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Impact of Mexican Germplasm on Brazilian Wheat Cropping: An *Ex-Post* Economic Analysis

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E C O N O M I C S

Working Paper 02-01

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Abstract: This paper reviews and analyzes economic returns to wheat research in Brazil's main wheat-producing regions in Rio Grande do Sul and Paraná. Between 1975 and 1991, the area planted to wheat in Brazil increased significantly and yields grew at a yearly rate of about 3.8%. The expanded wheat area and increased productivity resulted from a technological package that included soil management, chemicals, and new cultivars. Experimental cultivars developed by the International Maize and Wheat Improvement Center (CIMMYT), and research institutions that preceded it, played an important role in raising productivity. From 1975 to 1990, research investments in Rio Grande do Sul, totaled US$ 65.1 million. The net benefit from this investment was US$ 662.7 million, yielding an internal rate of return of 69%**.** In Paraná, research investments totaled US$ 31.7 million from 1977 to 1991, resulting in a net benefit of US$ 593.8 million and an internal rate of return of 77%**.** The net benefits emphasize the effectiveness of research investments and the impact of new technologies, including new cultivars developed through research. These benefits also justify continuing investment in wheat research by CIMMYT and the Brazilian government to develop technologies that will help producers increase production and productivity.

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Contents

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Tables

Figures

Impact of Mexican Germplasm on Brazilian Wheat Cropping: An *Ex-Post* Economic Analysis

Roque G. Annes Tomasini

Introduction

Wheat was first introduced into Brazil by Martin Afonso de Souza in 1534, in the region now occupied by the state of São Paulo (Carmo 1911). Remarkable progress was made in wheat production from 1824, when German and Italian settlers initiated intensive wheat cropping in Rio Grande do Sul, the southernmost state of Brazil. The state began exporting wheat shortly thereafter.

Intermittent occurrences of rust attacks from 1822 to 1914, however, led to reductions in wheat yields in Rio Grande do Sul and other states in the country. By 1822, Rio Grande do Sul ceased exporting wheat and became a wheat importer. Wheat production practically ceased in the state of Paraná in 1857 (Carmo 1911). A decade later, rust attacks occured again in the country (Bayma 1960). A rust outbreak in 1914 led to further reductions in wheat yields (Saint-Hilaire 1974). As there were no research facilities at the time, efforts against rust occurrences were limited to seed introductions from Europe and North America, in the hope that the new cultivars would be resistant to this disease.

It was only a little before 1900 that wheat research commenced in the United States of America (US), Canada, and Australia. These research efforts resulted in new technologies, including improved cultivars, and enabled these countries to become world leaders in wheat production.

In Brazil, where climate and soil conditions are less favorable for wheat production, wheat research began in 1919 with the establishment of the Alfredo Chaves experiment station in Rio Grande do Sul and the Ponta Grossa experiment station in Paraná by the federal government. Later, state governments and wheat cooperatives in different states also established their own wheat research institutions.

What would have happened to wheat cropping in Brazil if there was no wheat research? Did the resources invested in wheat research bring the expected social and economic returns? The answers to these questions will help explain the need for current and future investments in research.

This paper reviews and analyzes the economic returns to wheat research in the states of Rio Grande do Sul and Paraná, Brazil's two main wheat-producing regions, by examining and evaluating the economic impact of the introduction of experimental cultivars (Mexican germplasm) developed by the International Maize and Wheat Improvement Center (CIMMYT), or the institutions that preceded it, on Brazilian wheat cropping.

Materials and Methods

Basic data for this study came from stocks of inspected seed from 1978-1990 in Rio Grande do Sul and from 1980-1991 in Paraná. The analysis ends in 1990 because of lack of reliable data after that year resulting from major changes in agricultural policies (see below).

Since no data on actual seed use are available, it was assumed that all seeds cleared by the inspection service were actually sown, though in certain years this may have not taken place.

By studying wheat pedigrees up to the third ancestors, all cultivars released in Brazil were characterized as:

a) directly introduced (100% Mexican germplasm);

b) without Mexican germplasm (0%);

c) with some Mexican germplasm (6.25, 12.5, 25.0, 31.5, 50.0%).

The actual percentage of Mexican germplasm depended on the genealogy of parents and grandparents. The share of CIMMYT germplasm in each cultivar was calculated and respective year of release as a commercial cultivar confirmed. Finally, the share of Mexican germplasm in seed of each cultivar sown annually was determined in both states.

Annual yield data per cultivar, obtained from the South Brazilian Wheat Cultivar Trial, were used to estimate yield increases in Rio Grande do Sul resulting from the introduction of cultivars with Mexican germplasm. Since most of the wheat area in Rio Grande de Sul is located in wheat growing areas 3 and 4 (Figure 1), only mean area data were used. In Paraná, data from experiments located in the wheat growing areas in A and B (without aluminum) and C, E and F, (with aluminum) were used (Figure 2).

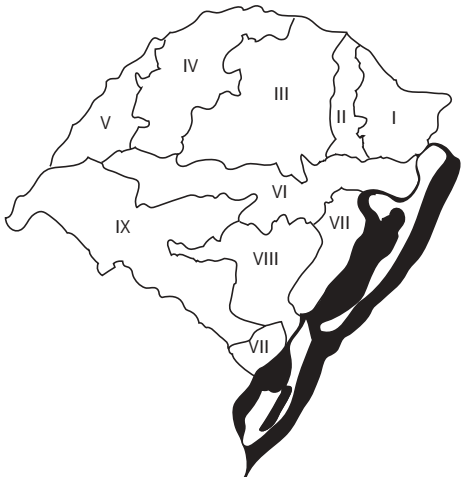

Figure 1. Wheat areas, Rio Grande do Sul, Brazil.

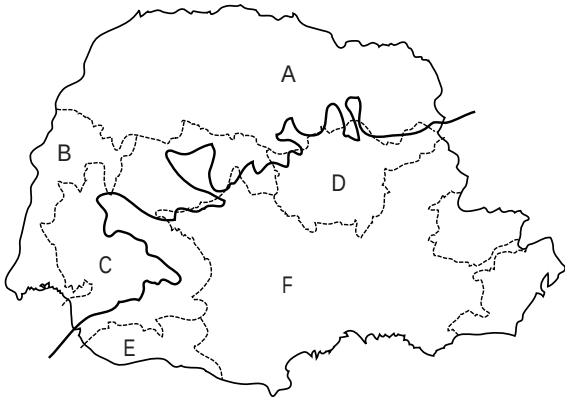

Figure 2. Wheat areas, Paraná, Brazil.

Annual mean yields were obtained by adjusting yield data of cultivars obtained from experiments in Rio Grande do Sul and Paraná with the REML (estimation of variance in non-orthogonal data by residual maximum likelihood) program (Robinson et al. 1987). This information formed the basis for comparisons with state-level yields published by the Instituto Brasileiro de Geografia e Estatística (IBGE) as the areas analyzed (Figure 1 and 2) represent most of the cropped area in the two states. Since the yields to which the REML procedure was applied were obtained from trial data, they were reduced by 40% to adjust them to the level of commercial fields.

The annual percentage supply shift relative to the base year[1] was then estimated and multiplied by the area sown to wheat in each state to obtain the additional gain in tons. Finally, physical gains were converted into constant US dollars by multiplying these gains by the contemporary wheat price expressed in dollars. The resulting series was deflated by the US producer price index.

The annual cost of wheat research in Rio Grande do Sul resulted from adding expenses incurred by the Centro Nacional de Pesquisa de Trigo (EMBRAPA Trigo), Federação Brasileira das Cooperativas de Trigo e Soja (now called FUNDACEP), and the Instituto de Pesquisas Agronômicas (IPAGRO). In Paraná, the total cost includes expenses incurred by the Fundação de Pesquisas Agronômicas do Paraná (IAPAR), the Organização das Cooperativas do Paraná (OCEPAR), and investments made by EMBRAPA Trigo in wheat research in Paraná.

The Centro Nacional de Pesquisa de Trigo is a national research Center located in Rio Grande do Sul that also works with other crops such as soybean, barley, triticale, and rye. An estimation of the amount actually invested by the Center on wheat research in Rio Grande do Sul and Paraná was obtained by deducing from its total budget expenditures in other crops or in wheat research in other states with information from research staff. Since records kept by other institutions were not always crop specific, estimates provided by research staff were used to calculate wheat expenses and to exclude expenses on other crops or activities.

Some institutions, such as the Instituto Agronômico de Campinas (IAC), were not included because of lack of relevant data. The IAC is attached to the government of São Paulo state, which was responsible for releasing the wheat cultivar IAC-5 (Maringá) that was extensively grown in Paraná and Rio Grande do Sul. Expenses incurred by CIMMYT for the generation of cultivars directly or through crosses in Brazil were also not considered as they may be regarded as "free goods" from Brazil's standpoint. The costs of disseminating these cultivars in the study area were also not included.

The AVALPESC (Avila, Cruz, and Vieira 1994) was used to determine the internal rate of return and remaining economic indicators. Wheat breeding research in Rio Grande do Sul and Paraná was already underway before the first year included in this study. For this reason, a lag of only three years between investments in research and the beginning of benefit generation was used to calculate net benefits.

[1] 1977 in Rio Grande do Sul; and 1979 in Paraná.

Evolution of Wheat Cropping in Brazil

Reliable statistical information on wheat production in Brazil exists only from 1962 until 1990. In 1962, the federal government took control of all wheat sales in the country. The federal government was the sole buyer and importer of wheat from 1967 until 1990, when all government intervention in wheat production and marketing ended.

Wheat yields averaged 800 kg/ha in Rio Grande do Sul and Paraná up till the 1980s (Figure 3). From the 1980s, there were considerable increases in yields, reaching an average of 1,800 kg/ha during 1985-87. In Rio Grande do Sul, commercial fields recorded yields as high as 5,000 kg/ha in 1989, and in both states, farms with access to advanced technology attained yields of up to 3,000 kg/ha in years with normal climatic conditions. Such evolution in yields in Rio Grande do Sul is evaluated by Tomasini (1991), who concluded that gains obtained in wheat research were proportionate to gains obtained by wheat producers.

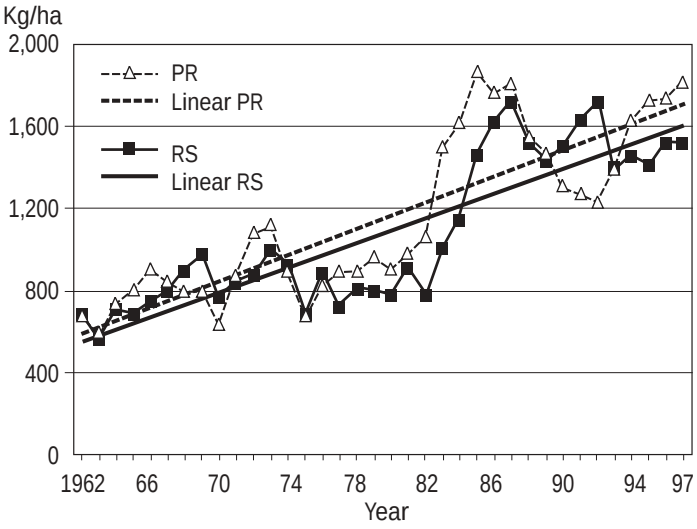

Figure 3. Wheat yield in Rio Grande do Sul and Paraná, 1962-97.

Table 1. Wheat production and yields, Rio Grande do Sul and Paraná, Brazil, 1962-99.

	Production (t)†		Yield (kg/ha)†	
Year	Paraná	Rio Grande do Sul	Paraná	Rio Grande do Sul
1962 -1964	7,104	171,628	675	685
1970 -1972	168,188	1,275,279	638	711
1980 -1982	1,109,744	878,507	903	776
1985 -1987	3,004,802	1,517,149	1,868	1,462
1990 -1992	1,555,951	964,576	1,312	1,500
1995 -1997	1,551,600	667,700	1,733	1,413
1997-1999	1,534,367	635,533	1,817	1,522

Note: †Production and yield values refer to the three-year moving average.
Source: Ctrin/Banco do Brasil, IBGE.

The high production growth rates in Paraná were initially a consequence of the expansion of wheat cultivation in the southern part of the state (C, D, F, and E in Figure 2). Later, wheat cultivation expanded into the western and northern areas where the aluminum-free soils favored the direct introduction of the Mexican cultivars, which were susceptible to aluminum toxicity (A and B, and a portion of C in Figure 2). The evolution of production and yields in several periods is shown in Table 1. Three-year moving means were used to reduce data variability.

The marked growth in production in both Paraná and Rio Grande do Sul from 1980-85, 28.3% and 14.6% respectively (Table 2), resulted from favorable credit and price support from the federal government, the introduction of new cultivars, and the rapid adoption of new crop management technologies, such as the rotation of winter crops, fungicide application, and integrated soil management. Technological variables were less important in Paraná which had more favorable climate and soil

conditions. During 1980-1990, annual yield growth rates reached 4.2% in Paraná and 7.6% in Rio Grande do Sul. This clearly shows the production potential of these regions.

Domestic wheat prices fell considerably in 1990 when the federal government withdrew from marketing operations. This increased the downside risk for producers who used less intensive technologies. In addition, Brazilian farmers had to compete with cheaper Argentine wheat that was imported under the MERCOSUR agreement.[2] The reduced profitability caused a reduction in wheat area and yields. Thus, production went down at the rate of 0.23% per year in Paraná and 0.79% in Rio Grande do Sul from 1990-1997.

Figure 4 shows the percentage evolution of wheat yields in Rio Grande do Sul and Paraná using the three-year moving averages. Yield variations were quite similar in both states, except that starting in 1987 wheat yields increases in Paraná were less than Rio Grande do Sul.

Table 2. Annual growth rates in wheat, Rio Grande do Sul and Paraná, Brazil, 1980-99.

Period	Growth rate (%)			
	Production		Yield per hectare	
	Paraná	Rio Grande do Sul	Paraná	Rio Grande do Sul
1980/70	23.3	-4.1	3.9	0.1
1985/80	28.3	14.6	19.9	17.2
1990/85	-15.2	-10.7	-8.5	0.6
1990/80	3.8	1.0	4.3	7.6
1990/70	12.4	-1.5	3.9	3.6

Note: †Since growth rates were calculated with moving averages, the value for 1990 is affected by changes in prices and policies in 1991, which resulted in marked reduction in wheat production.
Source: Ctrin/Banco do Brasil, IBGE.

Yield and Mexican Germplasm

The growth in wheat yield in Brazil resulted from both the use of Mexican germplasm and a new set of crop management technologies. To illustrate this, a number of graphs were prepared using yield data and percentage area occupied by cultivars with and without Mexican germplasm, and the percentage of Mexican germplasm in seed stocks sown each year (Figure 5). The data

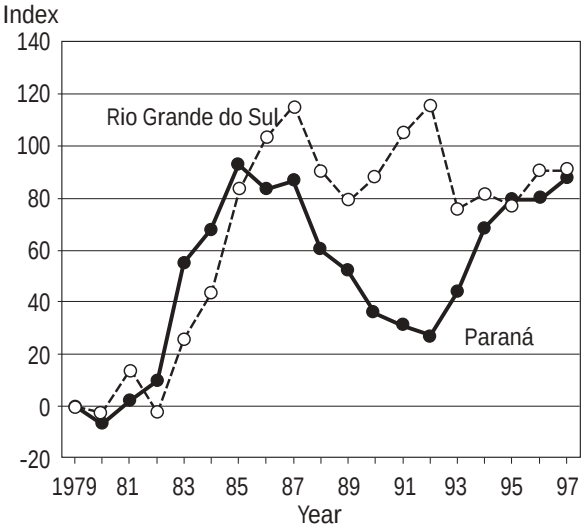

Figure 4. Evolution of wheat yields, Paraná and Rio Grande do Sul, Brazil 1979-97.

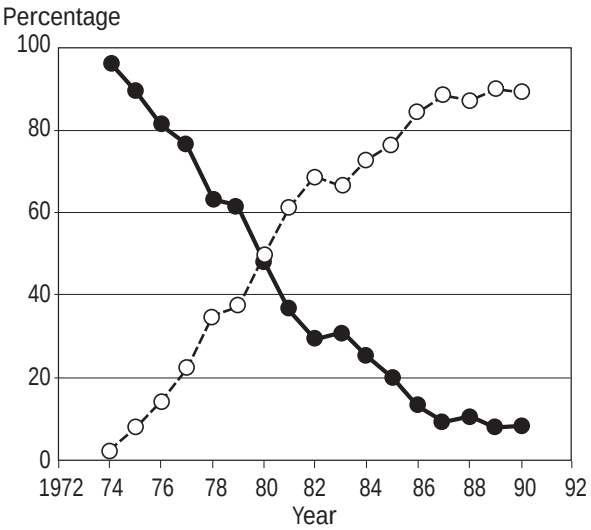

Figure 5. Evolution of cropped wheat area in Argentina, with and without Mexican germplasm, 1972-92.

[2] MERCOSUR was created in 1991 and became an imperfect customs union in 1995.

used for figures 6, 7, and 8 were obtained by dividing the seed stock of each cultivar by the total seed stock. Data used in the preparation of Figures 9 and 10 were obtained by multiplying the percentage of germplasm content in each cultivar by the respective seed stock.

From 1973 to 1985, average yield in Rio Grande do Sul fluctuated between 460 kg/ha and 1,244 kg/ha (Figure 6). Mexican cultivars were not introduced directly into Rio Grande do Sul because of their susceptibility to aluminum toxicity. They were introduced through cultivars obtained from crosses with Brazilian material made either in Mexico or in Brazil. Mexican germplasm could be found as early as 1977, in the cultivar Nobre (S 31), which then represented 30% of seed stock.

In 1977, Brazilian cultivars obtained from crosses with Mexican germplasm were present in 62% of cropped area; this fell to 23% in 1985. Yield increases were triggered by a wheat policy that used subsidized credits to encourage producers to adopt a winter crop rotation or fallow to avoid root diseases. This new technological package coincided with the release of several Brazilian materials with Mexican germplasm. These materials occupied 97% of cropped area in 1990. The relationship between yield increase and an increasing percentage of wheat area with Mexican germplasm becomes evident in the graph, especially from 1985 onwards. Climatic problems were responsible for yield reductions in 1990.

The relationship between the use of the germplasm and yield also involves interactions with other parameters in Paraná, such as sowing in areas with and without aluminum, adoption of crop rotations, and fungicide application. The favorable soil and climate in wheat areas in western and northern Paraná allowed direct introduction of many Mexican cultivars, like INIA (from 1976) and Jupateco (from 1978). In 1979, these two cultivars represented 29% and 17%, respectively, of seed stock

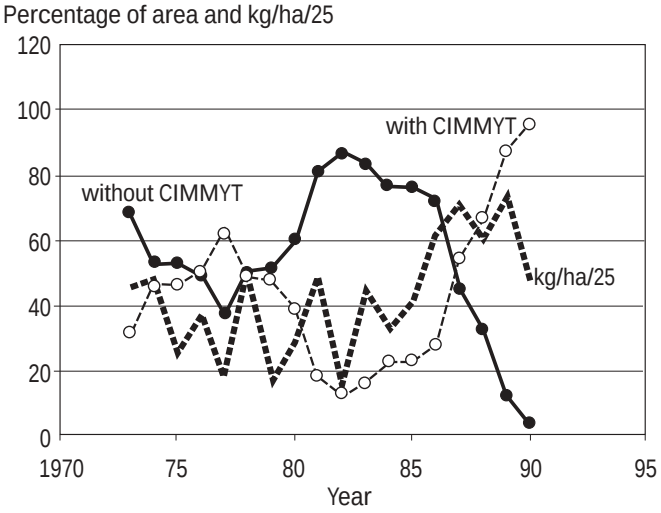

Figure 6. Wheat yield growth and Mexican germplasm, Rio Grande do Sul, Brazil 1972-92.

Figure 7 shows the prevailing position of Mexican germplasm in wheat cropping in Paraná and its positive relationship with yields. Exceptions occurred during the 1986 season when germplasm was severely attacked by a blast caused by the fungus *Pyricularia grisea*. Susceptible materials with Mexican ancestors were partly replaced in 1987 by Brazilian material resistant to this disease and may have contributed to yield growth. The reduction in yield in 1990 was due to a delay in sowing. From 1979-1984, there is a clear relationship between

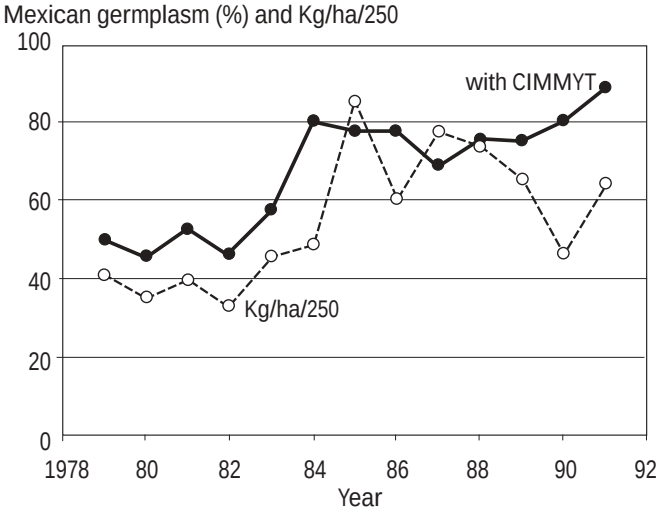

Figure 7. What yield growth and % of Mexican germplasm, Paraná, Brazil 1977-91.

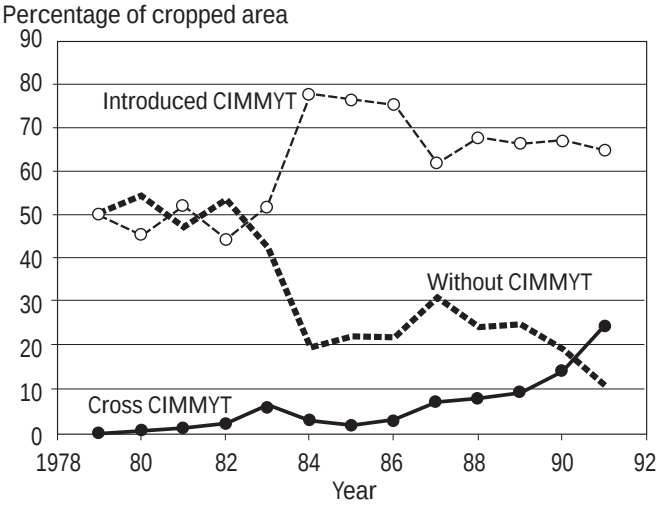

Figure 8. Genealogy of cultivars, Paraná, Brazil 1978-92.

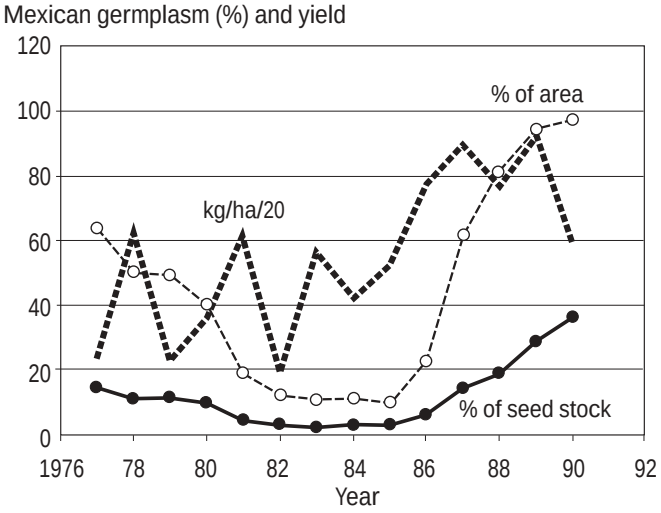

Figure 9. Wheat genealogy and yields, Rio Grande do Sul, Brazil, 1976-92.

the percentage of area with cultivars having Mexican germplasm and yields. A positive relationship between the presence of the germplasm and yield is also present from 1985-1991, although this is not as evident as the earlier period. After 1984, cultivars directly introduced from CIMMYT represented between 60% (1987) and 80% (1984) of area sown to wheat. From 1989, crosses of Mexican germplasm with Brazilian material or from other sources represented more than 10% of cropped area.

As mentioned earlier, there was no direct introduction of Mexican germplasm in Rio Grande do Sul, therefore, the percentage of this germplasm in the seed stock oscillated around 10 over the period 1977-86. With the release of the cultivars CEP 14-TAPES and BR-23 after 1987 this share almost reached 40% in 1990. In this last year, Mexican germplasm covered 100% of the state's wheat area.

In Paraná, where cultivars were directly introduced, the percentage of Mexican germplasm in total germplasm was about 50% from1979-1983 (Figure 10). After 1984, this percentage jumped to around 70%. Yield increases, except in 1985, 1987, and 1990, were always directly related to the presence of Mexican germplasm.

The regression analysis between the percentage area occupied by cultivars with Mexican germplasm and yield over the period 1979-1991 indicates that 46.7% of yield variations are explained by the presence of Mexican germplasm.

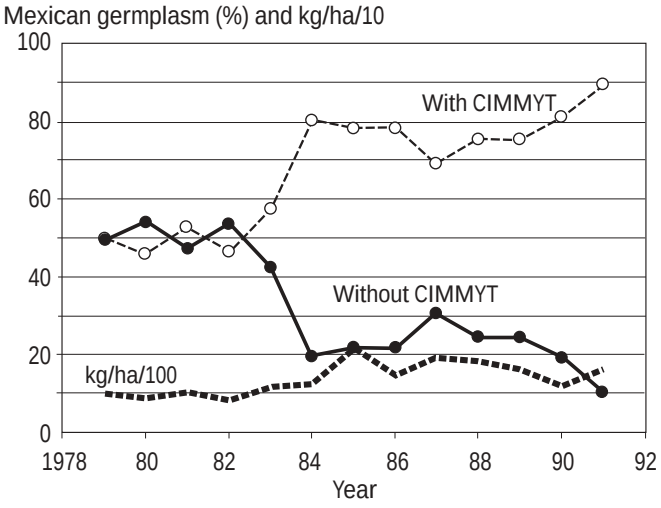

Figure 10. Wheat genealogy and yields, Paraná, Brazil, 1978-92.

When the independent variable is the share of Mexican germplasm in total germplasm of all cultivars, the regression indicates that 49.8% of variations are explained by the presence of Mexican germplasm.

In contrast, only 14.8% of yield variation in Rio Grande do Sul over the period 1977-1990 is explained by the percentage area occupied by cultivars having Mexican germplasm. If the regression considers total germplasm in all cultivars, only 13.91% of variations are due to this germplasm. The lower impact of Mexican germplasm in Rio Grande do Sul is mostly due to root diseases, damage caused by above-ground diseases, low fertility levels, and climatic problems that have prevented cultivars from this germplasm from reaching their yield potential.

Investments in Research in Rio Grande do Sul and Paraná

As stated earlier, wheat research began in 1919 in Rio Grande do Sul with the establishment of research stations by the federal government and later, by state governments and producer cooperatives. By the end of 1975, the federal government centered its activities in southern Brazil at EMBRAPA Trigo.

Table 3 illustrates investments in wheat research by the Federação das Cooperativas e Trigo e Soja do Rio Grande do Sul (FECOTRIGO), IPAGRO, and EMBRAPA Trigo in Rio Grande de Sul from 1975 until 1990. In this period, FECOTRIGO and IPAGRO gradually reduced their investments in wheat research because of institutional problems, and/or switching research activities to other crops. Despite continuous and stable flow of resources, EMBRAPA Trigo reduced research

Table 3. Wheat research investments, Rio Grande do Sul, Brazil, 1975-90 (1990 US$).

Year	FECOTRIGO†	IPAGRO†	EMBRAPA Trigo‡	Total
1975	1,213,003	427,775	3,643,924	5,284,702
1976	1,146,263	499,778	4,292,952	5,938,993
1977	1,076,195	377,589	3,588,436	5,042,220
1978	1,000,200	400,766	4,108,992	5,509,958
1979	899,199	370,225	3,509,724	4,779,068
1980	506,971	205,922	3,367,980	4,080,873
1981	459,176	222,069	4,003,691	4,684,936
1982	432,959	263,428	4,645,316	5,341,704
1983	419,342	160,309	3,087,742	3,667,393
1984	402,162	128,630	2,446,316	2,977,108
1985	388,491	84,243	2,764,902	3,237,636
1986	381,225	80,537	2,371,290	2,833,052
1987	367,520	83,203	2,543,349	2,994,073
1988	353,474	87,158	2,766,268	3,206,899
1989	337,233	76,091	2,321,999	2,735,323
1990	320,000	73,895	2,377,142	2,771,037
Total	**9,703,413**	**3,541,620**	**51,840,023**	**65,084,977**

Note: †Estimated expenditure based on information from research staff.
‡ Estimated expenditure based upon recorded expenses and information from research staff .

investments in the state as its resources were diverted to the completion of its building infrastructure, expansion into other Brazilian states, and later, diversification of research activities to other crops such as barley, triticale, rapeseed, flax, lupinus, and soybeans. During the period, EMBRAPA Trigo spent US$ 51,840,023 in wheat research.

Research investments by the Paraná state government from 1977-1991(through IAPAR) exceeded those made by EMBRAPA Trigo. These investments were also gradually reduced because of institutional reasons and diversification. During the period under analysis, EMBRAPA Trigo expanded its activities especially in Paraná, the main national wheat producer (Table 4), as the conclusion of basic investments enabled it to free resources to fulfill its mission of working at a national level.

Table 4. Wheat research investments, Paraná, Brazil, 1977–91 (at 1990 US$).

Year	OCEPAR†	IAPAR†	EMBRAPA Trigo‡	Total
1977	834,694	1,669,389	300,827	2,804,910
1978	861,948	1,723,895	344,466	2,930,310
1979	836,450	1,672,901	327,574	2,836,925
1980	585,947	1,171,895	467,775	2,225,617
1981	655,905	1,311,809	556,068	2,523,782
1982	565,485	1,130,970	645,183	2,341,638
1983	372,625	745,250	529,327	1,647,202
1984	324,431	648,863	438,146	1,411,440
1985	171,482	342,965	495,206	1,009,653
1986	292,828	585,656	592,823	1,471,307
1987	268,175	536,350	635,837	1,440,362
1988	546,576	1,093,151	691,567	2,331,294
1989	594,689	1,189,377	844,363	2,628,429
1990	446,900	893,800	864,415	2,205,115
1991	313,575	627,150	910,627	1,851,352
Total	**7,671,712**	**15,343,420**	**8,644,204**	**31,659,338**

Note: †Estimated expenditure based upon comments of research staff at the institution.
‡ Estimated expenditure based upon recorded expenses and comments of research staff at the institution.

Net Benefit of Investments

The use of annual yield data from trials allowed calculation of the annual shift of the supply curve. Most studies cannot do this estimation because they use average yield differences between traditional and improved varieties and the percentage area cropped with new varieties (Ávila, Cruz, and Vieira 1994).

The additional income generated from 1977-1990 in Rio Grande do Sul was as high as US$ 727.7 million (Table 5). This resulted from a combination of technologies applied in 15,763,000 hectares. In 1990, the adjusted yield was 121.2% higher than the base year, 1977.

Even though the total wheat area in Paraná (18,103,000 hectares) was larger than Rio Grande do Sul, the total additional income, US$ 593.8 million, was lower (Table 6). Additional benefits in Paraná were smaller because initial yields in this state were higher than Rio Grande do Sul but were almost equal in the last year of the analysis. The adjusted yield in 1991 was only 49% higher than the base year, 1979.

Table 5. Wheat research benefits, Rio Grande do Sul, Brazil, 1977-90.

Year	Adjusted yield Kg/ha	% supply shift	Deflated price PPI-EUA US$/ton (at 1990 US$)	Area 1,000/ha	Additional income† (at 1990 US$)
1977	1,228	0.000	441.0	1,382	-
1978	1,309	0.066	415.8	1,221	20,063,427
1979	1,306	0.064	288.1	2,185	24,191,372
1980	1,349	0.099	304.6	1,435	25,941,878
1981	1,386	0.129	347.5	879	23,607,230
1982	1,465	0.193	346.4	1,377	55,247,542
1983	1,522	0.240	242.2	683	23,803,281
1984	1,578	0.285	254.8	722	31,488,083
1985	1,651	0.345	285.9	941	55,693,388
1986	1,856	0.512	283.4	1,169	101,689,976
1987	2,151	0.752	205.2	981	90,838,698
1988	2,314	0.884	185.5	1,012	99,615,663
1989	2,602	1.120	152.5	788	80,702,787
1990	2,716	1.212	132.0	988	94,835,391
Total				**15,763**	**727,718,717**

Note: †Assuming a 40% reduction in commercial fields relative to experimental data.

Table 6. Wheat research benefits, Paraná, Brazil, 1979-91.

Year	Adjusted yield Kg/ha	% supply shift	Deflated price PPI-EUA US$/ton (at 1990 US$)	Area 1,000/ha	Additional income† (at 1990 US$)
1979	1,797	0.0000	288.1	1,576	-
1980	1,836	0.0220	304.6	1,568	6,298,402
1981	1,821	0.0134	347.5	930	2,591,772
1982	1,949	0.0845	346.4	1,232	21,636,116
1983	2,129	0.1847	242.2	926	24,864,321
1984	2,354	0.3101	254.8	912	43,241,465
1985	2,392	0.3311	285.9	1,273	72,293,262
1986	2,426	0.3500	283.4	1,942	115,585,123
1987	2,422	0.3479	205.2	1,717	73,562,766
1988	2,519	0.4021	185.5	1,775	79,436,315
1989	2,550	0.4191	152.4	1,925	73,792,820
1990	2,593	0.4428	132.0	1,197	41,967,713
1991	2,678	0.4904	115.9	1,130	38,552,226
Total				**18,103**	**593,822,301**

Note: †Assuming a 40% reduction in commercial fields relative to experimental data.

Return to Investments in Research

According to Evenson (1977), the period between the release of a technology and its adoption is at least three years, and the mean period between the first results and maximum adoption would be about seven years.

The net benefit accumulated from 1975-1990 in Rio Grande do Sul was US$ 662.6 million (Table 7). In Paraná, it was US$ 562.1 million from 1977-1991 (Table 8).

Table 7. Net benefit of wheat research, Rio Grande do Sul, Brazil, 1975-90 (at 1990 US$) .

Year	Benefit	Cost	Net benefit
1975	-	5,284,702	(5,284,702)
1976	-	5,938,993	(5,938,993)
1977	-	5,042,220	(5,042,220)
1978	20,063,427	5,509,958	14,553,469
1979	24,191,372	4,779,068	19,412,304
1980	25,941,878	4,080,873	21,861,005
1981	23,607,230	4,684,936	18,922,294
1982	55,247,542	5,341,704	49,905,838
1983	23,803,281	3,667,393	20,135,888
1984	31,488,083	2,977,108	28,510,975
1985	55,693,388	3,237,636	52,455,752
1986	101,689,976	2,833,052	98,856,924
1987	90,838,698	2,994,073	87,844,625
1988	99,615,663	3,306,899	96,408,764
1989	80,702,787	2,735,323	77,967,464
1990	94,835,391	2,771,037	92,064,354
Total	**727,718,717**	**65,084,977**	**662,633,740**

Table 8. Net benefit of wheat research in Paraná, Brazil 1977-91 (at 1990 US$).

Year	Benefit	Cost	Net benefit
1977	-	2,804,910	(2,804,910)
1978	-	2,930,310	(2,930,310)
1979	-	2,836,925	(2,836,925)
1980	6,298,402	2,225,617	4,072,785
1981	2,591,772	2,523,782	67,989
1982	21,636,116	2,341,638	19,294,478
1983	24,864,321	1,647,202	23,217,119
1984	43,241,465	1,411,440	41,830,024
1985	72,293,262	1,009,653	71,283,609
1986	115,585,123	1,471,307	114,113,816
1987	73,562,766	1,440,362	72,122,404
1988	79,436,315	2,331,294	77,105,021
1989	73,792,820	2,628,429	71,164,391
1990	41,967,713	2,205,115	39,762,597
1991	38,552,226	1,851,352	36,700,874
Total	**593,822,301**	**31,659,338**	**562,162,963**

Internal Rate of Return and Cost-Benefit Relationship

The internal rate of return (IRR) is the discount rate that equalizes the actual value of all benefits in a project and the actual value of all costs.

The IRR of wheat research for Rio Grande do Sul was 69% and 77% for Paraná. These rates compare very favorably to those obtained for wheat research in Argentina over 1966-1990 (32%) (Macagno and Chao 1992). Using a different data set and method, Ambrosi and Cruz (1986) also found a high return rate to wheat research in Brazil (74.2%).

Net Present Value

Considering a discount rate of 4%, the net present value of investment in wheat research was US$ 411.6 million in Rio Grande do Sul, and US$ 367.3 million in Paraná; for a 10% rate, the net present value of investment was US$ 212.8 million and US$ 201.9 million, respectively. The cost-benefit relationship (for a 10% discount rate) is 7.05 for Rio Grande do Sul, and 12.85 for Paraná.

Conclusion

Nearly 85% of Brazilian wheat is produced in the states of Rio Grande do Sul and Paraná. The annual average yield increase in the period 1970-1990 in Rio Grande do Sul was 3.6% and 3.9% in Paraná. The analysis of such high rates clearly indicates that significant changes took place in wheat cropping in both states.

Growth in production and yield resulted from a combination of favorable government policies (e.g., assurance of a higher fixed purchase price for local wheat than imported wheat, provision of credit, and subsidized interest rate for agriculture), investments in training and basic infrastructure for wheat research, and the introduction of new crop management technologies and new cultivars.

An important positive correlation between yield increases and the introduction of Mexican germplasm by CIMMYT (or institutions that preceded it) was found. While the Mexican germplasm had less impact in Rio Grande do Sul due to the presence of aluminum toxicity and a less favorable climate, it was an important asset for Brazil and was most likely responsible for high yield growth rates.

Total investments in research for both states amounted to US$ 96.7 million while the benefits were US$ 1,321 million representing a net benefit of US$ 1,224 million.

The IRR for Rio Grande do Sul was 68.96%, and 76.52% for Paraná. Compared to alternative uses for resources, it is found that such investments were profitable. The net present value for Rio Grande do Sul, considering an annual discount rate of 4%, was US$ 411,568,679; for Paraná it was US$ 367,328,755.

The IRR and the net present value found in this study reflect the high profitability of a combination of research investments with direct and indirect introduction of Mexican germplasm. It is also evidence of the value of collaboration between CIMMYT and Brazilian research institutions.

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