an important requirement when a wider adaptation is sought as is the case of this program. The classification of the Brazilian wheat cultivars for aluminum toxicity in acid soils can be found in Sousa, 1998. Major agronomic characteristics of presently grown wheats can be observed in Table 2.

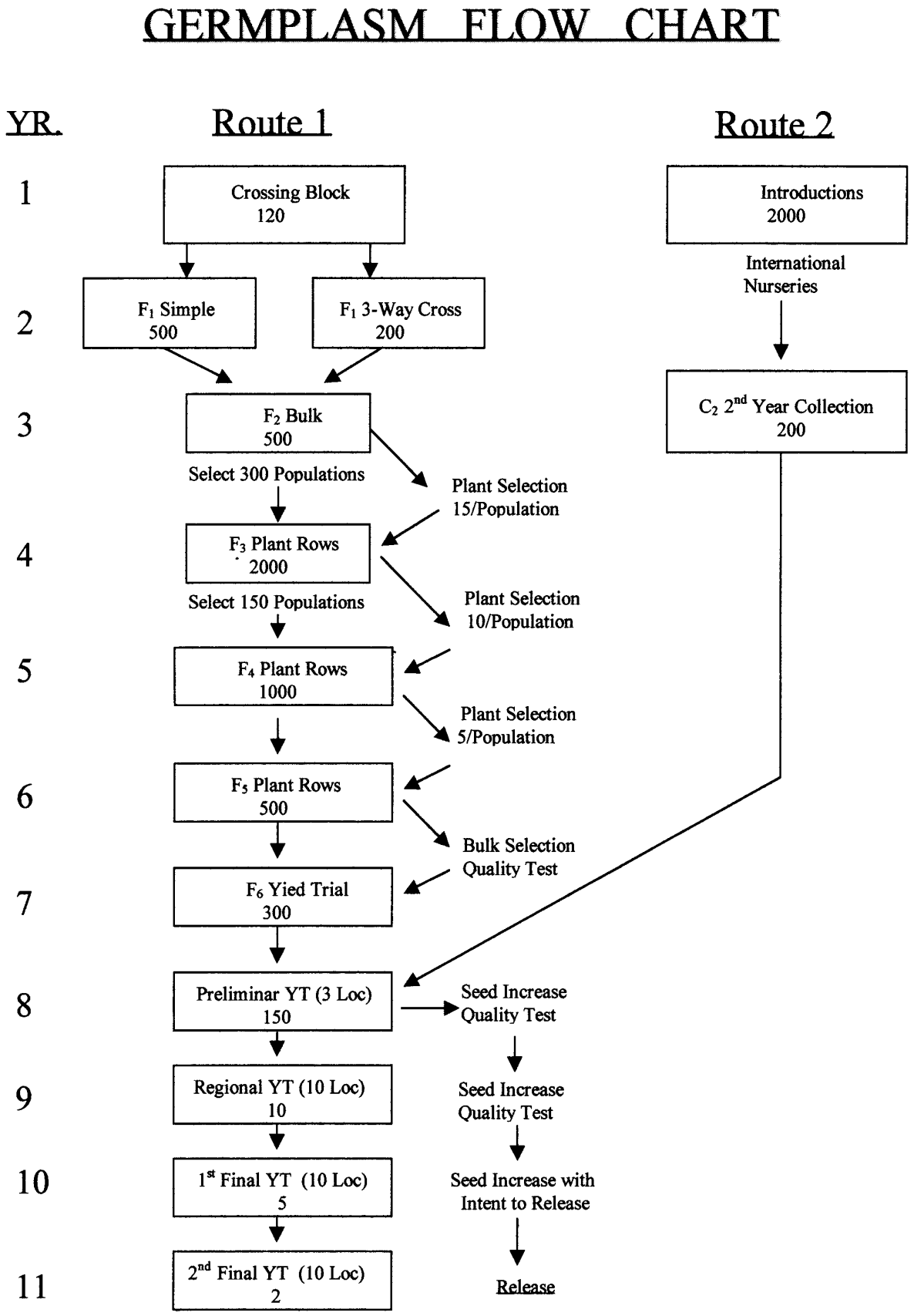

Figure 1 - Management steps in the cultivar development procedure.

The cultivars developed by the Wheat Project from 1980 to 1999 are presented in Table 1.

Table 1 - Released wheat cultivars by IAPAR's Breeding Program.

Cultivar	Line	Pedigree	Release Year
IAPAR 1 – Mitacoré	IA 783	IAS50/JARAL"S"	1980
IAPAR 3 – Aracatu	IA 787	UNKNOWN	1981
IAPAR 6 –Tapejara[1/]	LD 7835	UNKNOWN	1982
IAPAR 17 – Caeté	LD 7998	JUPATECO/BLUEJAY"S"	1986
IAPAR 18 – Marumbi[2/]	PG 8116	PF72640/PF7326/PF7065/ALD"S"	1986
IAPAR 21 – Taquari	IA 78112	KVZ//CIANO67/PJ	1987
IAPAR 22 – Guaraúna[1/]	PG 8215	CNT8/ALONDRA"S"	1987
IAPAR 28 – Igapó	IA 7959	KVZ/BUHO"S"//KAL/BB	1988
IAPAR 29 – Cacatu	IA 832	BLUEJAY"S"/JUPATECO	1988
IAPAR 30 – Piratã	LD 8249	ALD//CNT7/PF70354/3/PAT24//KAL/BB	1988
IAPAR 32 – Guaratã[2/]	PG 836	ALDAN"S"/IAS58	1989
IAPAR 33 - Guarapuava[1]	PG 83107	ALONDRA"S"/TIFTON	1989
IAPAR 34 – Guaragi[2/]	PG 8452	ALONDRA"S"/PAT7219	1989
IAPAR 40 – Mirim[2/]	LD 8552	IRN327.73/IAC5 - MARINGÁ	1990
IAPAR 41 – Tamacoré[1/]	PG 852	TIFTON/MASC//KVZ/HD2009	1990
IAPAR 42 – Ibiara[1/]	PG 866	CEP7779//MR"S"/COC	1990
IAPAR 46[2/]	PG 86136	MASC/ALD"S"//IAC 5 - MARINGÁ	1991
IAPAR 47	IA 7960	KVZ/TI//TITO"S"	1991
IAPAR 53[1/]	LD 3730	SULINO/IA7929	1992
IAPAR 60[1/]	LD 8740	BJY"S"/JUP73//TAN"S"	1993
IAPAR 78[1/]	IA 9113	VEE"S"/BOW"S"	1996
IPR 84[1/]	PG 9337	ANA75/PF7455//PF72556/3/PAM"S"/ALD"S"/KVK"S"	1998
IPR 85[1/]	LD 941	IAPAR30/BR18	1999

[1/] Indicated for soils with aluminum saturation higher than 5% (maximum 35%).
[2/] Indicated for soils with aluminum saturation higher than 5%.

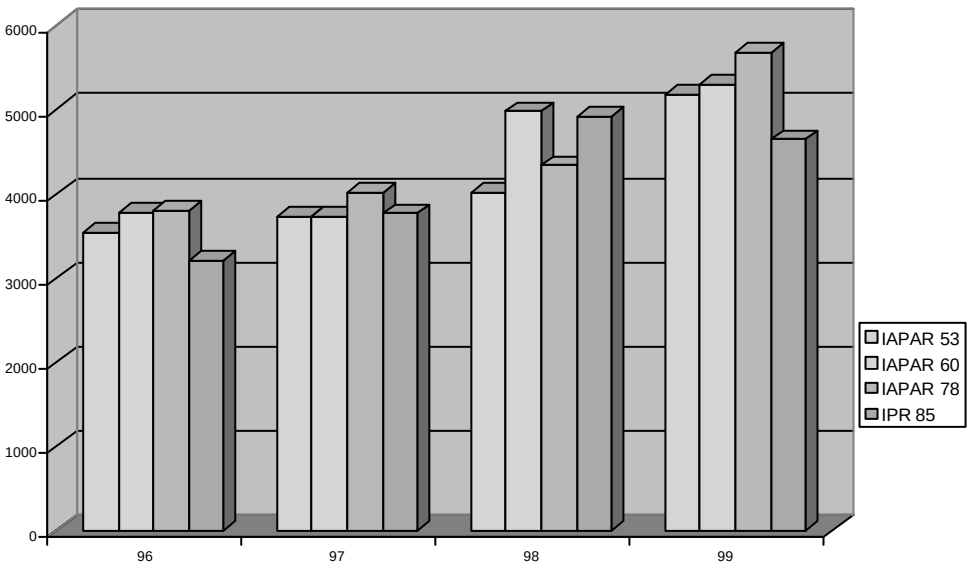

Figure 2. Average grain yield (kg.ha^{-1}) of wheat cultivars from IAPAR, period of 1996-99. Adptation Region n^{o} 6 .

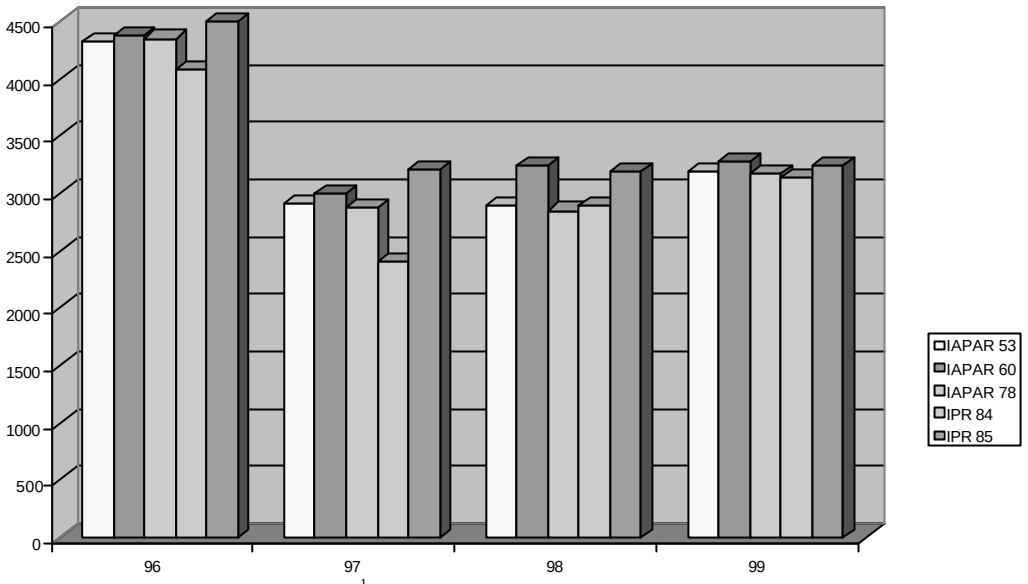

Figure 3. Average grain yield (kg.ha^{-1}) of wheat cultivars from IAPAR, period of 1996-99. Adptation Region n^{o} 7 .

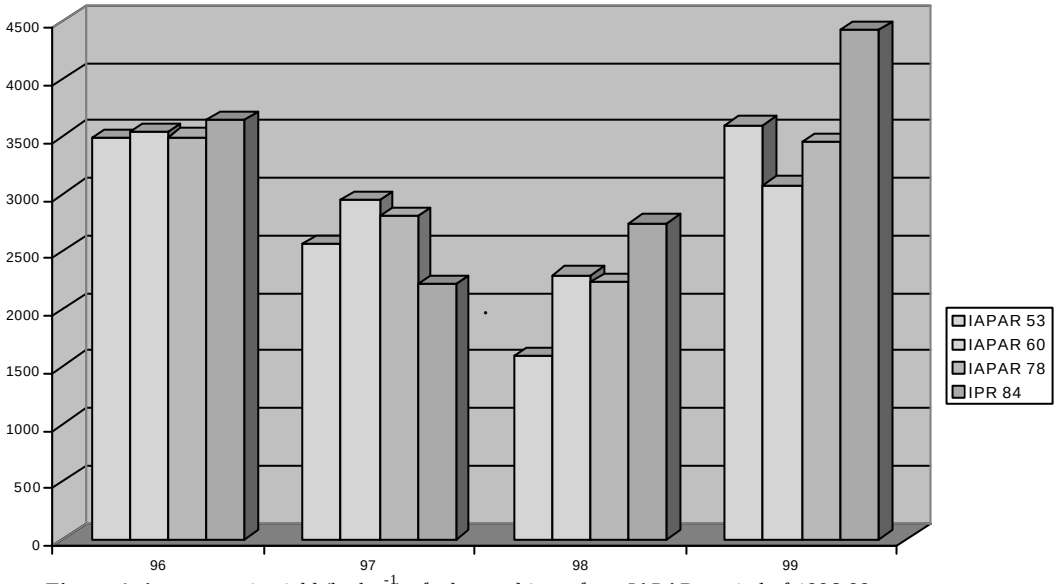

Figure 4. Average grain yield (kg.ha^{-1}) of wheat cultivars from IAPAR, period of 1996-99. Adptation Region n^{o} 8 .

Table 2 - Agronomic characteristics of wheat cultivars from IAPAR presently under cultivation.

Cultivar	Plant Height	Maturity	Aluminum Tolerance	Lodging Reaction	Shattering Reaction
IAPAR 17-Caeté	s.dwf. [1/]	early [2/]	S [3/]	R [4/]	MR
IAPAR 28-Igapó	s.dwf.	interm.	MS	R	MR
IAPAR 29-Cacatu	s.dwf.	interm.	S	R	MR
IAPAR 53	med.	interm.	MT	MS	R
IAPAR 60	med.	early	MT	MR	MS
IAPAR 78	med.	interm.	MT	MR	MR
IPR 84	med.	interm.	MT	MR	R
IPR 85	med.	early	MT	MS	MR

[1/] s.dwf. < 81 cm; med.: 82 to 97 cm. [2/] early: < 69 days; interm.: 69 to 84 days to heading stage.
[3/] S: sensitive; MS: mod. sensitive; MT: mod. tolerant. [4/] R: resistant; MS: mod. Susceptible; MR: mod. resistant.

Breeding for quality is an important priority of the project that aims at developing new cultivars suitable for the industry. Thus, the milling, bakery, pasta and cookie sectors can be supplied with appropriate flour to every product so the consumer will have diversified products. The classification of cultivars presently in cultivation is presented in Table 3.

Table 3 - Technological quality of wheat cultivars developed by IAPAR, according to the percentage class distribution and rheologycal analysis of samples.

Cultivar	Improver	Bread	Soft	Other Uses	W [1/] (10^{-4} J)	STB [2/] (min)	FN [3/] (s)	Class [4/]
	Percentage							
IAPAR 17-Caeté	75	25	0	0	302	15,3	518	Improver
IAPAR 28-Igapó	10	90	0	0	234	7,9	510	Bread
IAPAR 29-Cacatu	20	80	0	0	249	11,1	519	Bread
IAPAR 53	23	62	15	0	262	16,8	400	Bread
IAPAR 60	0	70	25	5	194	9,4	502	Bread
IAPAR 78	5	60	35	0	204	6,7	436	Bread
IPR 84	17	54	29	0	236	-	410	Bread
IPR 85	83	17	0	0	377	-	491	Improver

[1/] W is the Alveograph value and STB [2/] is the Farinograph Stability, both measure the gluten strength. FN[3/] indicates the Falling number, which is related to the preharvest field sprouting. [4/] Improver: excellent quality; Bread: good quality; Soft: weak gluten.

Approximately 38% of the several seed classes available for cultivation in the year 2000 which are certified by APASEM (Paraná Seed Growers Association), are cutivars from IAPAR. Some important kernel characteristics of IAPAR cultivar´s which can help in the choice of material do be sowed, are presented in Table 4.

Table 4 - Kernel characteristics of wheat cultivars developed by IAPAR.

Cultivar	Kernel Hardness	Sprouting Resistance	Hectoliter Weight (g)	TKW [1/] (g)
IAPAR 17-Caeté	Vitreous	MR-MS [2/]	79	33
IAPAR 28-Igapó	Vitreous	S	78	33
IAPAR 29-Cacatu	Vitreous	S	78	32
IAPAR 53	Med. Hard	MR	79	40
IAPAR 60	Med. Hard	MS	79	36
IAPAR 78	Vitreous	MR-MS	79	40
IPR 84	Med. Hard	MR	77	39
IPR 85	Vitreous	MR	81	45

[1/] TKM: Thousand Kernel Weight; [2/] MR: mod. Resistant; MS: mod. Susceptible; S: susceptible.

After the enforcement of the Plant Breeder's Right Law in Brazil, the new cultivar registration will need to have a Value of Cultivation and Use (VCU) determination to ensure the seed commercialization in the country. If a cultivar protection is pursued, than a more complete cultivar descriptors form will be required from the SNPC – National Service for Cultivar Protection, associated with the Secretary of Agriculture and Provision. Regarding to cultivar indication to farmers, the state of Paraná has been divided in three major adaptation regions according to climatic and soils properties (Figure 5).

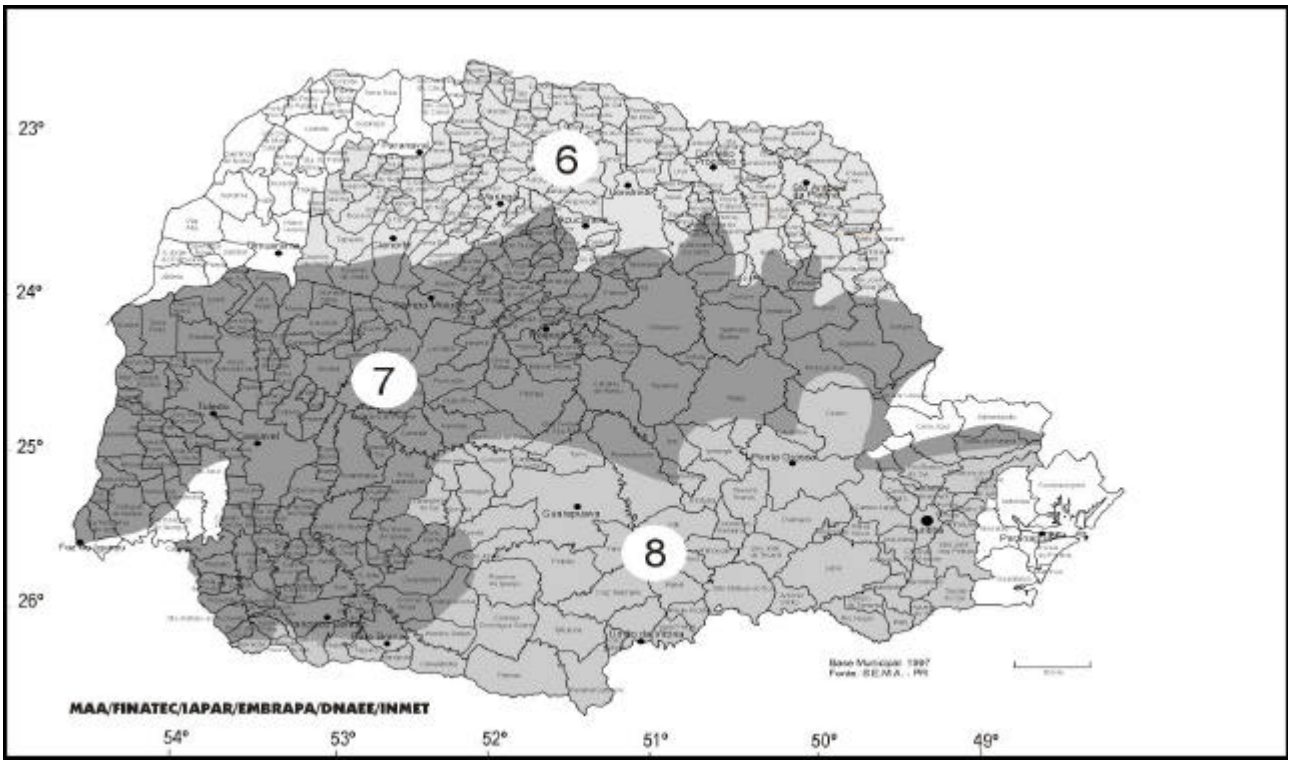

Figure 5 - Adaptation regions for the Cultivation and Use Values for Wheat in Paraná.

Two recent cultivars will be described in some detail, to show the pedigree management in the program, as well as the selection history of the populations.

PEDIGREE OF IAPAR 53

IAPAR 53 was derived from a simple SULINO/ IA 7929 cross . The pedigree of the two parental genotypes are described below according to Purdy et al. (1968).

– SULINO: PLATIFEN/CIANO "S"//GIRUÁ/ PURPLESTRW

– IA 7929: BLUEBIRD/4/SONORA 64/ ANDES 64//NADADORES/3/JARAL "S"

SULINO is a Brazilian cultivar developed by FUNDACEP, and IA 7929 is an IAPAR germplasm introduction from CIMMYT-Mexico. The genetic contribution of each genotype to the pedigree of IAPAR 53 can be observed in Figure 6.

It can be seen that IAPAR 53 has a major genetic contribution from Mexico- CIMMYT (59.4%), but also expressive contributions from Chile, Brazil and USA. In Figure 6, the importance of pedigree maintenance in tracing back the genetic contribution of parental genotypes and in the planning of future crosses to combine new sources of adaptative traits is shown .

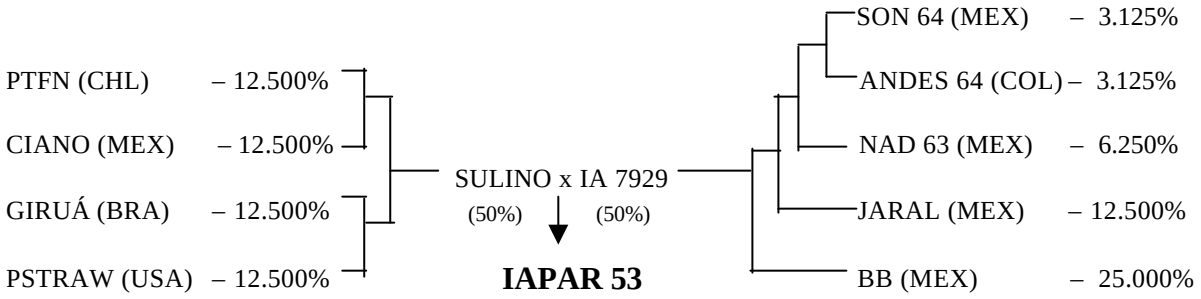

Figure 6 - Gene pool contribution to the development of IAPAR 53.

Development of IPR 85 wheat

1. Genetic Origin: The cultivar IPR 85 was originated from a simple cross between IAPAR 30 and Trigo BR 18 – Terena made in 1987. The pedigree is described below:

IAPAR 30/Trigo BR 18 - Terena – IP 8966-3L-0L-0L-3L-0L

2. Breeding Method: The breeding method used was the Modified Pedigree, with annual selections of individual plants or bulks according to generation and the field conditions, taking into consideration the biotic and abiotic stresses.

3. Description:

1987 – Year in which the cross was done; IP 8966 is the cross number;

1988 – Generation F_1: mass selection in two rows of 2 m length;

1989 – Generation F_2: third individual plant, selected from a 10.0 m² plot in Londrina (L)

1990 – Generation F_3: bulk selection from a 5.0 m² plot;

1991 – Generation F_4: bulk selection from a 5.0 m² plot;

1992 – Generation $F_{5:}$ third individual plant, selected from a 5.0 m² plot;

1993 – Generation F_6: mass selection of the population;

1994 – Agronomic evaluation in augmented design;

1995 – Preliminar Yield Trial in Londrina and nomination of line LD 941;
1996 – Regional Yield Trial in 10 locations;
1997 – First Final Yield Trial in 10 locations;
1998 – Second Final Yield Trial in 10 locations;
1999 – Release and Registration of Cultivar IPR 85;
2000 – Breeder's Right Protection (Temporary Protection Certificate Nº 00194).

The average grain yield for two adaptation regions in three years as well as the quality evaluation of IPR 85 are presented in Tables 5 and 6 respectively.

Table 5 - Average grain yield in kg.ha^{-1} and percent relation to the checks in three years and two Adaptation Regions of Paraná State.

REGION 6		**1996**				**1997**				**1998**				
CULTIVAR	**EB[a]**	**LD**	**MN**	**%**	**EB**	**LD**	**MN**	**%**	**CA**	**LD**	**MN**	**%**	**MNF**	**%**
IPR 85	2530	4040	3285	102	2520	4668	3594	106	4313	5230	4772	109	3884	106
IAPAR 29 (Ck 1)	2580	3790	3185	99	2730	4093	3412	101	4374	3965	4170	95	3589	98
BR 18 (Ck 2)	2730	3730	3230	101	2590	4110	3350	99	4522	4713	4618	105	3733	102
MEAN (Ck 1+ Ck 2)	2655	3760	3208	100	2660	4102	3381	100	4448	4339	4394	100	3661	100
Coef. of Variation	10.10	4.24			11.56	8.29			9.92	9.62				

REGION 7		1996			1997			1998				
CULTIVAR	SM	PL	MN	%	PL	MN	%	PL	MN	%	MNF	%
IPR 85	3150	4338	3744	87	3210	3210	93	3189	3189	102	3381	93
IAPAR 29 (Ck 1)	3480	4685	4083	*95*	3422	3422	*99*	3159	3159	*101*	3555	98
BR 18 (Ck 2)	3870	5235	4553	*105*	3484	3484	*101*	3078	3078	*99*	3705	102
MEAN (Ck 1+ Ck 2)	3675	4960	4318	*100*	3453	3453	*100*	3119	3119	*100*	3630	100
Coef. of Variation	3.20	7.09			9.95			8.31				

[1/] EB: Engenheiro Beltrão; CA: Cambará; SM: São Miguel do Iguaçu; PL: Palotina; LD: Londrina; MN: Mean; MNF: Final Mean; %: Percentage in relation to the checks (Ck 1, Ck 2 and Ck 1 + Ck 2).

Table 6 - Technological Quality evaluation of cultivar IPR 85.

Year	**Smp [1/]**	**HW [2/] (kg/hl)**	**TKW[3/] (g)**	**EXT [4/] (%)**	**W [5/] (10^{-4} J)**	**P/L [6/]**	**PRT [7/] (%)**	**SDS [8/] (ml)**	**FN [9/] (s)**
1995	1	83	42.8	70.58	348	0.83	-	20.2	405
1996	5	84	48.4	67.44	383	1.32	10.3	14.9	509
1997	1	79	-	-	395	1.11	-	-	382
1998	5	82	43.2	64.89	362	2.04	14.1	13.6	492
Mean		82	45.0	67.64	372	1.32	12.2	16.2	447

[1/] SMP: Number of samples; [2/] HW: Hectoliter Weight; [3/] TKM: Thousand Kernel Weight; [4/] EXT.: Milling Extraction; [5/] W: Alveograph value; [6/] P/L: Gluten elasticity; [7/] PRT: Protein content; [8/] SDS: Sedimentation value; [9/] FN: Falling number.

Major reasons for IPR 85 release are earliness with an average of 60 days to heading and 113 days to maturity. Excelent technological quality, being classified as an Improver Wheat. Good resistance to leaf rust, powdery mildew and leaf blight (Riede et al., 1999).

NEW BREEDING TOOLS

New biotechnogical techniques such as haploidy, which uses wheat x maize crosses (Laurie and Bennett, 1988 and Scheeren et al., 1999) or microspore culture (Kasha et al., 1998), marker assisted selection (Langridge and Chalmers, 1998; Dubcovsky, 1998 and Anderson, 1998), and transformation (Barcelo et al., 1998 and Pellegrineschi, 1999) are here to help speeding up breeding programs, in making indirect selections more efficiently and in transfering genes from other species, breaking up the sexual crossing barriers. The new generation of plant breeders have to be able to understand and manipulate these new molecular tools in order to make further improvements in the cereal crops.

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RESUMO

Vinte e Seis Anos de Atividades com Melhoramento de Trigo no IAPAR

A descrição do programa de melhoramento genético de trigo nos seus 26 anos de existência procura apresentar suas principais realizações, dando idéia do tamanho do programa, objetivos do melhoramento e metodologias utilizadas. Um diagrama do caminhamento do germoplasma indica os passos que as populações devem seguir iniciando pelos cruzamentos ou pelas introduções de material genético até que linhas avançadas ou linhagens possam ser reunidas e avaliadas obtendo-se assim novos cultivares. Uma lista dos 23 cultivares desenvolvidos pelo programa, com suas respectivas genealogias, é apresentada como uma contribuição especial. Considerando-se os cultivares desenvolvidos mais recentemente, são apresentadas as informações referentes a rendimento de grãos, características agronômicas, qualidade tecnológica e propriedades dos grãos. A descrição da genealogia do 'IAPAR 53' e o desenvolvimento do 'IPR 85' estão apresentados com detalhes. Novas ferramentas biotecnológicas que possam tornar o melhoramento de trigo mais eficiente são discutidas.

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