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BIOTECHNOLOGY AND DEVELOPING COUNTRY AGRICULTURE: MAIZE IN BRAZIL

by

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Research programme on:
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RÉSUMÉ

Avec une production annuelle moyenne supérieure à 20 millions de tonnes, le Brésil occupe la deuxième place, après la Chine, parmi les pays en développement producteurs de maïs ; à l'échelle mondiale, il se situe au troisième rang. Cette étude examine la technologie et la recherche qui, au Brésil, ont présidé au développement et à l'extension de cette culture. Fondée sur une approche socio-économique et politico-institutionnelle, elle met l'accent sur les acteurs et les facteurs qui déterminent la recherche et sa mise en application dans la production.

L'étude comporte deux parties. La première traite de la place du maïs dans l'économie brésilienne - principales caractéristiques de sa production, de sa commercialisation et de sa consommation - ; elle aborde également la politique économique qui s'y applique et l'organisation de la production des semences. La seconde partie s'attache, quant à elle, à la recherche et à la technologie relatives au maïs, aux agents de leur développement respectif et aux possibilités d'expansion liées à l'usage des biotechnologies.

On trouvera, en annexe, un aperçu du développement des biotechnologies au Brésil.

De nombreuses personnes ont contribué à l'élaboration de cette étude. Les auteurs tiennent à remercier particulièrement le Centre national de la recherche sur le maïs et le sorgho de l'EMBRAPA et les participants au séminaire de travail préparatoire organisé par le Centre de Développement de l'OCDE en mai 1989.

SUMMARY

With annual production averaging over 20 million metric tons, Brazil is the second largest developing country producer of maize (after China) and the third largest in the world. This report analyses development and dissemination of maize research and technology in Brazil from a socio-economic and politico-institutional perspective. It concentrates therefore on agents and factors which influence development of research and its productive application.

The report is in two parts. First it describes the role of maize in the Brazilian economy - the main characteristics of its production, marketing and consumption, together with relevant sectoral policies and regulation of seed production. Then it analyses the development of maize research and technology in Brazil, identifying the main agents involved and possible future developments in the light of the introduction of biotechnologies.

As an Appendix, the authors review development of biotechnologies in Brazil.

Many people have collaborated in this report and the authors would like especially to thank the researchers at EMBRAPA's National Research Centre on Maize and Sorghum, the Brazilian firm AGROCERES, and the participants in the preparatory workshop organised by the OECD Development Centre in May 1989.

PREFACE

This case study of Brazil has been undertaken as part of a research project on "Biotechnology and Developing Country Agriculture: the Case of Maize", carried out in the context of the Development Centre's research programme on "Changing Comparative Advantages in Food and Agriculture". The project, which assesses the prospects for selected developing countries of incorporating new biotechnologies in maize production and, by implication, enhancing their competitiveness, focuses on the institutional aspects of technological change.

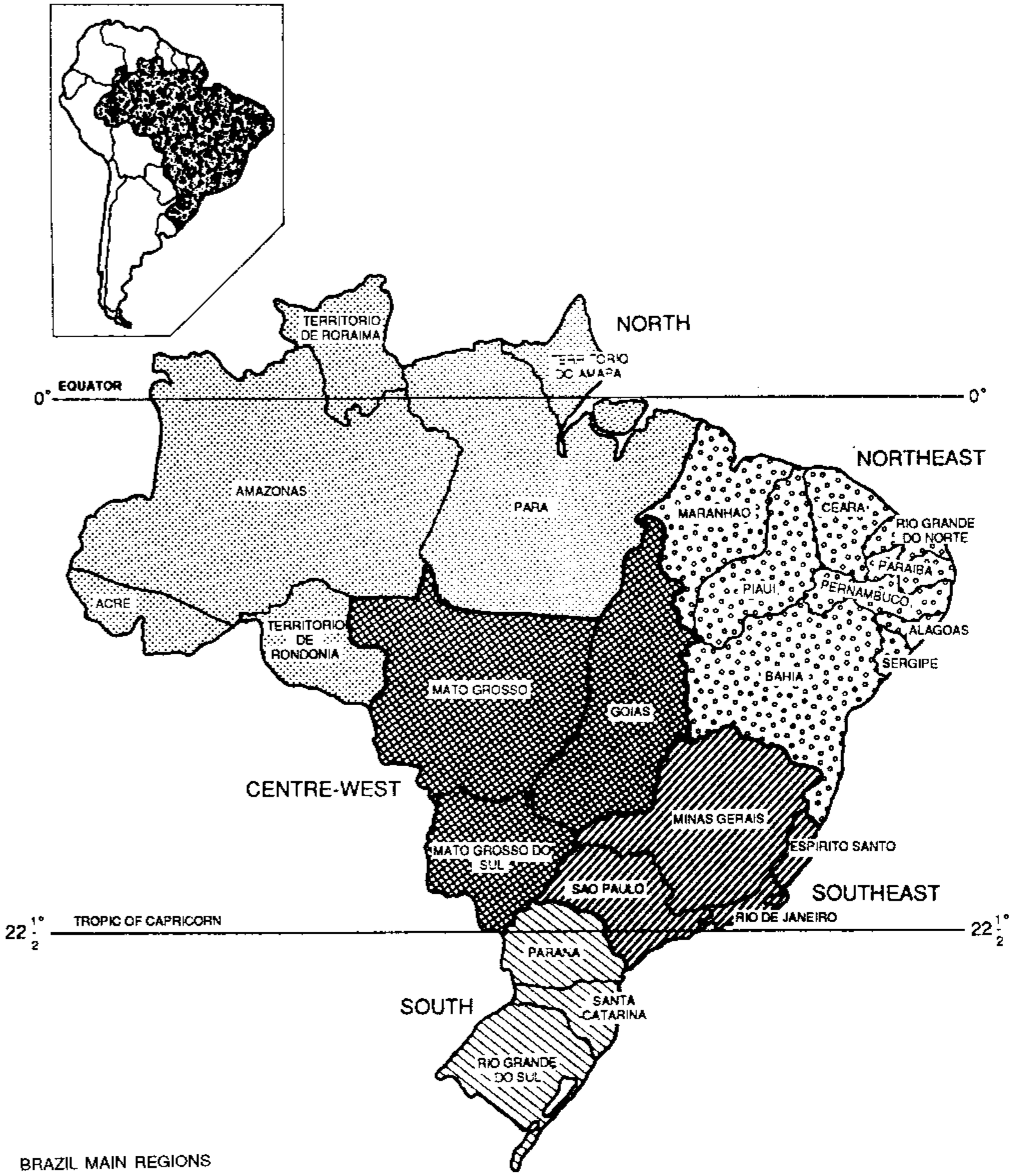
Maize was selected as an eminently suitable subject for examining how new technological developments in industrialised countries "interact" with the situation in developing countries. One of the world's major cereal crops, in many developing countries maize is an important food and/or feed crop for which demand continues to expand, particularly for use as livestock feed. Maize is also a crop on which major biological research effort has been focused. This effort resulted in the innovation of hybridization in the 1930s and shows promise with respect to new biotechnologies.

Drs. Bernardo Sorj and John Wilkinson have contributed this case study of Brazil which traces production and consumption trends, examines Brazil's maize research, technology development and diffusion system and concludes that, in the short term, productivity gains will come from existing technology. In addition to the Brazilian case, the project includes case studies of Indonesia, Mexico and Thailand. It also analyses trends in research on the emerging maize biotechnologies and in the supply, demand and trade of maize internationally. The country studies, together with the analysis of technology trends (entitled "Emerging Maize Biotechnologies and their Potential Impact") are all being published in this Technical Papers series. The conclusions and policy implications to be drawn from the project will be published by the OECD in a separate volume by Carliene Brenner.

Louis Emmerij
President of the OECD Development Centre
May 1990

BRAZIL

STATE AND REGIONAL BOUNDARIES



BRAZIL MAIN REGIONS

North	(Rain Forest)
North-East	(Semi-arid)
Center-West	(Savanna)
South-East	(Tropical and Semi-tropical)
South	(Semi-tropical and Temperate)

Part One

MAIZE IN THE BRAZILIAN AGRO-INDUSTRIAL COMPLEX

Introduction

Before the 1960s, Brazilian agriculture had two sectors: production for the domestic market with little resort to industrial inputs and often based on subsistence farmers, and an export agriculture using significant imported industrial inputs (tractors, fertilizers). This was complemented by a traditional and regionally organised food industry little influenced by packaging, quality control and marketing technologies.

From the end of the 1960s however, a modern agro-industrial complex emerges based on renewed industrial growth - particularly the expansion of the steel, automobile and petrochemical industry - and with multinational companies and state firms jointly responsible for administrative, technological, and marketing modernisation.

This new agro-industrial complex includes the tractor and agricultural machinery industry, fertilizers, animal feed, herbicides/pesticides and veterinary products. Downstream, modern food firms emerge nationally based on marketing technology and industrial quality control. This industry is stimulated by growing urban population, particularly the middle classes, and serviced by supermarkets which dominate retailing in urban centres.

The new complex increases intersectoral industry relations, diminishes the share of farm production in the value added of final food production and alters rural organisational and administrative structures.

Agricultural production for domestic and export markets is transformed. New export products are launched of which Brazil becomes a leading world supplier - soybeans, oranges, and poultry - exploiting the potential of its agro-industrial base.

Many export products are also directed to the domestic market (soybeans and poultry). Typical domestic market products (beans, rice) are not competitive internationally, and export products which have lost their competitivity have been reoriented to the domestic market (sugar). It has been argued that technological innovations have favoured export products which as a result became competitive internationally. This however presupposes the existence of **typical** export products which as we have seen do not exist.

The impact of the agro-industrial complex was to remodel the social structure of Brazilian agriculture, raising the technological threshold of a fraction of farmers and marginalising the rest (see Table 1).

Table 1

AGRICULTURAL PRODUCERS
1980

	Number of Farms (thousands)	Percentage of total
Traditional	3.851	75
Modern	1.306	25
(Total)	5.157	100

Source: CENSO Agropecuario, 1980, Rio de Janeiro, IBGE, v. 2, t. 3, n. 1, 1983-4, G. Muller, *O agrario brasileiro e a medicao do dinamico e do atrasado*, Sao Paulo, CEBRAP, mimeo, 1987.

While small farmers with less than 50 hectares continue to play an important role in production of certain crops, their influence is declining and their share of agricultural production is now around 40 per cent.

Agricultural modernization has spread everywhere, but unevenly. While in the Centre-South many farmers, including small-scale producers, have become integrated into the agro-industrial complex, in the North and the North-East, most small farmers are still marginalised, while the Centre-West is dominated by large mechanised estates.

In the wake of this modernisation, much of the traditional workforce has been proletarianised and urbanised, while the administrative structure of agriculture has been transformed, leading to formation of large producer cooperatives.

Consolidation of the agro-industrial complex received strong support from the state. It was imposed during a military dictatorship when social and labour demands were repressed. So modernisation was strongly biased in favour of large holdings. The state was also the source of subsidised credit which stimulated purchase of industrial inputs and machinery.

The strengthening of federal institutions against the power of the states, as we will see in the second section, benefitted centralised research, extension and inspection bodies which until then had had a largely state character.

Expansion and consolidation of the maize complex in Brazil should be situated in this framework. While hybrid seed production preceded creation of the agro-industrial complex, demand for hybrids soared once the poultry and animal feed industries were established. This poultry complex which set off the expansion of maize is closely associated with foreign capital investment in veterinary products, animal feeds and technology, while the poultry matrices are imported. The large-scale implantation of foreign seed firms also occurs in this period: Pioneer (1964), Cargill (1965), Continental Grain (1971), Upjohn (1971), Limagrain (1977), DeKalb (1978) and Ciba-Geigy (1979).

In the 1980s, with the agro-industrial complex already consolidated, agriculture continues to expand despite the crisis of the industrial sector (Rezende, 1989). The sector continues to receive incentives from the government, not so much as subsidised credit, but through more realistic pricing. In recent years, increasing fiscal disequilibrium, inflation and economic shocks have strongly affected farming. The Cruzado Plan in 1986 increased internal demand and froze interest, whereas in 1987 price freeing and fall in consumption hit production for the internal market and continued into 1988 and 1989. Nevertheless agriculture remains the major source of Brazil's trading surplus, and therefore of hard currency for repaying interest on the foreign debt.

Meanwhile the fiscal crisis of the state, the difficulty of importing laboratory equipment and a fall in real salaries of public sector researchers begins to affect the country's capacity for agricultural research. In the private sector, economic uncertainty leads to a contraction of investment in research and development and slows down technological modernisation which will influence the sector's future competitivity.

Production

Among agricultural products in Brazil, maize absorbs the most labour, occupies the largest area under production, and comes third in production value after cattle and soybeans. Growth in maize production has been constant since the 1950s, doubling between 1954/58 and 1968/70 and almost doubling again between then and 1986/88 (Table 2).

Brazilian production of commercial maize seeds is around 180 000 tons. Of this, some 20 per cent comes from the public sector (but is marketed by private firms). Overproduction is between 15 to 25 per cent, probably because the main firms want to be ready for extra demand and/or to use it to force prices down if needed.

Maize is produced as a single crop (particularly in Saő Paulo and Goias), planted together with permanent crops (Minas Gerais) and planted in association with other temporary crops in the North and the North-East. In some states, all three production systems are present (Santa Catarina, Paraná). Productivity is much higher in single crop planting.

Table 2

QUANTITY PRODUCED AND AVERAGE YIELDS OF MAIZE
1960-1985

Year	Area (ha)	Quantity produced (tons)	Average yields (kg/ha)
1960	6 681 165	8 671 952	1 297
1961	6 885 740	9 036 237	1 312
1962	7 347 881	9 587 285	1 304
1963	7 957 633	10 478 267	1 316
1964	8 105 894	9 408 043	1 160
1965	8 771 318	12 111 921	1 380
1966	8 703 169	11 371 455	1 306
1967	9 274 321	12 824 500	1 382
1968	9 584 754	12 813 638	1 336
1969	9 653 757	12 693 435	1 314
1970	9 858 108	14 216 009	1 442
1971	...	...	...
1972	...	...	...
1973	9 923 570	14 185 877	1 429
1974	10 672 450	16 273 227	1 524
1975	10 854 687	16 334 516	1 504
1976	11 117 570	17 751 077	1 596
1977	11 797 411	19 255 936	1 632
1978	11 124 827	13 569 401	1 219
1979	11 318 885	16 306 380	1 440
1980	11 451 297	20 372 072	1 779
1981	11 520 336	21 116 908	1 833
1982	12 619 531	21 842 477	1 731
1983	10 705 979	18 731 216	1 750
1984	12 205 201	21 174 179	1 735
1985	11 801 549	22 019 725	1 874

Sources: Ministry of Agriculture to 1970; IBGE as from 1973; *Agroanalysis*, January 1987.

In the North-East, improved seeds and fertilizers are hardly used and animal traction is common. In the Centre-South, mechanisation is general and 70-85 per cent of farmers use improved seeds and fertilizers. While large-scale production increases rapidly, more than half the national crop is produced on farms of less than 50 hectares.

Although maize is produced throughout the country, most comes from the Centre-South and Southern regions, with the Centre-West the region of fastest growth. Highest productivity is in the South (around 2,500 kg/ha), while in the North-East average productivity is below 500 kg. Here and in the North, maize is generally a subsistence product, using little or no off-farm inputs.

Maize is a typical small farmer product. In Table 3 we see that in the North and North-East, more than 95 per cent comes from farms of less than 50 ha. and more than 80 per cent from properties of less than 10 hectares. In the South-East and Centre-West a larger share of regional production comes from properties of over 100 ha (11.6 and 27 per cent respectively).

Increased maize production during the 1950s and 1960s was largely due to increased area cultivated. In the 1970s, greater productivity became the main factor (Table 4 and 5).

Table 3

QUANTITY OF MAIZE PRODUCED BY DIFFERENT SIZE FARMS
(Percentage)

Area (ha)	REGION				
	North	North-East	South-East	South	Centre-West
10	89.3	82.7	44.9	67.7	37.3
10-50	9.6	13.8	33.3	28.0	24.3
50-100	0.8	1.7	10.2	02.4	11.4
100-200	0.3	0.9	6.6	1.1	12.3
200-500	---	0.5	3.8	0.6	10.0
500	---	0.4	1.2	0.2	4.7

Source: FIBGE, Censo Agropecuario de 1975, in Garcia, Vencovsky, n.d.

Table 4

GROWTH IN MAIZE PRODUCTION
1948-69
(Percentage)

	Rate of production growth (ann.av.)	Area	Yield	Change in location
1948/50 to 1959/61	3.7	92.9	9.6	-2.5
1959/61 to 1967/69	4.3	95.3	2.5	2.2

Source: G.F. Patrick (s.d.), in J.C. Garcia, R. Venkovsky.

Table 5

GROWTH AND SOURCE OF PRODUCTION GROWTH IN MAIZE
1970/72 to 1980/82

Increase in production		6 820 770 t.
Increase due to:		
Addition in area	33.4 %	2 281 390 t.
Addition in yield	66.6 %	4 477 350 t.
Addition in location	0.1 %	62 026 t.

Source: J.C. Garcia and R. Venkovsky, n.d.

The 1986/87 maize harvest, in the wake of the consumer explosion and the frozen interest rates of the Cruzado Plan, reached a record 26.14 million tons. The following year it fell to 24 million, with soybean production in the Centre-South higher than maize. This reflects the severe fluctuations in the Brazilian economy in recent years, with purchasing power falling and difficulties in maintaining export markets for poultry and favourable international prices for soybean. As a result, larger and more modernised farmers have shifted to soybean production.

In the last two decades, maize production has been tied to expansion of the poultry sector. Production increases have therefore been absorbed as animal feed. As shown in Tables 6 and 7, maize is Brazil's most important cereal in volume of production, accounting for almost half the total, followed by soybeans and rice. A sack of soybeans costs twice as much as one of maize, which is the cheapest cereal on the Brazilian market.

Table 6

GRAIN PRODUCTION - 1976/77 to 1986/87
(Millions of 60kg sacks)

(Harvest)	Rice	Beans	Maize	Soya	Wheat	(Total)
1976/77	149.90	38.17	320.93	208.55	34.43	751.98
1977/78	121.60	36.57	226.15	159.02	44.85	588.18
1978/79	126.58	36.43	271.77	170.67	48.78	654.23
1979/80	162.93	32.80	339.53	252.60	45.03	832.90
1980/81	137.03	39.02	351.95	250.12	36.83	815.05
1981/82	162.25	48.38	364.03	213.93	30.45	819.05
1982/83	129.03	26.35	312.18	243.03	37.28	747.88
1983/84	150.45	43.77	352.73	259.02	33.05	839.02
1984/85	150.42	42.48	366.97	304.97	72.00	936.52
1985/86	173.42	36.98	342.35	222.25	93.97	868.97
1986/87	173.70	33.65	446.45	280.23	98.15	1 032.18

Source: IBGE, *Agroanalysis*, July 1988.

Table 7

GRAIN PRODUCTION AT CONSTANT PRICES FOR HARVESTS
1975/76 to 1986/87
(Millions of Cz$)

Harvest	Rice	Beans	Maize	Soya	Wheat	Grains
1975/76	238 952.43	117 394.33	219 895.08	269 904.93	93 578.53	939 725.30
1976/77	220 266.29	146 104.90	238 538.65	300 821.27	60 116.06	965 847.17
1977/78	178 681.66	139 979.98	168 089.48	229 372.31	78 302.18	794 425.61
1978/79	186 004.28	139 469.57	201 994.77	246 176.76	85 169.26	858 814.64
1979/80	239 417.75	125 560.89	252 363.39	364 360.04	78 622.26	1 060 325.13
1980/81	201 506.67	149 358.77	261 592.27	360 778.77	64 306.14	1 037 542.62
1981/82	238 413.65	185 215.08	270 573.39	308 586.41	53 161.68	1 055 950.21
1982/83	189 604.36	100 869.80	232 035.08	350 561.47	65 091.78	938 162.50
1983/84	221 074.47	167 542.13	262 174.49	373 616.51	51 700.94	1 082 108.54
1984/85	221 025.49	162 629.43	272 753.64	439 439.94	125 702.50	1 221 551.00
1985/86	254 822.19	141 575.01	254 456.92	320 582.72	164 053.40	1 135 490.24
1986/87	255 238.52	128 814.76	331 830.85	404 220.32	171 356.95	1 291 461.40

Source: IBGE, *Agroanalysis*, July 1988.

Maize is produced throughout the country but mostly in the Centre-South and the South. From 1975 to 1987, the North-East contained 12 per cent of total area cultivated but only six per cent of total production. As a result, except for 1984-86, the North-East has had to import maize from other regions or from abroad.

Paraná state, the largest producer (about 20 per cent of the total), consumes almost all its production, while other producer states (Saõ Paulo, Rio Grande do Sul, Santa Catarina), as a result of the poultry industry, are net importers depending largely on production from the Centre-West, and particularly Goias state, which has the largest maize surplus.

This situation affects prices through transport costs because of the long distances between main producer and consumer regions and will probably lead to relocation of the poultry industry.

Marketing

Maize in Brazil has traditionally been a domestic market product, with imports and exports only marginal (Table 8). The only exception was during 1986/87 when imports were as high as 15 per cent of domestic consumption.

Table 8

BALANCE IN SUPPLY AND DEMAND OF MAIZE
1980/81 - 1987/88
(Thousands of tons)

Year	Initial Stock (1)	Production (2)	Imports (3)	Total Supply (4) = (1)+(2)+(3)	Internal Consumption (5)	Surplus (6) = (4)-(5)	Exports (7)	Final Stock (8) = (6)-(7)
1980/81	1 180	21 283	0	22 463	21100	1 363	0	1 363
1981/82	1 363	21 604	0	22 967	20 600	2 367	543	1 824
1982/83	1 823	19 014	465	21 302	19 740	1 562	739	823
1983/84	824	21 178	0	22 002	19 700	2 302	1 802	122
1984/85	2 121	21 174	200	23 495	21 053	2 442	0	442
1985/86	600	20 264	2 936	23 800	22 200	1 600	0	1 600
1986/87	1 600	26 770	360	28 730	25 810	2 920	0	2 920
1987/88	2 920	25 031	0	27 951	23 730	4 221	0	4 221

(*) Provisional estimate.
(**) Initial stock for harvest 1985/86 refers to 1/3/86.
Final harvest stock 1984/85 refers to 31/12/85.

Source: I. Wedekin and L.A. Pirazza, 1988.

Brazilian maize is internationally competitive at farm level, but storage and transport costs are prohibitive. This is particularly so in the Centre-West. Even so, "packaged maize" in the form of poultry is highly competitive internationally.

In general, marketing is through traders - 85 per cent in the North-East and 65 per cent in other regions. Most maize producers do not belong to cooperatives.

Inadequate storage is the main cause of losses, especially with less modernised producers. There is no estimate of losses, which occur more during super harvests and cause reduction in nutritional quality, loss in weight and commercial value. Lack of interest in investing in storage is due to lack of incentive for immobilising capital in a sector where the state is quick to intervene with its controlling stocks when prices begin to rise.

Productivity

Temperate and sub-tropical regions are best for maize production in the current state of technology. There is no equivalent of the US "Corn Belt" in Brazil, but there are some areas of higher productivity, as shown in Table 9.

Table 9

CENTRE-SOUTH AND NORTH-NORTH-EAST
EVOLUTION OF MAIZE PRODUCTION
1980/81-1987/88

Year	Centre-South			North-North-East		
	Area (1000ha)	Production (1000t)	Yields kg/ha	Area (1000ha)	Production (1000t)	Yields kg/ha
1980/81	8 960	20 397	2 277	3 185	886	278
1981/82	9 512	20 139	2 117	3 257	1 465	450
1982/83	8 934	18 489	2 070	2 723	525	193
1983/84	9 449	19 375	2 050	2 755	1 802	654
1984/85	8 999	19 473	2 164	2 941	1 701	578
1985/86	9 644	18 074	1 874	3 439	2 190	637
1986/87	10 892	25 629	2 353	3 718	1 130	304
1987/88	9 622	22 542	2 343	3 712	2 489	671

Source: I. Wedekin and L.A. Pinazza, 1988.

However, as Table 10 below shows, the "low-tech" producer predominates in the North-East, whereas elsewhere input use is widespread. Disparities both between regions and within the same region greatly lower productivity. While this has increased in recent years, productivity still lags far behind averages in advanced countries. Only five per cent of farmers use recommended levels of fertilizer, and despite the volume of production, maize accounts for only 10 per cent of fertilizer use in Brazil.

Table 10

PERCENTAGE OF NATIONAL PRODUCTION
PERCENTAGE INCREASE IN PRODUCTION AND YIELDS OBTAINED (kg/ha)
FOR MAIZE IN REGIONS
1970/72 to 1980/82

Regions	Percentage of production		Percentage increase in production	Yields kg/ha 1980/82
	1970/72 (A)	1980/82 (B)		
North	0.4	1.2	361	1 296
North-East	9.5	4.3	-33	381
South-East	34.0	28.8	25	1 997
South	49.9	55.3	63	2 540
Centre-West	6.2	10.4	147	2 016
Brazil	100	100	47	1 777

Source: FIBGE, Garcia, Vencovsky, n.d. CNPMS.

Even so, in some regions productivity approaches the levels of advanced countries. The winner of the national maize productivity competition among the most "high-tech" farmers during the 1987/88 harvest had a per hectare production of 15 077 kilos.

Table 11

MAIZE YIELD IN THE UNITED STATES AND BRAZIL VARIOUS YEARS
(kg/ha)

Period	United States	Brazil	US/Brazil
1916/1917	1 530 (1)	1 690	0.91
1931	1 538 (2)	--[a]	--
1941	1 959 (2)	1 184[b](3)	1.65
1951	2 317 (2)	1 214[c](3)	1.91
1961	3 914 (2)	1 312 (3)	2.98
1971	5 449 (2)	1 339 (3)	4.07
1981	5 898 (4)	1 836 (3)	3.75
1980/1981	6 617 (4)	1 781 (3)	3.72

a no data. b year for 1945. c year for 1952.
1) *source*: Hunnicutt (1924).
2) *source*: Jugenheimer (1976).
3) *source*: FIBGE (v.a.).
4) *source*: USDA (1983); J.C. Garcia and R. Venkowsky, (n.d.).

The generally low productivity indicated in Table 11 reveals great potential for expanding production without resorting to incorporation of new areas. Such an increase is unlikely in the North-East however because of poor technology, because production is largely for on-farm consumption and because ecological conditions do not favour commercial production. Low soil fertility and irregular climate and rainfall discourage investment in commercial inputs. The practice of intercropping in its turn - recommended for such climatic conditions - lowers productivity even further.

Productivity in the region, which averaged 500kg/ha between 1976-88, could be increased with a combination of irrigation policies and production of seeds genetically adapted to the region. Irrigation is the key to production and stable productivity, in addition to full use of modern inputs. However, in the North-East, maize does not seem the best crop for irrigated agriculture. Other crops show greater returns.

Intercropping, as we have seen, is dominant in the North-East (some 90 per cent of total production) but is also present in the Centre-South (about 23 per cent of total production). In general, intercropping declines as production area increases. In the North-East (Table 12 and 13), on-farm consumption is as much as half of total production, whereas some two-thirds is marketed in the Centre-South.

Table 12

NORTH-EAST: COMMERCIAL AND RURAL CONSUMPTION OF MAIZE
1980-1984
(thousand of tons)

	1980	1981	1982	1983	1984
Commercial	712	716	698	710	732
Rural	938	914	962	898	988
(Total)	1 650	1 630	1 660	1 608	1 720

Source: CA, *Agroanalysis*, 87.

Table 13

NORTH-EAST: PRODUCTION AND CONSUMPTION OF MAIZE
1980-87
(thousands of tons)

Item	1980	1981	1982	1983	1984	1985[1]	1986[1]	1987[1]
Production	1 172.6	885.5	1 465.1	525.4	1 802.2	1 700.1	2 174.0	840.2
Consumption	1 650.0	1 630.0	1 660.0	1 608.0	1 720.0	NA	2 055.4	2 155.2
Difference	-477.4	-744.5	-194.9	-1 082.6	82.2	NA	114.6	-1 315.2

Source: CFP, *Agroanalysis*, December 1987.
1) Consumption estimated on basis of global data from North and North-East regions, with 86 per cent participation of the North-East.
n.a.: not available.

The Northern region, with its tropical climate and still-expanding frontier, has a precarious infrastructure. Its population centres are dispersed and population density is low. Maize production here is some 10 per cent of national production. Productivity is between that of the North-East and the Centre-South regions and averages about 1,250 kg/ha. The expanding frontier and constant increase in demand are responsible for a continuous expansion of maize production.

The Centre-South and Centre-West, despite heterogeneity of production systems, have the biggest proportion of capitalised farmers. In the Centre-West especially, large properties predominate. The more capitalised farmers generally buy their hybrid seeds annually, whereas farmers on a lower technological level tend to use a second generation produced on the farm, even though this lowers productivity. For a capitalised producer, hybrid seeds are between two to three per cent of his production costs. It is the second generation (S2) hybrid which is sold in Brazil rather than the S1, which is marketed in the United States. The S1 is more expensive, but more homogeneous and facilitates mechanisation.

The more "high-tech" farmer (responsible for 15-20 per cent of national production) is highly sensitive to price fluctuations and rapidly migrates to other crops. In recent years, this has led to loss of the most "high-tech" farmers to soybean production.

Consumption

Some 65 per cent of maize produced in Brazil is for animal feed, with 35 per cent for human consumption - fecula, starch, flour, and vegetable oil. There is little difference between different types of maize from the point of view of consumption.

Mainly used for poultry, maize is becoming increasingly important also for pigfeed and cattlefeed (in feed-lots). Between 1973 and 1987, domestic consumption of poultry meat more than tripled (+353 per cent) while pigmeat almost doubled (+174 per cent). The poultry sector has also become a major exporter (Tables 14 and 15).

Until the mid-1960s, pig and poultry production centred on the small farming sector. Towards the end of the 1960s and the early 1970s, the poultry industry began to occupy and expand the market. This involved imported matrices and international technology for large-scale poultry production. The animal feed and veterinary input sectors, based largely on multinational firms, accompanied this expansion. As Table 16 shows, there has been enormous progress in main productivity indicators - average weight, age of slaughter, food conversion and mortality rates.

Table 14

QUANTITY OF MAIZE TRANSFORMED BY THE ANIMAL FEED INDUSTRY
1971-85

Year	Thousands of tons
1971	1 700
1972	2 000
1973	2 500
1974	3 200
1975	3 500
1976	5 766
1977	6 628
1978	7 752
1979	9 742
1980	10 880
1981	9 631
1982	8 500
1983	7 737
1984	7 095
1985	7 307

Source: Agroanalysis, January 1987.

Table 15

POULTRY MEAT
PRODUCTION, EXPORT (QUANTITY, VALUE, AVERAGE PRICE), INTERNAL AVAILABILITY AND PER CAPITA CONSUMPTION

Year	Production[1] (t)	Exports			Internal Availability (t)	Per Capita Consumption (kg/ano)
		Quantity (t)	Value (US$1 000)	Average Price (US$/FOB)		
1980	1 306 000	168 713	206 690	1 225	1 137 287	9.6
1981	1 490 000	293 933	354 291	1 205	1 196 067	9.8
1982	1 604 000	301 793	285 475	946	1 302 207	10.4
1983	1 584 000	289 301	242 212	837	1 294 699	10.0
1984	1 443 000	287 494	268 976	936	1 155 506	8.8
1985	1 577 000	273 010	238 570	874	1 303 990	9.7

Source: APINCO, ABEF, IBGE, *Agroanalysis*, June 1986.
1) estimate on basis of poultry meat production.

Table 16

COMMERCIAL POULTRY
AVERAGE WEIGHT, SLAUGHTER AGE, RATE OF FOOD CONVERSION, MORTALITY
1934-1994

Year	Average weight (kg)	Slaughter age (day)	Rates of food conversion (kg of animal/ kg of feed weight)	Mortality (%)
1934	1.30	95	4.30	13.0
1944	1.35	84	3.90	10.0
1954	1.40	74	3.00	7.0
1964	1.58	63	2.30	5.5
1974	1.70	59	2.00	5.0
1984	1.89	47	1.96	4.5
1994[1]	2.05	42	1.82	4.5

Source: ANFAR.
1) projection.

During this period, the matrices have been entirely imported. Agroceres however has now contracted with Ross Breeders of Scotland for the transfer of genetic lines and their production in Brazil.

Maize is the principal component (about two-thirds) of commercial animal feed and represents 70 per cent of the final cost of poultry and 80 per cent in the case of pigs. Favourable prices for poultry compared with red meat have accounted for the constant increase in demand for it among Brazilians.

In 1988, per capita consumption of red meat in Brazil was 13.5 kilos per year, as against 12.4 kilos in the case of poultry. In the United States, the figures are 33 and 37 kilos respectively. Both countries have shifted towards white meat consumption. In the United States in 1980, the figures were 35 and 28, and in Brazil 15.6 and 9.5 respectively. In the United States, the shift represents changing health habits. In Brazil, it reflects a decline in purchasing power for most of the population during the 1980s (Table 17).

Table 17

SAO PAULO STATE
NOMINAL AND REAL VALUES OF MONTHLY MINIMUM WAGE
NOMINAL AND REAL PRICES OF RED MEAT AND POULTRY
1970-85

	Minimum Wage			Red Meat			Poultry		
	Nominal	Real		Nominal	Real		Nominal	Real	
Year	Cr$	Cr$	1970=100	Cr$/kg	Cr$/kg	1970=100	Cr$/kg	Cr$/kg	1970=100
1970	192	192	100	4.05	4.05	100	4.00	4.00	100
1971	232	193	101	5.02	4.17	103	4.30	3.57	89
1972	292	207	108	5.97	4.23	104	4.96	3.51	88
1973	330	204	106	8.91	5.49	136	6.76	4.17	104
1974	387	185	96	10.97	5.26	130	8.41	4.03	101
1975	525	197	103	13.94	5.22	129	9.49	3.56	89
1976	754	200	96	16.89	4.48	111	13.22	3.51	88
1977	1 086	202	104	22.53	4.19	103	16.95	3.15	79
1978	1 539	206	107	40.61	5.45	135	26.31	3.53	88
1979	2 387	208	108	76.84	6.69	165	43.63	3.80	95
1980	4 500	196	102	140.86	6.13	151	72.66	3.16	79
1981	9 144	190	99	234.48	4.86	120	133.39	2.77	69
1982	18 172	193	101	433 03	4.59	113	227.37	2.41	60
1983	39 524	165	86	1 265.83	5.27	130	686.00	2.86	72
1984	109 268	142	74	3 889.60	5.07	125	2 103.00	2.73	68
1985	372 080	149	78	11 646.00	4.65	115	6 602.00	2.64	66

Source: Banco Central and IEA-SP, *Agroanalysis*, January 1987.
1) corrected by the IGP-DI for 1970.
2) includes the 13th month wage.

Most white meat production is in the South, whence it is exported to other regions and abroad. A sharpening of international competition (from the United States, Europe and more recently Thailand), together with increased domestic production by erstwhile importers (Middle East), has harmed Brazilian exports (Tables 18 and 19). In 1987, Brazil was still the third largest exporter but its share was cut from 17 to 15 per cent. The United States on the other hand increased its share from 21 to 26 per cent. French exports fell from 19 to 17 per cent. While industrialised countries benefit from export subsidies, Brazilian producers have had to face the effects of a fiscal crisis which has reduced direct and indirect subsidies to exporters.

Table 18

POULTRY
EXPORTS (QUANTITY, VALUE AND AVERAGE PRICE)
1975-1985

Year	Quantity (tons)	value ($1 FOB)	Average price ($/ton)	% variation in price
1975	3 469	3 289	950	-
1976	19 636	19 565	1 000	5
1977	32 829	31 572	960	-4
1978	50 805	46 872	920	-4
1979	81 096	81 148	1 000	9
1980	168 713	206 690	1 230	23
1981	293 936	354 291	1 210	-2
1982	295 551	280 657	950	-21
1983	299 231	251 476	840	-12
1984	287 494	268 976	936	12
1985	273 010	238 570	874	-7

Source: ABEF (a producer organisation), *Agroanalysis*, January 1987

However, new export markets have been won - Cuba, for example - and Brazil is developing competitive capacity in high quality markets since its combination of advanced technology and low labour costs allows it to explore the dynamic markets for speciality cuts (e.g. Japan).

Table 19

BRAZIL AND THE UNITED STATES
SALES OF POULTRY TO EGYPT AND IRAQ
1985-1987
(tons)

Origin	Destination: Egypt	Destination: Iraq
Brazil		
1985	50 019	65 629
1986	5 454	24 985
1987	---	13 333
USA		
1985	6 198	---
1986	25 575	---
1987	26 527	58 479

Source: United States Department of Agriculture (USDA) and ABEF, *Agroanalysis*, May 1988.

So far, non-traditional alternative uses of maize have not been developed nor are they being researched in Brazil. The combination of the sugar lobby and government subsidies has prevented use of maize as an alternative sweetener.

Policies

While there are no individual policies for maize, production is particularly sensitive to overall agricultural policy. Expansion of maize production cannot be dissociated from the subsidised credit which financed consolidation of the poultry industry in the 1970s. The subsidy for wheat over the last two decades (although recently this has declined) affects maize consumption as an alternative component in bread production.

Pressure of debt on hard currency earnings has led the government to support exports, while the struggle against inflation has led to rigid controls and at times freezing of prices of products for the domestic market. Resulting low prices for meat and grains have led farmers to move to soybeans.

Minimum price policies have been the main form of public support in recent years (Rezende, 1989) since storage is risky when the government uses its stocks or imports in the inter-harvest season to control inflationary pressures.

Most important however for maize production are macro-policies determining purchasing power, especially with increased competition in export markets. So production expansion is tied to development of the domestic market.

Public Control and Property Rights

Public controls over seed production are recent and still being consolidated. At first, Saõ Paulo state developed its own system for seed certification. It began in 1936, mainly concerned cotton and was completed in 1968. It involved control over seed origin, the establishment of quality norms, inspection and marketing systems. In this period, the Saõ Paulo state agricultural department was the main seed producer and had a stronger research infrastructure than the Federal Government.

In 1965, the Ministry of Agriculture laid down the first norms for inspection of seed sales, and began studies to define legislation in the area. The National Seed Plan was set up in 1967 as part of a global policy for developing the sector. This policy aimed to strengthen private sector participation while the public sector would continue basic research, quality control and inspection of the marketed product.

PLANASEM, as the national plan was called, distinguished a developed zone in the South and the South-East, and a priority zone in the North, North-East and Centre-West. In the former, private initiative was to be given pride of place. In the second, the state needed to develop infrastructure to enable growth of the private sector.

The law recognises two types of improved seeds: certified seeds with control over genetic origin through multiplication of basic seeds, and inspected seeds whose origin are known but which have not necessarily been multiplied from basic or certified seeds.

While seed inspection is now carried out in all states, certified seeds are still being consolidated in several states and are dominant only in Saõ Paulo.

Seed policy and inspection is carried out by state bodies linked to the federal organ CONASE, the National Seed and Plant Commission, created in 1978. While the latter defines minimum legislation, each state may add its own laws.

Brazilian law does not protect plants and animals. The system of patents is also excluded from the pharmaceutical and food industries both in terms of product and processes.

This may change soon. The new agricultural law being debated in Congress includes an article stipulating that within a year of promulgation, Brazil should regulate intellectual property rights of plant origin. Equally important is consensus in favour of legislation for the area among most of the seed sector and a large part of the public sector research community. In the private sector, there is concern about retaliation by potential importers of Brazilian seeds and plants because of the lack of legal protection. In fact, this has already happened. Equally important however is the need to enter new areas involving transfer of technology which is only possible if there is legal protection. Without such protection, the risk of investing in research into biotechnologies becomes too high since, unlike hybrids, they have no in-built monopoly which would dispense with legislation.

As we shall see, in the public sector, researchers are having to face the impact of fiscal crisis and particularly the effect of inflation on salaries. The possibility of royalties which would benefit researchers and help finance research centres is a major motive for the support by researchers for legislation. Finally there is agreement that in agricultural research, and particularly classical genetics, Brazil already has an internationally competitive capacity.

Part Two

RESEARCH, TECHNOLOGY, DEVELOPMENT AND DIFFUSION

Historical Background - The Shaping of the Public and Private Seed Sectors

While several agronomic centres were established in Brazil over the last century, agricultural research became concentrated in the Campinas Agronomic Institute (IAC) belonging to the state of Saõ Paulo. The Institute was a response to the coffee frontier's shift from the state of Rio, and its early years were devoted to work on this crop. Overproduction of coffee and the subsequent collapse of world prices stimulated agricultural diversification and with it demands for broader agricultural research, with cotton as the main beneficiary.

Interest in improving quality of coffee and cotton fibre led to emphasis on basic research rather than crop practices and field experiments. As a result, the Institute was restructured in the late 1920s to separate applied from basic research activities. Within the latter, a Genetics Section was formed under the Austrian E. Taschdjian. Coffee remained the research priority but the technological frontier in genetics was to favour work on maize.

A year after the restructuring, the agronomist C.A. Krug received a grant to specialise in genetics and citology at Cornell University. He researched into maize and wrote his thesis on the most recent developments in citogenetics and crop improvement as applied to maize.

With the return of Krug in 1932, maize improvement was integrated into the IAC's Genetics Section. This work focused on the controlled self-fertilisation of yellow hard grain Cateto varieties, white hard Cristal, and white-grained Amparo varieties with a view to deriving homogeneous lines for future synthesis of hybrid maize. During the late 1930s and 1940s, Cateto, Armour, and Asteca hybrid maize varieties were launched in Saõ Paulo state.

But there was a basic obstacle. Maize in Brazil is planted at different latitudes to the Corn Belt in the United States. So while the methodology of hybrids was adopted from the United States, resistance factors had to be incorporated from local lines (Cateto).

Maize research was also developed in the 1930s at Viçosa University in the Minas Gerais state, and was similarly directed towards hybrids as a result of training in the United States. The influence of this foreign postgraduate training at a time when the United States was wholly engaged in hybrid research would seem to explain the shift from open pollinated to hybrid research in Brazil. Research on hybrids in Viçosa began in 1937 using 100 North American lines. But only one was successful, and attention was directed to local lines crossed with a Mexican variety.

Close collaboration was maintained with US research, particularly at Purdue University. Developments in Viçosa however took a different direction from that at Campinas. After withdrawal of two leading researchers to form the private firm Agroceres, public research at Viçosa was paralysed. In compensation, Agroceres was to become the leading maize seed company in the Brazilian market.

With the success of the Saõ Paulo public sector in production of varieties, the question of diffusion defined priorities during the 1940s. In 1945, a special farm for hybrid maize production was established by agreement between the department of agriculture and the Saõ Paulo state government. This farm worked in close collaboration with the genetics section of the Campinas Institute, producing simple hybrids for subsequent commercial production of double hybrids. New varieties were launched in the late 1950s incorporating germplasm from Mexico.

By 1950, the Saõ Paulo department of agriculture was distributing over 3,000 tons of hybrid seeds - enough for half of the state's needs. Despite a doubling of the area planted with maize during the 1950s, diffusion of hybrids kept pace and accounted for more than half of Saõ Paulo's maize production.

The success of this integrated seed production system in Saõ Paulo enabled implementation of a Seed Certificate Procedure for hybrid maize in 1957, which implied public control within Saõ Paulo state over genetic origin of seed production in the private sector, in addition to imposition of quality norms and inspection of sales.

The 1960s however saw basic restructuring of public sector research, involving also redefinition of relations with the private seed industry. Three factors can be identified:

i) consolidation of a mature seed industry for hybrid maize
ii) a new national model of agricultural research
iii) expansion of the agricultural frontier to the South and Centre-West.

The seed research and production system in Saõ Paulo had promoted a network of small national firms with no in-house research base which multiplied and marketed public sector basic seeds. Of private firms in the 1950s, only Agroceres marketed its own variety - the AG7. Trials by Agroceres in the late 1940s showed that its hybrids were competitive against both open pollinated varieties and hybrids from the Campinas Institute. The latter's HMD 6999 public sector variety however was widely considered the most competitive. By 1959, the seed firms had joined to form the Saõ Paulo Association of Seed Producers.

Friction between public and private sector grew in the 1960s. The department of agriculture, with eight seed production posts, was able to supply over half the Saõ Paulo market. Its prices were also very close to normal grain prices. Serious over-production resulted and firms were left with large stocks. As a result, strong pressure was exerted to redefine public sector participation in seed markets.

After 1968, the Campinas Institute and other public research centres limited themselves to production of basic seeds and launching of hybrids was halted.

The strong public sector presence in Saõ Paulo led to predominance of small national firms in this state which depended on the Campinas Institute for research and launching of new hybrids. The exception at national level was Agroceres which, as we have seen, emerged from public research and in alliance with the US IBEC Corporation in the mid-1940s. Before the end of the decade it was launching its own varieties. It initially sought agreement with established agro-industrial firms for sales outlets (Anderson Clayton, Serrano), but quickly launched its own network and established decentralised processing units in all zones of future maize expansion. This decentralised presence at national level gave Agroceres a decisive advantage when major foreign firms began to enter the Brazilian market.

Cargill, which was to become the major foreign seed firm, established itself in Campinas in the mid-1960s and Pioneer set up shop in Rio Grande do Sul. The Corn Products Company subsidiary, Refinaçoes de Milho, which dominates maize processing in Brazil, was also active in seeds, marketing material from Funks. An unsuccessful attempt at market expansion however led it to sell out to Ciba-Geigy, which had meanwhile bought out Funks.

So pressure from the emerging private seed industry forced redefinition of the public sector's role and established a new national model. This was first evidenced in the National Seed Inspection Law of 1965 which rejected the genetic control of the Saõ Paulo certificate system in favour of physical controls over quality. This was followed by the National Seed Plan, which implied general redefinition of the public sector's role, limiting it to research and basic seed production. The Plan distinguished two zones - developed and priority - stimulating the private sector in the former (South and South-East) and assuming responsibility for diffusion of improved seeds in the latter (North and North-East).

These changes were part of global restructuring of public sector agricultural research which led in the early 1970s to creation of the Brazilian Agricultural Research Enterprise (EMBRAPA). Heavily influenced by the North American agricultural expert Edward Schuh, research was now organised around individual products rather than disciplines and strongly integrated into the network of International Agricultural Research Centres. Within this framework, the Brazilian National Centre for Maize and Sorghum (CNPMS) was established in 1976.

This consolidation of national research structure reflects expansion of the agricultural frontier away from the Saõ Paulo area. This is true also for maize, which assumes a growing importance as an input for the pig and poultry industry in the states of Paraná and Santa Catarina, stimulated also by growth of soybean production in the southern states. Without the long tradition of the Saõ Paulo public sector, plant improvement research in these states was not accompanied by production and marketing capacity. National policy was therefore to encourage emergence of a private seed industry, welcoming also foreign subsidiaries, since within the global science and technology policy of this period, agriculture was considered nonstrategic and open to foreign capital.

The National Public Sector Research Structure

Within the restructuring of public sector research, the National Centre for Maize and Sorghum in Minas Gerais, on the edge of the "cerrado" grains frontier region, became responsible for coordinating all maize research included for public financing. Data up to 1985 shows that the National Maize Research Programme comprised 148 projects developed by 31 research institutes (Table 20). As can be seen from the table however, research is very broad with only 43 projects directly concerned with genetic improvement. The CNPMS is itself responsible for 40 projects but only six concern genetic improvement (Table 21).

Table 20

NUMBER OF PROJECTS IN DIFFERENT LINES OF RESEARCH BY REGION IN THE PNP[1] MAIZE PROGRAMME UNTIL DECEMBER 1985

	Regions				
Evaluation of cultivars	North	North-East	South	Centre-South	Total
Improvement	5	6	3	29	43
Evaluation of cultivars	6	8	3	8	25
Crop practices	1	1	3	12	17
Fertilizer + nutrition	1		2	13	16
Storage pest control	1	2	1	6	10
Weed control		1	1	1	3
Irrigation			2	4	6
Soil treatment			1	2	3
Seed technology	1			1	2
Field pest control			1	6	7
Phytopathology				5	5
Economy				2	2
Mechanisation				2	2
Plant physiology				2	2
Climatology			2		2
Microbiology				1	1
Statistics				1	1
Technology diffusion				1	1
TOTAL	14	19	19	96	148

Source: CNPMS.

1 National Research Programme.

The maize improvement programme is based on work with plant populations or varieties as progenitors of intervarietal hybrids, or extraction of lines for creation of simple, double, triple and/or synthetic hybrids.

The programme's main aims, according to the CNPMS's quinquennial report, were production of modern cultivars with the following characteristics:

i) low size
ii) higher relation of dry material to total grain weight
iii) resistance to the main leaf diseases
iv) good capacity for converting nutrients into grain
v) greater tolerance to drought and mineral stress, especially aluminium
vi) greater efficiency in the use of energy
vii) high quality protein (lysine, triptophane)
viii) improvement of seeds for production of popcorn

Tropical maize populations have abundant foliage, are high in size and have a long cycle. Research in Brazil is increasingly interested in smaller cultivars which allow for greater population density and facilitate mechanical harvesting. Thirty-three populations of smaller cultivars from CIMMYT have been analysed and as a result, maize improvement research can now work with new small-size precocious and intermediary cycle populations.

Table 21

NATIONAL MAIZE RESEARCH PROGRAMME
PARTICIPANT INSTITUTIONS BY REGION AND NUMBER OF PROJECTS UNTIL DECEMBER 1985

Region	Institution	No of projects	Total
North	UEPAE/Rio Branco	1	
	UEPAE/Porto Velho	5	
	UEPAE/Manaus	2	
	UEPAE/Belem	2	
	UEPAT/Boa Vista	2	
	UEPAT/Macapa	2	14
North-East	EMAPA	2	
	UEPAE/Teresina	2	
	EMPARN	1	
	IPA	3	
	EPACE	2	
	EPABA	4	
	EMEPA	1	
	EPEAL	2	
	CNP-Coco	2	19
South	EMPASC	6	
	IPAGRO	9	
	FECOTRIGO	3	
	UFSM	1	19
Centre-South	IAPAR	4	
	FEALQ	10	
	IB	1	
	IAC	2	
	UEPAE/Dourados	2	
	EMPAER	2	
	UEPAE/Caceres	4	
	EMGOPA	8	
	EPAMIG	9	
	PESAGRO	6	
	EMCAPA	8	
	CNPMS	40	96
General total		148	148

Source: CNPMS.

In the North, where commercial production is very weak, the programme stimulates development of open pollinated varieties with specific agronomic characteristics: small size, early and medium cycles to avoid rains at harvest time, compactness to reduce insect attacks and improve storage conditions. Seven cultivars have resulted from this cooperation with research centres in the region.

In the North-East, the aim is to produce cultivars adapted to the three major climatic zones in cooperation with institutes in the region (Table 22). Eleven open pollinated varieties have so far been selected and three already launched (BR 105, 106, 108). Great hopes are now with a new variety recently launched, the São Francisco (BR 5028), which combines great adaptability with high productivity. These improved varieties are the basis of a future programme for production of hybrids which will respond to high level investment initiatives. The varieties chosen show great diversity in terms of cycle, which makes them appropriate for different rainfall conditions, but also for irrigated agriculture, enabling more than one harvest a year. Productivity of these varieties in the different climatic zones ranges from five to as much as eight tons per hectare (Table 23), with irrigation.

Table 22

MAIZE
IMPROVED VARIETIES DEVELOPED BY RESEARCH INSTITUTES
IN THE NORTH-EAST WITH CNPMS COOPERATION

Institution	Variety	Characteristics
EMPAPA, MA	CMS 04	Intermediary cycle
	CMS 07	Intermediary cycle
UEPAE Teresina, PI	BR 5006 Fidalgo	Intermediary cycle
EPACE, CE	EMPAMIL	Early cycle
EMPARN, RN	BR 5037 (Cruzeta)	Very early cycle
	CMS 35	Very early cycle
IPA, PE	Dentado	Late cycle, tall plant
	Composto-NE	
	Jatina C3 Anao	Early cycle, short plant
	CMS 22	Early cycle, short plant
EPEAL, AL	Centralmex	Late cycle, tall plant
CNPCO, SE	CMS 28	Early cycle, short plant
	CMS 11	Early cycle, short plant
EPABA, BA	BR 105	Early cycle, short plant

Source: CNPMS.

Uneven yields and the traditional nature of maize production mean there is little interest in production of seeds by private firms in the North-East. Diffusion of new varieties is therefore a major problem. Recent seed distribution campaigns of new maize varieties by North-Eastern state governors have had an important effect on productivity and may help increase use of improved varieties. The major seed firms however are still not present in the North-East. Agroceres has shown continuous preoccupation with the North-Eastern market, and even set up Agroceres Nordeste in 1975, only to close it down in 1979.

Under this programme, EMBRAPA's national centre, CNPMS, has an Active Germplasm Bank responsible for collecting, characterising, preserving and evaluating maize germplasm. Along with EMBRAPA's National Genetic Resource Centre (CENARGEN), CNPMS is in touch with with the world's main genetic resource centres. CENARGEN has a data bank on maize germplasm with on-line facilities for researchers.

As a result of this national research programme, coordinated by the CNPMS, varieties are available which are adapted to different agricultural regions of Brazil. In 1980/81, national trials included 25 early varieties, 35 normal ones and 14 short-stemmed varieties. Particularly notable was the recent launching of the cultivar BR 201, a hybrid suited to acid soils of the "cerrados," with higher resistance to heat, less need for expenditure on soil correction, adapted to mechanical harvesting and with yields of 8.5 tons per hectare. The work of EMBRAPA has been important in rapid expansion of the "cerrados" frontier since the mid-1970s.

Table 23

MAIZE YIELDS IN THE NORTH-EAST
1976-86 (kg/ha)

	State									
Year	MA	PI	CE	RN	PB	PE	AL	SE	BA	NE
1976	581	360	425	249	362	550	357	480	684	473
1977	596	660	660	506	657	797	604	720	674	663
1978	569	577	540	360	517	708	538	554	735	596
1979	567	443	422	122	402	541	548	673	712	521
1980	546	254	240	43	131	350	521	645	683	397
1981	310	165	180	84	123	225	436	302	315	253
1982	549	353	307	144	124	403	352	858	460	411
1983	238	121	120	71	136	156	383	440	311	195
1984	575	791	532	443	579	800	568	981	189	571
1985	348	713	372	355	560	651	463	1 041	869	592
1986	579	601	610	527	666	830	523	884	623	639
Average yield in the NE										500

Source: CNPMS.
MA - Maranhao; PI - Piaui; CE - Ceará; RN - Rio Grande do Norte; PB - Paraiba; PE - Pernambuco; AL - Alagoas; SE - Sergipe; BA - Bahia; NE - North-East.

Population Varieties

As we have seen, hybrids rather than population varieties have dominated public sector research in Brazil from the outset. Research in Brazil from the 1930s on was based on maize hybrid research in the United States. Work on population varieties has been restricted to the more subsistence production conditions in the North. Market share of population varieties is thus very limited and is around five per cent. This figure is hard to gauge however since such varieties can be re-used by farmers. Their diffusion seems to be limited by the type of grain, which is not favoured, and the price which is not much cheaper than hybrid varieties. Recently however, in 1988, EMBRAPA developed a new high protein quality variety, the BR 451.

In their work on population varieties for the Northern region, researchers cite the following advantages:

i) Production and maintenance of seeds from open pollinated varieties are relatively simple, so planning targets can be easily and rapidly reached.

ii) New and better varieties extracted from a continuously-improving population can replace old varieties, either with new ones or improved versions of existing ones. Exchanges between one variety and another can be carried out rapidly, as when a diseased variety needs to be replaced by a resistant or tolerant variety.

iii) Production costs for seeds are relatively low and quantities can be quickly increased. Commercial production of grains is possible in only two generations from the improved seed.

iv) Open pollinated varieties are distinctly advantageous where distribution is difficult. Seeds from such varieties can be taken from farmer to farmer and stored for several years.

v) Exchange of cultivars between national programmes is easier than with cultivars which involve property rights.

Interestingly, as we will see below, developments in biotechnology research in Brazil have also included work on open-pollinated populations.

The recent interest shown by major cooperatives in the South may influence developments in favour of population varieties. The two major cooperative groupings in the states of Rio Grande do Sul and Paraná - COTRIJUI and OCEPAR have launched research programmes on maize populations. This may challenge the private hybrid seed market.

As we have seen however, for the more developed markets of the South, the public sector has traditionally developed hybrids and continues to do so, as a new hybrid variety for the "cerrados" indicates. According to CNPMS researchers, for productivities of up to five to six tons per hectare, open pollinated varieties are competitive with hybrids. The latter however are more responsive to modern inputs and may yield up to 10 tons, whereas varieties produce at most half that.

But the decisive argument for hybrids seems to be the scope they provide for emergence of a private seed industry, since seeds cannot be saved from a first planting for planting a second time without substantial decreases in yield.

International Cooperation

An extensive network of international cooperation has been developed since the 1970s. The CNPMS cooperates with CIMMYT in Mexico, exchanging varieties and training researchers. Details of international CIMMYT trials in Brazil can be seen in Table 24. Since 1976, CNPMS population selections have made intense use of CIMMYT material. More recently, 23 populations of high protein quality have been introduced and are being analysed for productivity and adaptation.

Table 24

CIMMYT INTERNATIONAL TRIALS CARRIED OUT IN BRAZIL

Type	1980/81	1981/82	1982/83	1983/84
IPTT	2	--	6	5
EVT	8	12	14	25
ELVT	4	9	0	2

Source: CNPMS.

In addition to international disease trials, the CNPMS participates as regional coordinator of the Maize Project in the Institute for Interamerican Agricultural Cooperation's (IICA) Southern Cone Programme for Agricultural Research supported by the Inter-American Development Bank. The CNPMS's most significant contribution has been selection of a composition of hard grains, formed through controlled recombination of eight types of germplasm from six countries. In 1981, the crosses were carried out and two years later the Southern Cone composition was sent to participating countries for selection. In 1985, progenies were obtained for testing in the six countries of the Southern Cone and the composition is now being improved by a method of convergent-divergent capacity selection. In contrast with other crops, public plant improvement capacity in maize now falls behind the private sector and the CNPMS has only four doctorates in plant improvement. In 1982, there were only an estimated nine for the whole national public sector maize improvement programme, while the private sector had an estimated 13.

Biotechnology and Maize Improvement

In recent years, biotechnology has been become a priority within EMBRAPA and the CENARGEN is now a centre of excellence. Two institutes are involved in application of biotechnology to maize improvement - the Escola Superior de

Agricultura Luis de Queiroz (ESALQ) and the University of Campinas (UNICAMP), both in Saõ Paulo. According to Dr Moro, an ex-EMBRAPA researcher working at the ESALQ, for biotechnologies to be useful for introduction of genetic variability, the plant must be capable of regeneration "in vitro." So far, with maize, few lines or hybrids have responded to tissue culture. The genetics departments of ESALQ and UNICAMP have confirmed this using the methodology of Green and Phillips. Given the genetic variability of tropical and subtropical maize - more than 250 races have been described - introduction of exogenous variability is determined by aims such as herbicide resistance, resistance to specific diseases or development of a more efficient system of male sterility. Biotechnology however offers alternatives for obtaining lines through culture of haploid cells and subsequent duplication of the chromosomic number.

Work on regeneration of somatic maize tissue has begun in the genetics departments of ESALQ and UNICAMP. The methodologies developed in the international literature were followed with small changes in line with the different genotypes of Brazilian maize. Both laboratories soon mastered the technique.

Within ESALQ, two laboratories in the genetics department are working on maize tissue culture with a focus on citogenic and citological regeneration, and exploring possibilities of maize genetic improvement.

Few genotypes respond positively to "in vitro" tissue culture, so work has been on populations of open pollinated varieties within the National Maize Programme. Sixteen synthetics from different groups of elite lines have been used. These lines are now in the S4/S5 generation and most can still be regenerated somatically.

Current research on maize tissue culture focuses on possibilities of somaclonal variation in genetic improvement of maize. Effects of induced "in vitro" genetic variability, both in themselves and in crosses, are compared with the classic programme for obtaining lines through self-fertilisation.

Production of diploid homozigotic lines on the basis of cells and/or haploid tissue lines is also being researched. So far, about 40,000 non-pollinated ovaries have been placed in cultures to produce haploid seedlings. These ovaries have been reasonably developed but as yet without regeneration. The methodology needs considerable development for success with maize. "In vitro" fertilisation seems to be more promising through modifying the nutritive culture with hormones and other compositions to alter the process of double fertilisation. Results are hoped for soon.

Links with the private sector do not seem organised yet around specific research programmes. Agroceres, for instance, has supported the genetics centre at Campinas through financing researchers' salaries. This seems to reflect the state of biotechnology research, which is still at the level of mastering the main techniques.

So while in classical genetics Brazil has a research structure able to accompany international advances, in biotechnology research centres are mostly at the stage of mastering techniques and forming research teams, and no private firms are in a position to generate new advances.

Public Sector Sales and Diffusion

With the disorganisation of the Campinas Agronomic Institute (IAC) and restructuring of the national maize research and production programme, the launching of public sector commercial hybrids was discontinued. Nevertheless the Coordination for Integrated Technical Assistance (CATI) in Saõ Paulo still markets its double hybrids, especially the HMD 7974 variety which dates from 1966, and in 1980/81 still produced over 25,000 tons, some 15 per cent of the Brazilian market. Only 25 per cent of this is produced by CATI itself. The rest is produced by more than 20 private firms, mainly small national companies with no research base, but also including foreign firms awaiting development of their own varieties.

By the 1980s, CATI had a powerful production and sales infrastructure in Saõ Paulo, with sales outlets in every administrative district. Annual production was around 9 000 tons. Pressure from the private sector has since led to curtailment of its activities, and production of commercial maize seed is now only about 4,000 tons a year. On a national scale, the EMBRAPA Centre for Basic Seed Production (SPSB) sells mainly population varieties (Table 25).

Table 25

MAIZE
CULTIVAR SOLD BY THE SPSB IN 1981

Cultivar	tons	per cent
Maize population	914.0	79.2
Maya	472.3	40.9
Centralmex	319.2	27.7
EMGOPA	45.5	3.9
BR 501	40.3	3.5
BR 126	33.1	2.9
Others	3.6	0.3
Maize hybrid	240.0	20.8
Total	1 154.0	100.0

Source: SPSB.

More recently, the Saõ Paulo department of agriculture has produced two new hybrids (HMD 8214 and HMD 8222) and the Institute of Agricultural Research in Rio Grande do Sul (IPAGRO) has produced varieties under the name SAVE with very good results in official trials. In 1986, EMBRAPA launched its hybrid for the "cerrados" which has proved equal to the best from either Cargill or Agroceres. The adaptability of this hybrid now allows it to be planted from the state of Santa Catarina northwards. EMBRAPA sells the parents to private national companies which then produce the double hybrid for sale to farmers. Launching this hybrid has given new life to small seed firms which depended increasingly on aging lines from the Saõ Paulo public sector. The area planted with this hybrid has jumped from 45,000 ha in the first year to 340,000 in the second and a projected 600,000 in 1989 - some eight per cent of total area planted with hybrids.

In providing competition for small and medium firms, EMBRAPA sees itself as a counterweight to the extreme concentration of the maize seed market. The major firms however have criticised the secrecy of the public sector about its own lines, which are not exchanged. This contrasts with North American public sector research, according to Cargill representatives, which periodically releases important lines for incorporation by the private sector.

The Private Sector

With the above reservations about open pollinated varieties, we have seen how public sector seed research and production consolidated an important hybrid seed market for maize. The dominance of the Saõ Paulo public sector in commercial production of hybrids shaped the nascent national seed industry. Many small to medium-sized seed firms were created in Saõ Paulo. However they did no basic research and depended on continued production of commercial hybrids by the public sector. The one exception was Agroceres, which distinguished itself by being science-based from the outset and linked to foreign capital until 1980.

With entry of other foreign firms in the 1960s - Cargill, Pioneer - and the move to commercial production, pressure was against production of commercial hybrids by the public sector. This put the small Saõ Paulo based firms in a weak position since they were increasingly limited to marketing older varieties of public hybrids with a declining share of the market. It is too early to say how new hybrids launched in the mid-1980s by the Saõ Paulo public sector will affect this trend. The "cerrados" hybrid recently launched by EMBRAPA is also giving these firms a competitive alternative, as indicated above.

The dominance of the Saõ Paulo public sector also influenced the geography of the Brazilian seed industry. While in Saõ Paulo the public sector and small private national seed companies are commercially strong, in newer maize production areas further south there are more private foreign firms, with the public sector limiting itself to research. The Rio Grande do Sul research centre IPAGRO however has launched varieties under the SAVE label, and cooperatives are beginning to explore open pollinated varieties.

The private hybrid maize seed market is dominated by two firms - Agroceres and Cargill. From the 1950s, Agroceres aimed to establish itself in all areas of maize expansion, and has five research centres in the four principal producer states - Saõ Paulo, Minas Gerais, Rio Grande do Sul and Paraná. Diffusion depended on adaptability of varieties to different regions and close contacts with farmers when communications, both physical and informational, were rudimentary.

Cargill had a similar strategy to Agroceres and the two firms rapidly dominated the new maize frontier in Paraná state. Cargill's worldwide presence allowed it to develop varieties on the basis of germplasm imported from subsidiaries in other tropical and semi-tropical regions - the Caribbean and Thailand. Pioneer, which also established itself in Brazil in the late 1960s, adopted a different strategy. It specialised in the small but expanding market of the southernmost state - Rio Grande do Sul - where its own North American varieties could be adapted. The success of these however depended on technical assistance and fertilizer use. This has led it to develop a very high profile market among the most "high-tech" producers but limits its expansion, given the nature of maize production in Brazil and the tendency for "high-tech" farmers to move on to soybean production.

In the 1970s, many big international seed firms established subsidiaries in the Brazilian market - Limagrain, Continental Grain, Upjohn, Pfizer (Table 26). These sold public sector seeds while developing their own varieties with local material (often derived from public hybrids), given the problems of adapting North American or European varieties. All have developed research facilities in Brazil. Cargill, Limagrain, Continental Grains, Ciba-Geigy are based in Saõ Paulo, and Pioneer in Rio Grande do Sul. By the early 1980s, none had more than five per cent of the Brazilian market. Both Agroceres, with a 40 per cent share, and Cargill (20 per cent) had varieties well adapted to major production zones, including the new "cerrados" frontier. Of the two, Cargill has concentrated on the more modernised sector and has a less diffused infrastructure, while Agroceres has varieties with broad adaptablity to different technological production systems (Table 27).

Table 26

DATE OF INSTALLATION, ORIGIN OR CAPITAL, PARTICIPATION IN SALES IN THE HYBRID MAIZE SEED MARKET AND ORIGIN OF GENETIC MATERIAL OF MAIN FIRMS IN THE HYBRID SEED MARKET IN BRAZIL

Firm	Date	Capital Origin	Particip. in market 1981 (%)	Source of genetic material
Sementes Agroceres S.A.	1947	Rockefeller(USA) (60%) + Brasileiro (40%)	39.0	Own or through agreements with EMBRAPA, ESALQ, IAC, UFV
Cargill Ltda.	1965	North American	19.5	Own or through agreements
Mogiana Ltda.	1959	Brazilian	6.0	IAC-SAA-SP, EMBRAPA (varieties)
Germinal	1969	North American (Funk's Seeds) after		Material Funk's Seeds
	1975	Swiss (Ciba-Geigy)	5.7	Initially IAC-SAA-SP
Pioneer Hi-Bred Ltda.	1965	North American (through the purchase of PROAGRO Ltda.)	5.3	Own
Colorado Ltda.	1970	Brazilian	5.2	IAC-SAA-SP
Reis de Ouro	1971	Brazilian	4.9	Initially SAA-SP After intervarietal hybrids with public material
Dinamilho (Limegrain)	1975	French	4.0	Initially SAA-SP
Contibrasil (Continental Grains)	1971	North American	2.1	Initially IAC-SAA-SP
Asgrow (Upjohn)	1975	North American	-	Own
DeKalb (1) (Pfizer) (Pfizer)	1978	North American	-	Own

Source: CNPMS; J.M. Silveira, Ducos (op.cit.)

Table 27

MAIZE SEED PRODUCTION OF THE MAIN FIRMS IN BRAZIL
1978-1981 (tons)

	1978	1979	1980	1981
Agroceres	35 880	38 000	45 099	54 000
Cargill	18 040	18 280	20 566	22 000
Department of Agriculture (CATI)	7 768	7 550	8 708	9 200
Mogiana + Ipanema	4 641	3 543	7 712	6 800
Germinal	3 360	3 440	3 748	6 400
Pioneer	5 120	4 920	5 520	6 000
Colorado	5 760	4 960	4 400	5 200
Dinamilho	971	2 017	2 752	4 520
Reis de Ouro	5 760	10 095	1 628	2 400
Contibrasil	3 960	3 056	2 248	2 400
Formoso	-	-	571	1 600
Agromen	1 080	1 200	1 596	1 600
Uniao	1 640	1 600	1 800	1 600
Others	14 708	5 759	9 084	16 880
Total	108 688	107 970	114 812	140 600

Source: Chantal Ducos, P.B. Joly and J.P. Bertrand, 1983.

The newer multinational seed firms have complained that Agroceres and Cargill hinder development of a market for modern hybrids. In fact, compared with world prices, hybrid seeds in Brazil are cheap, which discourages research. Variety of climates has favoured development of widely adaptable over highly specific hybrids. Since it is not exported, maize tends to be an unstable transitional crop, with its most technologically developed producers always likely to shift to soybean production. The market is therefore a low profit sector favouring more conventional hybrids with broad adaptability. Several more recently-arrived foreign firms have responded by diversifying into other hybrid seed markets - forage crops, sorghum and market-gardening.

As early as the 1950s, Agroceres was looking to diversify through hybrids - into market-gardening, poultry and pig production. Its relations with the Rockefeller IBEC company were complex. On the one hand, IBEC gave it decisive financial backing for rapid expansion, access to state-of-the-art equipment in seed production and a network of contacts at research and development level. From the 1950s, Agroceres was involved in genetic material exchange with international groups -- Funks and the International Pool in Cuba. IBEC however controlled lines of expansion. In the late 1950s, Agroceres wanted to move into poultry and contacted Pioneer. DeKalb was negotiating entry into poultry in Brazil at the same time. IBEC however blocked this development and it was shelved for more than a decade.

Agroceres led key innovations in the 1960s, developing hybrids on the basis of male sterility which involved greater stability in crossing and dispensed with the need to remove female tassles. When these hybrids began to reveal susceptibility to fungus in the North American harvest, Agroceres had to stop seed sales and rebuild its stocks with alternative basic material. Again, relations with IBEC, together with the favourable economic conditions in Brazil, enabled rapid recovery.

The second major innovation was development of a high-protein "opaque" maize. Agroceres invested heavily in research on this, both for its nutritional importance for small farmers, its industrial potential as an alternative to wheat, and as an improved animal food. Despite important advances, this development was frustrated by the power of two major agro-industrial groupings - the wheat and the soya complexes. The latter supplied the protein for the white meat complex and the former mobilised a major import substitution programme in which high-protein white maize flour was an important threat.

Plans to market products with the Quaker Group, despite major advances in research and development, did not get off the ground and Quaker relied on wheat. Research however continues on this variety in the public sector, where there is renewed interest in its nutritive and industrial capacities. But it will have to compete with similar developments in soybeans, where powerful agro-industrial groups are experimenting with soybean flour.

Agroceres diversified into market-gardening, setting up a subsidiary, Horticeres, and producing onion, cauliflower, and cabbage hybrids. It also tried to dominate pig breeding. This proved more complex and it contracted with the British PIC company for transfer of the genetic package. This model was followed with poultry with nationalisation of Agroceres in the 1980s. A joint venture with the Scottish firm Ross Breeders for research in Brazil led to production of the grandparents, the basic genetic material for production of poultry hybrids. This will give Agroceres a strategic position in the dynamic poultry industry since so far grandparents for production of commercial poultry are entirely imported.

This constant preoccupation with technological synergies on the frontiers extends to biotechnology. While Agroceres cannot develop in-house capacity, it maintains links with public sector research by financing scientists. It has bought up a tissue culture firm, Biomatrix, which sells market-gardening products, potatoes and forestry plants. It also monitors developments in the sector and is ready to make agreements with leading firms such as Monsanto if a change in the patent law speeds up application of biotechnology products.

In the maize seeds market, rival firms would claim Agroceres' hybrids are middle range and less geared to the most "high-tech" producers. In compensation, Agroceres has a reach unequalled by other firms, with over 3,000 sales outlets, 11 production units and five research centres in the different ecological regions. Agroceres has always maintained strong international links both with public sector bodies (CIMMYT) and private firms which give it access to genetic material and state-of-the-art developments. Nevertheless, if the patent law changes, it may be vulnerable to competition from the many subsidiaries of multinational seed firms now in Brazil.

Cargill, its main competitor, with a claimed market share of some 30 per cent (900,000 - 1,000,000 sacks of seeds per year), has an apparently modest structure and is almost entirely devoted to maize. In the late 1960s, it established itself in the market distributing seeds from the public sector. By the early 1970s, it was marketing its first hybrids, developed entirely in Brazil but with material adapted from its other companies in tropical and semi-tropical regions (Mexico, Thailand, Pakistan). The company now has 14 different hybrids of three basic types - late, medium and early-developed - in four research centres and with a total team of nine persons, six of them senior.

Multiplication of seeds is relatively unstable in Brazil because of the low price of hybrids and therefore low remuneration to farmers, who often migrate to other crops. According to Cargill, maize is always uncompetitive in tropical conditions because soil fertility and capacity to retain rain water is lower. So maize is unlikely to become an export crop. Government controls on basic food prices also put a ceiling on maize. This makes the sector a low profit one unable to support more ambitious research.

Relations with the public sector are ambivalent. The sector is vital for testing hybrids and use of public sector experimental stations enables rapid nationwide testing. At the same time the public sector continues to turn out hybrids for production by small firms, which accounts for as much as 15-20 per cent of the market, and competes with the private sector.

Cargill does no work on biotechnology. It considers the work being done in Brazil, such as that in Campinas, as basically training researchers and that practical results are still a long way off. In the United States, Cargill has its own molecular genetics laboratory which in favourable commercial and juridical conditions could supply its Brazilian subsidiary with material.

Cargill's conservative estimate of the Brazilian market makes it opt for broad adaptability rather than highly specific hybrids. Pioneer, as we have seen, using material from its parent company, has focused on the most technically advanced farmers. This has required close technical assistance and, according to some, may have made Pioneer vulnerable, given the limitations and volatility of this market. However, Pioneer has now expanded from the southern state with research stations in Londrina, Paraná and Goias in the "Cerrados" (1988). Some two-thirds of its clients are now outside Rio Grande do Sul.

Although its share of the seed market has fallen, overall sales continue to rise. Pioneer seeds are now planted on 500,000 ha, some six per cent of the total maize production area, but with its high average productivity (6,000 kg/ha) this counts for 12-15 per cent of total production, justifying the higher price of Pioneer seeds. Pioneer also considers it has the highest rate of investment in research. International cooperation with other subsidiaries of Pioneer is intense both in exchange of germplasm and training.

The difficulty of the Brazilian market, which has already led the Corn Products subsidiary to sell out, can be adduced from complaints by new entrants that the "low tech" strategy of the big two is making acceptability of modern hybrids more difficult. More likely the constraints of the maize market in Brazil is the main obstacle. Despite these unfavourable factors, almost all major international seed firms are now present in Brazil, stimulated partly by the need for access to important sources of genetic variety. They are also ready for restructuring of seed markets under the impact of biotechnologies.

So the effect of research advances is likely to be limited. Productivity increases will be mainly through better use of existing technology and within the poultry complex major advances will probably be in animal feed/meat conversion ratios.

A P P E N D I X

THE SHAPING OF THE BIOTECHNOLOGY INDUSTRY IN BRAZIL

THE SHAPING OF THE BIOTECHNOLOGY INDUSTRY IN BRAZIL

Introduction

Any useful analysis of the emerging biotechnology sector in Brazil must take into account the economic and political climate of the 1980s. This decade has seen aggregate industrial stagnation combined with dynamic export sectors, and a buoyant agricultural sector which has increased grains production from some 55 million tons to almost 70 million. The performance of agriculture has been closely tied to the other major factor of the 1980s - foreign indebtedness. While industrial imports have nearly equalled exports, the agricultural trade surplus has reached some 10 billion dollars a year and become the basis of debt repayment.

The pressures of debt repayment have led to fiscal instability, with zig-zags in policy priorities and erratic funding with important consequences for scientific and technological research, together with enormous pressure to reduce public spending.

Industrial policy has also reached a crossroads. With a first cycle of import substitution completed through consolidation of energy and capital goods sectors, strategies for technological and industrial competitivity are now polarised between proponents of a second generation of import substitution and those favouring greater flexibility of international technology transfer, joint ventures, and other international cooperation.

The problems and potential of biotechnology in Brazil can best be understood in the light of this complex mosaic of overall economic stagnation and buoyant export sectors, a fiscal crisis involving also redefinition of the public sector, and an industrial policy where there is argument about the mix between foreign investment and promotion of domestic capacity.

Brazil and international competitiveness

Brazil is increasingly considered by rich countries as a competitor rather than a developing country with rights to special treatment. This view has been strengthened by the success of non-traditional exports, both agro-industrial (soybeans, poultry, fruit juice) and industrial (textiles, but also steel and automobiles). Industrial and science and technology policy are no longer only determined by traditional developing country preoccupations with self-sufficiency, but by international competitivity.

This has sometimes led to exaggerated optimism about Brazil's potential for competing at the frontiers of science and technology. So we must be clear about the distance between Brazil and the industrialised countries in biotechnologies, particularly since Brazil is increasingly cited in the literature for its emerging biotechnology industry.

Castro Reinach, a leading Brazilian microbiologist, warned recently that if Brazil did everything right in science and technology policy and funding, its scientific capacity by the year 2000 would only equal present levels of the industrialised countries. The major public financing institution for research and pre-competitive development, FINEP, has also denounced Brazil's laboratory equipment as at least 10 years out of date. In the same year, 1988, public funding for laboratory equipment was cut by half.

In 1987, the United States spent some $4.3 billion on biotechnologies, compared with $150 million in Brazil. The Brazilian research community financed by the National Research Council amounts to some 21,000 people, 6,000 of them abroad. Japan meanwhile supports some 35,000 researchers abroad.

So Brazil must be firmly situated among developing countries when considering frontiers of science and technology. At the same time, as in the case of the Proalcool, Brazil's capacity for rapid mobilisation of resources should not be underestimated.

Public policy and biotechnology

1. *Proalcool*

In the mid-1970s, faced with stagnant sugar export markets, overproduction in terms of domestic demand, and stimulated by the sharp increase in oil prices, Brazil launched an ambitious biomass programme to produce alcohol fuel to replace petrol in automobiles. After only a decade, most Brazilian cars now run on alcohol, whose annual production is now over 13 billion litres. Here was a unique oportunity to apply new biotechnologies. Important advances in continuous fermentation techniques were developed to lower costs with chemical inputs.

Few of these developments however were transferred to the industrial fermentation sector, which was cushioned by ample subsidies and ability to increase production through incorporation of new lands. As a result, this huge programme was not a launching pad for industrial biotechnology in Brazil. Only more recently, threatened by subsidy cuts and increasing opposition to the Proalcool Programme, especially from Petrobras, have serious moves been made to harness biotechnologies to increase productivity in the sugar/alcohol complex, something we shall analyse later.

2. *The national biotechnology programme*

Brazil was quick to define its National Biotechnology Programme, reflecting its ties with international debate and priorities. These priorities emphasised identification and support of existing biotechnology-related teaching programmes and research. Two factors limited the programme's effectiveness. No new funds were allocated and there was no clear definition of biotechnology. As a result, the programme was unable to define new directions for biotechnology research. Preferential allocation of resources for biotechnology led also to inclusion of much traditional research under this heading.

Effective new funding became available with the World Bank supportedProgramme for the Development of Science and Technology, involving some $90 million over five years from 1984, with half for health and a quarter for agriculture.

The end of the military regime in 1985 was a watershed in policy development with creation of a ministry for science and technology, a major demand of progressive interests, and within it a special secretariat for biotechnology. This office had little power however since major research and development institutions -- Oswaldo Cruz for health, EMBRAPA for agriculture, IPT for industrial biotechnology -- remained under other ministries.

Nevertheless, three important initiatives deserve mention. First, creation of biotechnology centres on an interdisciplinary and regional basis was stimulated. This organisational innovation was quickly adopted, concentrating existing capacity and developing more specific links with the productive sector. The more significant examples will be examined below.

Secondly, the special secretariat for biotechnology, under the Southern Cone regional integration protocols, promoted creation of an Argentine-Brazilian Bi-national Centre for Biotechnology (CABBIO). This has led to establishment of a bi-national training course, bi-national research projects, and a favourable climate for establishment of bi-national joint ventures such as Biobras (the major new Brazilian biotechnology firm in the health sector) and Biosidus, for development of interferon.

Finally, the special secretariat also set up a scientific information system in the Cenargen (The National Centre for Genetic Resources) for agriculture, in Oswaldo Cruz for health and in ESALQ for energy.

More recently, in 1987, an Interministerial Committee for Fine Chemicals and Biotechnology was created to deal especially with patents and regulation of research. Inclusion of fine chemicals and biotechnology is particularly important since the two emerging industrial sectors have quite different policies on state-of-the-art technology acquisition, as we shall see below.

New organisational structures for biotechnology research and development

In major areas of application of biotechnology, Brazil has a long tradition of applied research and production. In health, two major institutions - Butanta in Saõ Paulo, and especially the Oswaldo Cruz in Rio de Janeiro - have researched and produced vaccines and serum since the beginning of the century. Energy conversion has been similarly developed, mainly in Saõ Paulo at the IPT and ESALQ Institutes. EMBRAPA has developed a broad capacity in classical plant genetics.

These institutions, together with the major universities in Saõ Paulo, Rio de Janeiro, Minas Gerais, Brasilia, Rio Grande do Sul, all now have some competence in genetic engineering. Biotechnology centres are being coordinated in many universities for interdisciplinary research and teaching, and masters courses in biotechnology are now offered.

Most significant however has been creation of biotechnology centres for applied research and development. These have mushroomed since 1985.

In Saõ Paulo, two major biotechnology complexes are emerging around the state university USP and the University of Campinas. The Butanta and IPT, previously mentioned, are associated with the USP centre which comprises some 50 researchers involved in 30 projects. The Campinas Biotechnology Centre is a pole of attraction for the ESALQ, in the nearby city of Piracicaba, which has a long tradition in fermentation and plant biotechnology. This centre has now acquired Monsanto's Latin American Agricultural Research Centre with state-of-the-art equipment for plant research. Ten projects are under way, although their nature has not been disclosed.

Each southern state has also taken steps to develop regional biotechnology poles. In the highly agro-industrial state of Parana, a networking arrangement has been promoted between the three major research centres in the interior of the state, comprising the universities of Londrina and Maringa and the agricultural research unit IAPAR. Research is on animal vaccines, natural product substitutes for chemical inputs, bio-insecticides and development of new products such as Stevia, a natural sweetener, and artifical skin from cellulosic bacteria. This network of biotechnology centres has guaranteed state funding and is supported by 11 local industries which have formed a State Association of Biotechnology Industries.

Further south, in Santa Catarina, a biotechnology centre has been established in the industrial town of Joinville. Supported by local industry to the tune of one million dollars and with a promise of larger funding from the National Research Council, the centre is based on a joint research project with the West German research centre Gesellschaft Bioteknologie Forschung (GBF). The programme aims to research secondary characteristics of tropical plants for international markets, beginning with extraction and purification of caffeine from the Amazon plant guarana. Rather than basing itself on local capacity, the project aims at partnership with a key laboratory in a major industrial country. Technology transfer and profit-sharing on the Brazilian side are matched by the West German laboratory's interest in access to Brazil's rich germplasm.

In Rio Grande do Sul, Brazil's southernmost state, applied research is being conducted at the University of Caxias do Sul in close collaboration with the local wine industry to develop new yeasts using genetic engineering. Advanced genetic engineering techniques are developed at the biotechnology centre of the federal university in Porto Alegre, which has become a major national research centre and science park and where research is being done on vaccines and plant genetic improvement.

Further north, in Minas Gerais state, a regional industrial biotechnology pole is emerging. Two major national biotechnology firms, especially active in animal and human health products, were attracted to the region initially by regional incentives from the Northeastern Development Agency, SUDENE. They have established close manpower and contract research links with the regional agricultural institute Viçosa and with the state university, which is combined with in-house research activity.

Perhaps the most ambitious and far-reaching project is in Rio de Janeiro state. Biorio, as it is called, is planned as a university-industry biotechnology complex. On completion, it will comprise postgraduate teaching and research reinforced by international academic cooperation, an incubator for development of enterprises under contract to industry, with non-polluting biotechnology firms on campus.

Biorio is also inviting international participation to establish itself as a centre for international technology transfer. The momentum of this $20 million project, now officially launched, has suffered from delays in release of public funds. It nevertheless has the backing of the powerful federal university of Rio de Janeiro and the Oswaldo Cruz Foundation, recently strengthened with a $20 million grant as the Latin American Centre for genetic engineering research into new vaccines for endemic diseases. Biorio is also supported by the Brazilian Biotechnology Industry Association, ABRABI.

As well as these biotechnology centres which involve new organisational alliances both with public sector institutions, and between these and the private sector, traditional agricultural institutions have developed advanced plant biotechnology capacity. CENARGEN, the public sector Centre for Germ Plasm Collections, with 40 research staff supervised by three PhDs in genetic engineering, has developed state-of-the-art research in plant gene transfer. Other sectoral institutions, such as Copersucar for sugar, Aracruz for cellulose and CEPLAC for cocoa, are involved in plant cloning, tissue culture, and micropropagation.

Regional poles for fine chemicals

We mentioned earlier creation of an Interministerial Committee for Fine Chemicals and Biotechnology. While boundaries between the two areas are increasingly blurred as biotechnologies become used for production of intermediaries, the industrial strategies for fine chemicals have not been a model for the emerging biotechnology sector.

While Brazil was traditionally strong in immunological health products, foreign capital assumed overwhelming control of the pharmaceutical industry with emergence of new therapeutic drugs, beginning with penicillin during World War II. Between 1967 and 1983, some 54 national laboratories were sold to multinational companies. Control over active ingredients of therapeutic drugs has been the basis of multinational dominance.

To break this dependence, the Technological Development Company (CODETEC) was set up in Campinas in 1976 by researchers from the local university to develop products for industry. The company now has strong public and private industrial support, with participation of some 27 national firms. Research and development has concentrated on production of active ingredients based on systematic use of information in internationally-registered patents, which are not recognised for health and food products or processes in Brazil. By 1990, some 80 active ingredients will have been developed for national industries. This will be an estimated annual saving of some $55 million whereas the centre itself cost only $3 million to build and $1.5 million a year to run.

The centre is now moving into biotechnology with a further $2 million investment for developing antibiotics, hormones, reagents for diagnostic probes, enzymes and vitamins.

Technology centres for fine chemicals are also being planned around the country's three petrochemical poles - Triunfo in Rio Grande do Sul, CEPED in Bahia and Tequimica in Rio de Janeiro - with active industrial participation. It is not clear whether these centres will follow the import substitution strategy of CODETEC based on non-recognition of patents, or continue the tripartite model of the petrochemical industry itself.

Demand pull - import substitution and export competitivity

Some incentive to develop biotechnology products comes directly from public sector social objectives. In agriculture, genetic engineering has been applied by EMBRAPA to transfer proteins from the Brazil nut to beans, part of popular diet. With increasing ecological concern, support may soon appear for use of tissue culture and micropropagation to repopulate threatened species.

Government influence however is much greater in the health sector, not only in support for vaccine and serum production, in which Brazil should be self-sufficient by 1990, but in controlling the important public health market. Access to this is governed by a public body - the Medicine Centre, CEME - which since 1984 has coordinated the National Biotechnology Programme for the pharmaceutical industry. CEME controls 35 per cent of the national pharmaceutical market and is stimulating production of biotechnology-based active ingredients by national firms. A particularly dynamic area is production in the public sector of reagents for diagnostic probes, by Oswaldo Cruz and a growing number of small private firms.

This policy coincides with the import substitution strategy in the fine chemicals sector by CODETEC with strong support from national industrial interests. The Brazilian fine chemicals sector is valued at some $4 billion, largely agro-chemical, pharmaceutical and food industry intermediary products and strongly dominated by multinationals which account for some 70 per cent of domestic demand. In recent years however, this market has been contested by an articulate national industrial sector which has split from the National Chemicals Association (ABIQUIM), with its strong multinational representation, to form a National Fine Chemicals Association (ABIFINA). So this sector strongly supports development of biotechnology but this is seen as part of a broader import substitution strategy, which has to face both opposition from multinationals in Brazil and increasing commercial pressure from the United States.

Biotechnologies will also increasingly find fertile ground in the sugar/alcohol sector. We saw earlier how the huge Proalcool initiative failed to launch a biotechnology industry. Now the Proalcool is part of a fiscal crisis which is curtailing subsidies. The Proalcool also has to face increasingly open opposition from the state petroleum company Petrobras, which argues that the market for gasoline, a necessary co-product of oil refining, will soon be saturated.

All this creates favourable conditions for technologies to significantly increase productivity. We can expect the sugar/alcohol complex to take greater advantage of fermentation technology developed but little used over the last 10 years.

Copersucar, the sector's major cooperative responsible for some 35 per cent of total production, has accelerated its biotechnology research, investing some $2.5 million over the last two years in a technology centre in Piracicaba. Research projects are underway with West Germany and Japan and new fermentation technology being tested will increase productivity by as much as half. The centre will also research new co-products, from animal feed and fertilizer to acetone-butanol and lactic acid. Copersucar has also been developing new sugar varieties and recently signed a $200,000 three-year agreement with Cornell University to develop a genetic engineering programme for sugar-cane.

A question mark hangs over the alcohol-chemicals sector. Considered by the president of the Chemicals Industry Association to be technologically superior to any other country, its future is tied to subsidy/productivity levels of the Proalcool. Eleven industries, including multinationals Union Carbide, Stauffer and Rhodia, and major national companies such as Elekeiroz and the Companhia Brasileira de Estireno, use up to 500 million litres of alcohol a year. Depending on subsidies, some $100 million worth of products are exported annually, mainly to Japan. Future expansion of the sector is likely through regionalisation by annexes to existing distilleries. Recently, a working group for the Saõ Paulo Secretariat of Science and Technology, while rejecting an alcohol-chemicals pole, defended the viability of units annexed to distilleries.

The Proalcool Programme became a major pollutant as fermentation residues were dumped in inland rivers. Research has responded with technologies to transform such residues into fertilizer and animal feed. Waste treatment by anaerobic digestion is treating urban sewage and has been adopted industrially by the country's two major beer producers.

We saw earlier how in Paraná state, biotechnology strategies were harnessed to provide substitutes for agro-chemical inputs. This has become an important research and development area, both for bioinsecticides and the biological fixation of nitrogen. The latter, combining public research with efforts of the MIRCEN network, has made important advances, resulting in use of rhizobium innoculants in half the area planted with soybeans, with eight firms responsible for production and distribution. Use of rhizobium is a saving of 100:1, but its further use has been threatened by uneven quality of bacteria. Research at the IPT aims to improve the medium in which bacteria is transported. This will increase costs, but savings are still calculated to be about 20:1. A range of bioinsecticides is being marketed for soybeans, maize, sugar-cane and grazing pasture.

Import substitution strategies in seeds and plants are also opportunities for biotechnologies. A major aim is substitution of potato seed imports and development through tissue culture and micropropagation of virus-free potato seed. The public agricultural research institute EMBRAPA and at least three major private firms - SBS, COTIA and Biomatrix - are involved. They are also extending production into horticulture and floriculture.

Energy costs have also spurred recourse to biotechnology. Wood is increasingly used as fuel in the steel industry and major firms such as Acesita are financing microprogation research for rapid renewal of eucalyptus plantations. This firm is negotiating an ambitious joint venture with an Italian group to develop biomass conversion technology, as is Biopart, a Minas Gerais biotechnology firm. About nine Brazilian firms are studying cooperation projects to develop biomass technology promoted by the European Community Commission.

While modernisation of the Brazilian agrofood system has been dominated by multinationals, national firms have conquered important areas. In the hybrid seed market, national presence is dominant through the public agency EMBRAPA and the national firm Agroceres, which controls half the maize market. Strong competition however comes from the multinationals. Cargill, Pioneer, Ciba-Geigy and Pioneer producte herbicide-resistant seeds by genetic engineering. To stay competitive, Agroceres will have to be forced to increase its activity in advanced biotechnologies, if not through in-house research, then through joint ventures.

In animal genetics, Agroceres has made important advances. Brazil is the world's second exporter of poultry but has not mastered production of matrices. Through a technology transfer agreement with the British firm Ross Breeders, which may prefigure similar moves in plant biotechnology, Agroceres will now internalise production of matrices.

Brazil is also emerging as a major exporter of beef and processed meat and has replaced Argentina as the Southern Cone's main exporter. The competitivity of world markets has led to adoption of advanced genetic technologies. By 1983, about 23 firms were producing and marketing semen and eight firms were registered as involved in embryo transfers.

The southern states, as we saw, are increasingly aware of the threat of advances in genetic engineering concerning oil crops to continuing competitivity of the soybean complex. Leading cooperatives in the region however still promote biotechnology, but a thorough rethink of agro-industrial strategy is now under way as a result of competition from Brazil's southern neighbours, following regional integration.

The diversity of Brazil's industrial and particularly agro-industrial sectors stimulates biotechnology applications - tissue culture for tropical crops (cocoa), forestry, and horticulture; enzyme and fermentation technology in the sugar-and and wine sectors; secondary metabolities as natural ingredients for the food system; and biological alternatives to agro-chemical inputs.

We should also mention the biomining sector which has important potential but has so far been little developed. Research in this sector in Brazil has been quite limited and only began in the 1980s. First efforts at creating a research team and programme were made by the IPT in Saõ Paulo between 1980-84. These efforts were renewed in 1986 but without practical result. Nucleabras set up two pilot plants for bacterial leaching of uranium, but serious problems in continuity resulted from vagueness in the Brazilian nuclear programme. With the dismantling of Nucleabras, the firm Uranio do Brasil was created (51 per cent public and 49 per cent private capital) and has shown interest in continuing the earlier experience.

Another government organ, the CETEM, previously part of the Ministry of Mines and Energy but now attached to the National Research Council has researched copper biomining. This body however has been effectively dismantled. The research institute CEPED in Bahia state has also begun laboratory research into copper biomining to service Caraiba Metais, an important firm in that State which produces some seven million tons of low-grade minerals a year.

The most advanced firm in effective application is the Morro Velho mine in Minas Gerais, a South African ore-producing company which has advanced to pilot plant stage and is ready to begin industrial production.

Although it has had a chequered history so far, biomining in Brazil now presents some positive features. Towards the end of 1988, biometallurgy became a recognised part of the PADCT programme, and a network of researchers is being organised. Mining firms have begun to show interest, particularly the giant Vale do Rio Doce, which wants to apply the technology to gold and copper in the Carajas project.

There are various reasons for optimism. Several national firms in mining with very large turnovers - big contracting firms, steel producers and specifically mining operations - could finance research. Brazil does not have the environmental or planning laws which make biomining difficult or impossible in other countries. Current technology is relatively simple and available, since genetically-modified bacteria have as yet no industrial application. Also, technology is developed particularly in peripheral advanced countries - Australia, Canada, South Africa, the USSR - and developing countries such as Chile have acquired an equal competence.

Will more advanced biomining technology based on genetic engineering and controlled environment techniques lead to marginalisation of firms and countries unable to sustain research and development costs? If new technology proves economically viable, Brazil will have the advantage of a strong industrial base to support research in the sector.

The emerging biotechnology industry

It is not surprising Brazil is singled out among developing countries for its private biotechnology industrial sector. Two national biotechnology associations have emerged. ABRABI, the Brazilian Association of Biotechnology Industries, is the most representative with more than 30 associates, including four state-owned and six foreign firms. ABIVEG groups a number of firms in the plant biotechnology sector. At state level, as mentioned earlier, the Paraná Association of Biotechnology Enterprises (APEBI) was also formed by 11 firms, only one of which is also an ABRABI associate. We should also include most of the nine firms in biomass conversion involved in cooperation with the EC, the eight companies in biological nitrogen fixation, together with a further eight in embryo transfer. As we will discuss below, the biotechnology associations are now merging within ABRABI.

Over 60 firms are therefore active in biotechnology application. Some - those in biological nitrogen fixation for example - are entirely dependent on public sector research. Others are essentially laboratory input suppliers, not involving any significant scale-up. Two areas account for most of these companies: tissue culture and micropropaation in the agricultural sector, and diagnostic kits in health, each of which involves about 10 firms.

In agriculture, the most important are Biomatrix and Bioplanta, to which could be added the Brazilian Seed Company (SBS), although its turnover is much smaller. Biomatrix was formed in 1984 by researchers at the federal university of Rio de Janeiro headed by Professor Antonio Pães de Carvalho, to produce and sell tissue culture products, especially vegetables and ornamental plants. After first negotiating with a large national economic group which planned to associate Biomatrix with an important US plant biotechnology firm, Biomatrix was bought in 1985 by Agroceres, which took majority share control.

Biomatrix is now marketing products worth a total one million dollars - particularly in forestry, tropical fruits and ornamental plants - and has started producing potato microtubes. However, despite its success, Biomatrix has not become technologically part of Agroceres, nor does the latter have surplus resources to invest in Biomatrix's expanding research sector. As a result, Agroceres has decided to incorporate new associates, while retaining a minority shareholding, to permit expansion at Biomatrix.

The firm SBS is following a similar path to Biomatrix. Set up in 1975 to produce seed potatoes, it opened a laboratory in 1983 to develop tissue culture to produce virus-free products. It is now producing seed potatoes and fruit tree plants on a small scale using micropropagation techniques. The firm aims to expand in seed potatoes, whose Brazilian market is worth 10 million dollars.

To expand commercially however, SBS will need a strong injection of capital and external technological support involving a basic change in the firm's structure, which is centred mainly on individual efforts of its owners.

Other firms in the agricultural and livestock sector can benefit from and absorb advanced technologies, particularly large cooperatives, some of which - for instance COTIA, a major horticulture producer also active on the new cereals frontiers - have substantial investment capacity. COTIA is now developing its research into tissue culture.

Use of innoculants for biological fixing of nitrogen is widespread in soybean-producing areas, and several firms have emerged from close collaboration with the research centres (TECPAR and MIRCEN/RG for the states of Paraná and Rio Grande do Sul respectively).

Foreign firms in Brazilian agriculture have made little move towards research in biotechnologies or to create new firms. The only exception is Bioplanta, created by British American Tobacco, which controls 80 per cent of the Brazilian cigarette market with a turnover of some $500 million. As part of diversification towards the agro-food sector, Bioplanta was set up in Campinas, Saõ Paulo, with a high density of researchers and was for a time associated with NPI in the United States. It specialises in fruit and forestry plants.

Two biotechnology firms however, both in the pharmaceutical sector, stand out for production and technological capacity. Biobras is perhaps the first pharmaceutical firm based on private national capital with a modern vision of development and absorption of technological innovation through in-house scientific capacity and close ties with academics. Established in the 1970s by researchers linked to the federal university of Minas Gerais, Biobras was first associated with Eli Lilly for producing insulin. Some years later, this association was broken, leaving Biobras with the Brazilian market for insulin, which is also exported. In addition to insulin Biobras produces reagents for diagnostics together with a wide variety of enzymes. Through creation of Bioferm, it has entered the market for fermenter plant inputs. More recently, it established cooperation with the Argentine firm Biosidus to develop interferon and insulin using genetic engineering. Contract research with the University of Minas Gerais is also under way to produce AZT.

Biobras has a turnover of some $15 million and reinvests seven per cent of this in research. It has established itself as a model for the national pharmaceutical sector through its incentives and selective support for public research, its willingness to industrialise applied research, and its capacity for joint ventures with foreign firms.

Vallee Nordeste follows a different path, though it too aims to become a pharmaceutical firm with high scientific and technological content. The firm belongs to CARFEPE which is based in agriculture. It was founded in 1978, continuing activities of the Vallee Institute, centred on production of foot and mouth vaccine. In 1987, Vallee Pesquisa was created to expand into human health, and Innovall was set up through association with the Merieux Institute to produce triple vaccines, haemoderivatives, and also to sell Merieux products - a joint venture which includes technology transfer and training technicians in France.

The emerging biotechnology industry in Brazil is significantly dependent on university research and international technology transfer. Many biotechnology entrepreneurs remain university professors. The sector is also very dependent on public funding for investment, research and development. Most firms are also still very small with turnovers between one and five million dollars. A more dynamic biotechnology sector is also hindered by lack of a culture favouring venture capital which could underwrite firms in early product development phase.

Industrial Policy for Biotechnology

As we have seen, industrial sectors directly involved in biotechnologies are notable for their level of organisation. While there are divisions within the biotechnology sector, the basic divide is between this sector and fine chemicals. This reflects polarisation in industrial strategies already noted favouring greater liberalisation or protectionism in developing technological and industrial capacity.

The Fine Chemicals Association was formed in opposition to the National Chemicals Association, which was deemed over-represented by multinational firms. As we have seen, this sector has developed import substitution based simultaneously on systemic use of patent information and non-recognition of patents in the Brazilian domestic market for processes or products in pharmaceuticals and food.

This policy has been increasingly opposed, particularly by the United States, leading to commercial retaliation. Pressure for recognition of patents also comes from European Commission which is drafting its own patent laws for biotechnology. In the Brazilian context, which includes a reserve market for microcomputers developed essentially through reverse engineering, patent recognition for pharmaceuticals is unlikely just yet. Nevertheless, US pressure should not be underestimated, as the example of Thailand shows. This country recently yielded to US commercial "persuasion" and now recognises patents. Patent legislation could be extended to advanced genetic engineering products and processes.

Both Brazilian biotechnology associations distanced themselves from the strategy of the fine chemicals sector. The ABIVEG said it favoured patent recognition along the lines of the UPOV convention and was against any discrimination towards foreign capital in access to financing or markets. ABRABI's position is more subtle, but is also opposed to a reserve market strategy and has promoted discussion of patent regulation. Joint ventures with industrialised country firms are seen to be an effective way to acquire technology. These however should maintain a majority national capital share and national firms should also be favoured by government procurement and credit measures. EMBRAPA is favourable to some kind of recognition of intellectual property rights for plant breeders.

ABRABI has recently drawn up a discussion document on patent regulation in biotechnology and submitted it to the academic community and associations representing the fine chemicals and pharmaceuticals industries. The strategy proposed is to link patent concessions to national technological competence. Patents would be extended progressively to those areas in which a minimum five national technology centres had confirmed competence.

This strategic initiative coincides with moves to merge the different biotechnology associations into one - ABRABI. A new regional and sectoral organisational structure has been developed to provide adequate expression for the diverse interests in the emerging biotechnology sector.

Strengthening and unifying these interests, both programmatically and organisationally, will allow greater influence in formulation of domestic policy and in international negotiations, whether at company or government level.

Will this new approach to patents, which ties their concession to achievement of national competence, be enough to unify all relevant sectors, both scientific and industrial, public and private? Also, will such a position be acceptable to the leading actors in the international arena? The economic fragility of the emerging biotechnology industry in Brazil may be offset by these strategic and organisational initiatives which will enable the sector to have important influence on policy formulation and priorities.

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