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STRUCTURAL ADJUSTMENT
AND THE INSTITUTIONAL DIMENSIONS
OF AGRICULTURAL RESEARCH
AND DEVELOPMENT IN BRAZIL:
SOYBEANS, WHEAT AND SUGAR CANE

by

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RÉSUMÉ

SUMMARY

Structural adjustment, liberalisation and the pressures of technological change are having major impact on the institutional organisation of the agro-industrial sector. In industrialised countries, the private sector is positioned to play the vanguard role in the next generation of agricultural technologies. Thus, the ability to promote and sustain new patterns of co-operation in research and development between the private and the public sectors will be a key determinant of future patterns of competitiveness.

This study of Brazil attempts to identify the main lines of technological and organisational innovation at present under way in important sectors of the Brazilian agricultural research system. It focuses on three crops -- soybeans, wheat and sugar -- which are strategic from the point of view of structural adjustment and liberalisation and at the same time involve both export and domestic markets.

PREFACE

INTRODUCTION

The impact of structural adjustment and liberalisation on the relative competitiveness of current agricultural production systems has received considerable attention, but the issue of technological change is becoming increasingly important. Here, the focus is less on the consequences of price transparency or the potentially rationalising implications of import constraints and higher real prices for inputs and machinery than on evaluation of the degree to which changes in relative prices are stimulating the emergence/diffusion of a new technology paradigm or production function. A particularly optimistic variant of this approach would see import constraints on agrochemical inputs and the lowering of real labour costs as an opportunity to shift towards a biotechnology base for agriculture in developing countries.

Given the evident importance of the new generic technologies, particularly information technology, new materials and biotechnology, the emergence of a large body of analytic literature is not surprising. Earlier debate was polarised between views of technology as emerging either from the autonomous development of science or on the basis of market demand. Recent literature tends to establish a greater symbiosis between industry, government, and academia in the crystallisation of broad technology competencies. In this view, the technology push/demand pull pressures that broadly determine technological opportunities are largely independent of specific market demand, and relative factor costs are still unknown. As research moves from basic to applied research and on to development the pressures of demand and competitive factor costs emerge with more determining force.

Within this perspective, attention must be given to the relation between technical change and structural adjustment and liberalisation and the impact of the latter on the institutional determinants of technology generation and diffusion. The major analytical approaches have addressed the issue of the importance of institutions for agricultural development. The *induced innovation* model, adapted to the specific features of agricultural production -- particularly its competitive and atomised structure -- defined institutions of public R&D as the central mechanisms mediating the production mix in accordance with changing factor prices¹. The *political economy* approach, which has been very influential in Latin America, also emphasized the importance of public institutions, but as the source for counterpoising market signals to the benefit of powerful interest groups². In its turn the technology push equivalent, in the form of the *agro-industrial complex* theses, accented institutional mechanisms for underwriting the expansion of industrial inputs and processing markets³.

In addition to the impact of adjustment and liberalisation on factor prices, the institutional implications of market transparency and privatisation are crucial to the

evaluation of technical change. This is particularly true for the challenge posed to developing countries by the new technological competencies of strategic importance to agricultural development and competitiveness. These technologies are leading to new forms of co-operation/competition between the private and the public spheres, blurring the distinction between basic and applied research, and locating innovative potential more decisively within the private sector. As the background paper to the Experts' Meeting at the Development Centre on 6-7 November 1990 aptly notes⁴: "Thus, in contrast to the earlier Green Revolution technologies, the new biotechnologies in food and agriculture are to an increasing extent being developed and "appropriated" outside the established agricultural research system, by private firms and by scientists not necessarily formerly concerned with agriculture."

Two interrelated issues are involved. To what extent do structural adjustment and liberalisation influence relative factor prices and product competitiveness so that major shifts in the technological base of agricultural production are favoured? Secondly, to what extent do they promote or inhibit the institutional arrangements necessary for successful adaptation?

Liberalisation should not be seen as a unilateral tendency towards privatisation but rather as the push for a greater market transparency in both the private and the public sphere. It corresponds to the deeper changes in the innovation process that are leading to greater involvement of the private sector in public research and to a greater sensitivity to the issue of client responsibility in public research agendas.

Current literature gives the institutional variable equal status with the market in the analysis of technological change. For agricultural development, the strategic role of public institutions, particularly of research and development, has been accepted by all schools of analysis. Thus, the impact of adjustment and liberalisation on institutional arrangements becomes a key to evaluating the prospects for developing country agriculture.

Because of the priorities of structural adjustment and liberalisation, Brazil is currently undergoing a radical reorganisation of macroeconomic and sectoral economic policies. It is also accelerating measures for regional integration. While the constraints of adjustment limit the scope of liberalisation in key areas, particularly imports, greater market transparency is having a decisive impact on agricultural policy and institutional arrangements.

Recent analysis by the OECD Development Centre⁵ has noted the importance of Brazil's agricultural research capacity in maintaining productivity levels during the 1980s. Unlike its major competitors, particularly the United States, the Brazilian private seed market is still very underdeveloped in the strategic crop areas. Even in maize the public sector is still responsible for important innovations, such as varieties for the Northeast and hybrids for the frontier region. In other crops -- soybeans, cotton, sugar, wheat -- the public and co-operative sectors dominate the creation and diffusion of new varieties. It is not realistic to imagine that the public sector can be quickly replaced by private actors in this area, which is crucial for future competitiveness. In industrialised countries, however, the private sector is positioned to play the vanguard role in the next generation of agricultural technologies. Thus, the ability to promote

and sustain new patterns of co-operation in research and development between the private and the public sector will be a key determinant of future patterns of competitiveness.

Structural adjustment, liberalisation and the pressures for technological change are also having a major impact on the institutional organisation of the agro-industrial sector. The very existence of the traditional single commodity export institutions is being called into question. The Co-operative structure is also having to revise its heavy dependence on a subsidised banking network. The public sector research institutes, in turn, risk seeing a lack of continuity in research programmes as budgets are cut and key researchers are attracted to the private sector in Brazil or abroad.

At the same time, the agricultural actors are forced to deal more directly with the pressures and opportunities of the market, and the public sector is rapidly developing new patterns of shared responsibility for research and development. The most visible expression of this tendency is the proliferation of university/industry research and development centres. Rather than a simple zero sum game in which the public sector transfers its functions to the market, there is a redefinition of the relative space of each.

This study attempts to identify the main lines of technological and organisational innovation presently underway in important sectors of the Brazilian agricultural research system for three crops -- soybeans, wheat and sugar -- that are strategic from the point of view of structural adjustment and liberalisation and involve both export and domestic markets. It also attempts to analyse how current tendencies are informing priorities at the level of research and development.

The institutional context in which these research and development objectives are being pursued is examined, and patterns of technology generation and transfer and the respective role of public and private actors both domestic and international are identified.

I. THE INSTITUTIONAL CONTEXT FOR AGRICULTURAL R&D IN SOYBEANS AND WHEAT

1. Introduction

Public sector agricultural R&D in Brazil during the 1980s cannot be understood without an appreciation of the circumstances that led to the formation of EMBRAPA, the Brazilian Enterprise for Agricultural Research. Earlier agricultural research was primarily regional and sectoral. Specific institutions (the Brazilian Coffee Institute, the Institute for Sugar and Alcohol, the Cocoa Planning Centre), located in the southern States and Sao Paulo, focused on the major export crops. EMBRAPA's creation in 1973 was part of a series of strategic measures for forming a modern agricultural system based on a domestic industrial structure able to supply inputs and machinery, and stimulated by a national subsidised credit system, in lieu of merchant capital, for incorporating integrated technology packages.

The traditional export agriculture model no longer fit the needs of an urban industrial society, and modernisation was required to meet domestic demands for agricultural inputs and final foods. At the same time, new export sectors had to be promoted. As strategic choices were made, agrarian reform and a modernised family farm structure were rejected in favour of a transformation of the existing agrarian structure. EMBRAPA's research programme was shaped by these broader social determinants.

The EMBRAPA model of agricultural research had the following features:

1. Research was directed towards productivity increase and adaptation of agricultural systems to the ecosystems of the new frontier: the Amazon, the Pantanal, the semi-arid interior and the Cerrados.
2. Extension services were subordinated to EMBRAPA, which distributed packages on improved varieties, soil correction and agricultural practices adapted to the use of industrial inputs and machinery.
3. With the exception of Sao Paulo and traditional export crops, the research system was centrally co-ordinated by EMBRAPA and formed either national individual product research centres or regional resource research centres for adapting agriculture to new ecosystems.
4. EMBRAPA was separate from the traditional public administrative structure. In particular, it was free to: i) recruit staff; ii) pursue its own human resources training

programme; iii) mobilise financial resources; iv) establish international co-operation agreements; v) apply resources as it saw fit; and vii) establish its own wage policy. Nevertheless, it remained dependent on Federal budget funding.

2. Consolidation of EMBRAPA in the context of economic crisis

The effort to modernise agriculture required an institutional strategy for:
i) developing agricultural research personnel; ii) integrating researchers into effective research programmes; iii) ensuring the continuity of research activities.

EMBRAPA's first task was to develop the human resources for its research activities. Table 1 below shows the evolution of EMBRAPA's research capacity to 1988. Categories I, II, III refer to B.Sc., M.Sc. and Ph.D recipients, respectively. The large increase from 1973 to 1974 reflects the selective integration of researchers from the previous Federal research structure and recruitment from the universities. At the outset, the research base was fragile, with only 15 doctorates. A massive training programme gave priority to doctoral research. The limited number and quality of programmes in Brazil led to massive overseas training, particularly in North American universities, and the programme depended heavily on foreign financing: BID, BIRD, USAID. EMBRAPA's wage and career structure enabled it to attract researchers from other public sectors and from the universities⁶.

Table 1 shows that by the end of the 1970s, research capacity had risen sharply (123 doctorates and 777 masters), and the conditions for establishing an effective research programme had been met. At that time, EMBRAPA's research model was organised around *national product-based units*, and its guiding theme became "research must begin and end with the farmer".

Data on EMBRAPA's research capacity by profession point to the overwhelming predominance of agronomists and veterinary personnel specialising in plant production, genetic improvement, soil science and phytopathology, the competencies associated with the improvement and adaptation of the Green Revolution technology packages. The small number of biologists took on importance as biotechnology assumed greater weight in research strategies.

Table 1 suggests a continuous cumulative progress in the research training programme throughout the 1980s. Foreign financing appears to have allowed for relative immunity to the impact of recession and fiscal austerity. There is, however, a sharp decline in the doctorate programme in 1987-88, from an average of 38 to 19 for overseas training. Although the decline may be partly attributable to a natural slowdown as the training programme matured, factors connected with the impact of the crisis on EMBRAPA's pay and career structure were also at work.

EMBRAPA's calculations point to a 96 per cent decline in real wages from 1976 to 1989, when a new pay and career structure was elaborated. However, the reform has not freed the institution from the problems facing the public sector as a whole, as recent strikes by EMBRAPA personnel show. Data covering expenditure on personnel show a sharp decline in the mid-1980s, a substantial recovery in 1987 (which probably

reflects the impact of the New Republic and the growth strategy of the Cruzado period), and renewed decline in 1988.

Outmigration of research staff from EMBRAPA began to assume serious proportions in the mid-1980s. It has been most significant for highly qualified consultants, many of them recruited in the 1980s when routine recruitment was frozen. Outmigration in the permanent staff is highest for doctorate researchers. As a result, EMBRAPA's ability to maintain its top level research ability -- indispensable for developing expertise in new areas such as biotechnology -- is uncertain.

The tendency is not likely to be reversed soon. The pressures of the crisis are pushing EMBRAPA to review other sources of revenue, such as commercial benefits from technology generated by EMBRAPA and remuneration of research staff on the basis of technology generated. Such strategies face serious administrative obstacles.

In financial terms, EMBRAPA shows growth until 1982, but severe budget restrictions characterise the period from 1982-85. The economic policy of the "Cruzado Plan" reverses this tendency in 1986-87, but recession recurs from 1988. A clearer picture emerges from the programmed budget allocations of the Federal Treasury. Excluding the exceptional figures for 1986, the year of the "Cruzado" plan, allocations show continuous decline throughout the 1980s. The decline does not affect the public agricultural research system alone; it reflects a major decline in budget allocations for the Agriculture Ministry as a whole. EMBRAPA's projected share in the Ministry's overall budget remains relatively stable.

If funding from all sources is considered, EMBRAPA's overall expenditure shows a high level of dependence on public federal resources, especially Treasury financing, following the decline in Federal Special Programmes. This presents a serious problem, in light of the trend of Treasury budget allocations. Given EMBRAPA's efforts to increase self-financing and the fact that maintaining research capacity will increasingly depend on its success in doing so, the receipts generated by EMBRAPA do not provide grounds for optimism. They oscillate at around 10 per cent of total funding for the decade but decline from 12 per cent in the early 1980s to less than 8 per cent in 1988. Resources from collaborative agreements have also declined and represent less than 2 per cent of total resources.

3. The Challenge of "Alternative Agriculture"

With the creation of EMBRAPA, the rural extension service, which had previously played a key role in diffusing new technologies and agricultural practices, was reformed (EMBRATER). Its new role was to promote the technology packages developed in EMBRAPA and diffused by EMBRAPA's own Department for the Diffusion of Technology⁷.

With the move towards national product-based programmes in the late 1970s, EMBRAPA's research was clearly oriented to largely monoculture modern commercial farming. This clashed with the polyculture farming practices of the small farmers who were largely the client base of the rural extension services. As agriculture became modernised, rural extension services tended to be supplanted by private firms or by

the services department of the industrial inputs suppliers. In addition, the extension service became heavily dependent on federal programmes for rural development financed largely by World Bank sources. This evolution led to tensions which were reflected in the continuous reformulation of the integrated rural development programmes during the late 1970s and early 1980s. In addition, as the subsidised credit system underpinning the adoption of modern inputs was gradually eliminated (from the late 1970s), small-scale farmers found access to modern inputs less attractive.

Within the research and extension systems, support for "alternative agriculture" models developed. It was reinforced by opposition to the negative impacts of the accelerated expansion of soja in southern Brazil. In the same period, non-government organisations became active in promoting parallel technical assistance programmes directed to small farmers which gave pride of place to traditional technologies.

The economic recession of the early 1980s coincided with the end of the military regime and the establishment of the New Republic. While the military regime had seen a major transformation in the economic basis of Brazilian society, political life had been largely frozen from 1964 to 1985, and many old political platforms adopted by the new Government were subsequently to influence the formulation of the new Constitution.

Following the establishment of the New Republic in 1985, an Agrarian Reform Ministry was created, and the organs of the Ministry of Agriculture reflected the policy shift. The new Presidency of EMBRAPA launched a Research Programme for Alternative Agriculture, which gave priority to research directed to: i) basic foodstuffs; ii) developing technologies appropriate to specific farming practices, to the quality of the environment, and to the saving of energy; and iii) establishing autonomy in genetic resources. Research on individual products was to give way to research on production systems. The Rio Grande do Sul State Programme for Research in Alternative Agricultural Technologies states as its basic objective to "develop techniques which allow for a modification in the proportion of the production factors in use, increasing the incorporation of those which are relatively abundant and cheap and reducing those which are relatively scarce and expensive."⁸

This programme represented much more than an alternative to existing research agendas. It implied a completely new technology paradigm, and it required an entirely different knowledge base. In addition, because it was substantially directed at a distinct clientele, it generated both economic and political conflicts of interest.

This alternative programme was defeated both from without and from within. The economic growth plan of the New Republic soon encountered the realities of economic recession. At the same time, the reform strategies encountered the political force of the interests generated by agricultural modernisation. Agrarian reform was shelved, and a reshuffling in the organs of the Agriculture Ministry weakened support for the alternative strategy. Within EMBRAPA, because of the organisation of the national research centres and the nature of the training of the research teams, the alternative programme was never enacted.

4. EMBRAPA moves towards a new model

At least four different but interacting strands determined the evolution of EMBRAPA's agricultural research system. The first is the dominant model of research priorities and capacities, which imposed a natural trajectory for subsequent development in research interests and problems. It competed with alternative objectives, based on different client priorities and involving different competencies and methodologies, pursued by interests both within and outside the official research system. These two paradigms were affected differently by the economic crisis and the changing political conjuncture of the 1980s. At the same time, the economic crisis increasingly reflected a profound restructuring of global economic activity, which involved new priorities and patterns of competitiveness. Adjustment initially took the form of survival tactics in the face of financial restrictions affecting both the research structure and its clients. Later, a new model of agricultural research and development was articulated to meet the demands of economic restructuring; it involved a new technology base, new demand priorities, new patterns of competitiveness, and new research methodologies and organisational forms. The evolution is captured in two moments: *The National Plan 1988-92* elaborated in 1987 and the *EMBRAPA Project: Agricultural Research for the 21st Century* of 1991.

The proposed new model represents nothing less than a paradigm shift in the public agricultural research system. Unlike the alternative technology proposal of the mid-1980s, it reflects the changing economic environment and seeks to enhance the competitiveness of its existing client base. Nevertheless, a number of qualifications need to be made. First, it is not clear what levels of resistance will be met in EMBRAPA's basic research units. Lack of financing may also frustrate initiatives for institutional reorganisation and human resources programmes. Deterioration in salaries and research running costs may undermine measures for new patterns of motivation.

At present, both public and private sources of international financing are scarce. The generic and easily applicable goals of modernisation and productivity are now largely replaced by more complex criteria of competitiveness, in conditions where access to the necessary scientific and technological capacity is highly problematic.

There is a stark contrast, therefore, between the coherence of the Project and the uncertainty surrounding its implementation. There is a similar contrast between the ability to identify global tendencies and the capacity to develop realistic strategies for competitive insertion. Brazil has shown a marked capacity to develop formal programmes and institutional models in line with those of the industrialised countries. Yet the nature of the domestic context often makes of them paper programmes and institutional shells. The new EMBRAPA model therefore must be examined with caution.

The next two chapters trace the evolution of the major EMBRAPA research centres for wheat and soybeans together with private sector initiatives concentrated primarily in co-operative structures, in order to try to show how these centres adjusted to changing conditions in the 1980s.

II. AGRICULTURAL RESEARCH AND DEVELOPMENT AND THE BRAZILIAN SOYBEAN COMPLEX

1. Introduction

The soybean complex has become the symbol of Brazil's agricultural modernisation. In 1960, some 274 000 hectares were planted to soybeans, and by 1970 there were 1 547 000. Production then exploded and reached 8 774 000 by 1980. Export revenue was second only to coffee and amounted to over \$2 billion. Expansion continued throughout the 1980s; the area planted in 1989 reached a record of 12 481 000 hectares but dropped to 11 481 000 in 1990⁹.

Unlike that of the United States and Argentina, Brazilian policy stimulated exports of soymeal rather than grain. The speed and scale of installing modern milling capacity outstripped the expansion of agricultural production by the 1980s: in 1970: 1 405 000 tonnes; in 1980: 18 000 000; in 1988: 30 128 000. Modern solvent technology replaced mechanical extraction, and a largely family-based milling sector was displaced by leading national and foreign agrofood actors¹⁰.

The co-operative structure, already present in the South due to prior support for wheat production, became the leading trader in soybeans and the principal intermediary of public sector marketing credit. At the same time, it moved into export and processing. It also played a major role in the modernisation of agricultural practices and in agricultural research and development.

Earlier analyses of the expansion of soybean production placed almost exclusive emphasis on the favourable international conjuncture: the high prices of the early 1970s, the decline in fish protein sources; and the fact that the Brazilian crop benefited from favourable out of season prices. More recently, attention has focused on a series of internal factors:¹¹

- i) soybean varieties from the United States were easily adapted to southern Brazil;
- ii) soybean occupies the same area as wheat and follows it as a summer crop; it uses the same machinery, equipment and labour and benefits from soil treatment for wheat;
- iii) because wheat production had been capitalised through government policies for self-sufficiency, soybeans benefited from the existing modernised agro-industrial structure;

- iv) soybean production is almost entirely mechanised;
- v) soybeans benefited from the coffee eradication programme, especially in Parana;
- vi) soybean production was part of a broader national expansion of agro-industry;
- vii) urbanisation favoured the rapid expansion of markets for vegetable oils and the substitution of existing products, particularly lard;
- viii) the co-operative structure for wheat was in place and experienced in technical assistance, marketing and processing;
- ix) there was an increasing demand for soymeal in the intensive meats sector;
- x) favourable conditions for the soybean boom coincided with the policy of subsidised credit for inputs and marketing;
- xi) technologies were developed for adapting soybeans to different climatic regions.

Whether they focus on international or domestic factors, analyses have tended to assume that agricultural research and development simply responds to stimuli. The market opportunities approach rarely considers the role of R&D in the speed of soybean's expansion in the 1970s, and the structural determinants approach emphasizes the importation of varieties already adapted to the latitudes of Brazil's southern states. While both views tend to minimise the importance of domestic R&D, an approach which gives autonomous weight to research and the institutional context may prove valuable.

2. Early research and EMBRAPA's participation

Soybean's initial expansion was based on the domestication of the Common Yellow variety¹², later replaced by new varieties imported from the United States. Two factors are important here. First, the international climate favoured the circulation of such varieties, due to the strength of US university agricultural research and the International Soybean Programme at the University of Illinois, which was supported by funding from USAID. Second, the transfer of embodied technology was accompanied by an intense transfer of know-how through systematic consultancy programmes between different US research centres and the newly reorganised co-operative agricultural research system coordinated by EMBRAPA. The organisation of the EMBRAPA system itself received fundamental inputs from this technical co-operation, which was an important factor in the implantation of a national research programme co-ordinated by the soybean centre¹³. Finally, during this period, major resources were dedicated to adapting the imported varieties to Brazilian conditions, and technical co-operation with US scientists was crucial. Planting schedules, soil treatment and management systems were all developed in this period¹⁴.

This corresponds to the concept of developing country research systems as basically adaptive, and the research policy adopted in this respect by EMBRAPA was opposed by researchers in traditional centres such as the Agronomic Institute of Campinas. The pattern of international research co-operation was also condemned as tributary to the expansionist strategies of the US agro-industry. International technology flows have diminished as the competitive potential of Brazil's soybean complex has increased.

This analysis needs to be placed in a more dynamic framework. Important plant improvement activity in soybeans was already being carried out in major traditional research centres, such as the Agronomic Institute of Campinas and the Agricultural Research Centres in Rio Grande do Sul. EMBRAPA's large investments in training enlarged the available pool of researchers and made possible the introduction of important new areas of research, particularly biological pest control and nitrogen fixation. Domestically developed varieties were available from the 1970s, including Santa Rosa, Delta, Campos Gerais, IAC-2, Viçosa and Mineira.

More important still, the Agronomic Institute of Campinas developed a variety, IAC-2, for cultivation in the low latitudes typical of tropical and subtropical countries. This was the start of genetic improvements that made possible the expansion of soybeans out of the traditional southern States into the Cerrados region and the northeast. By 1980 some 1 262 000 hectares, representing 13.4 per cent of total production, were planted in the new low latitude frontier areas. In 1989 this "frontier" region accounted for 44 per cent of total soybean production. Brazil has now established a leading position in the use of the so-called "juvenile gene" to condition varietal adaptation over different photoperiods, which has made it possible to grow soybeans as a tropical crop.

Increased productivity was partly due to the release of varieties adapted to new climatic conditions and resistant to pests and diseases. By 1980 some 46 varieties were officially recommended, 26 of which came from national plant improvement programmes. An important proportion of the increase in yields is also due to the development of appropriate agricultural practices. EMBRAPA's co-ordinating function allowed for rapid diffusion of research results and accelerated the expansion of the soybean frontier while improving levels of productivity.

3. Biological routes, diversification, and the new frontier

Critics have seen EMBRAPA's principal role as a distributor for upstream oligopoly supply structures. This is a greatly oversimplified view. In the first place, with the exception of seeds, agricultural research specialises in the transmission of (largely biological) know-how, which stands in an ambiguous relation to mechanical and chemical inputs. Indeed, agricultural research expertise traditionally tends to give priority to biological elements that may limit and even compete with the industrial inputs. Thus, the entomologist, the phytopathologist and the soil biologist search for permissible and more efficient uses of chemical and mechanical inputs. This almost always results in the exclusion of certain products and a reduction in the quantities traditionally used. Biological trajectories are even more important when ecological conditions favour the proliferation of pests and diseases. In such cases, plant

improvement programmes give high priority to developing resistance traits which would supplant actual or potential chemical alternatives¹⁵.

A major breakthrough in biological control was the discovery in 1975 of the anticarsia baculovirus which kills the soybean caterpillar and can be used in pulverised form. A pilot project undertaken in co-operation with soybean producers showed that this method of control was as efficient as chemicals and needed only one application, rather than the two required for chemicals. The co-operatives have actively disseminated this simple technology, and it is estimated that some 30 per cent of the area cultivated to soja is now treated in this manner, with savings of some \$10 million. Both the EMBRAPA and the co-operative research programmes situate biological controls in a pest management strategy which is claimed to have reduced average insecticide applications from 5 to 1.2 per harvest¹⁶.

Within this same perspective, early pioneering work on biological nitrogen fixation developed by Johanna Dobreiner led to the rapid diffusion of *Rhizobium*-based nitrogen fixation. This is now applied throughout the soybean crop, with a saving of over 5 million tonnes of nitrogen fertilizer annually and some 80 per cent of fertilizer costs. Recently, new strains make it possible to apply the same methods in the Cerrados.

The literature has also drawn attention to a specific productivity issue: high initial yields followed by stagnation in yields. During the 1980s, the three southern States (Rio Grande do Sul, Santa Catarina, Parana) averaged 1 800 kilos per hectare. However, Parana, taken separately, reaches 2 tonnes, and this is also the average in the new frontier regions. The plateau is not due to the limitations of existing varieties. The performance in field trials in the Rio Grande do Sul of the principal varieties used in the first half of the 1980s averaged around 500 kilos more per hectare. The official EMBRAPA view would point to the non-adoption of certain agricultural practices, particularly soil correction, conservation and management, together with an inadequate use of fertilizer.

Solutions to the question of stagnant or declining yields have also been sought in crop diversification strategies. The Co-operative Research System co-ordinated by EMBRAPA has developed a formal programme for diversification based primarily on the promotion of triticale and barley¹⁷. EMBRAPA's National Soybean Research Centre has sought to identify viable diversification options through the succession and rotation of different crops. These options presuppose a convergence between economic and agronomic objectives, exclude perceptions of risk, and overestimate degrees of interchangeability between crops. In practice, planting decisions are determined by market expectations and existing competencies. As a consequence, the wheat/soybeans cycle continues to predominate, with continuing stagnation in yields and increasing problems of soil erosion. Direct planting techniques for preserving the fertility of the soil and limiting soil compacting have also been promoted. They require greater use of herbicides, increase costs, and have recently been associated with the proliferation of plant disease.

Stagnant productivity occurred in the traditional soybean-producing states during the 1980s, despite the fact that data from the national soybean programme

show that new national varieties demonstrated consistently higher productivity and increased their participation in area cultivated and the further fact that major advances were achieved in pest control, nitrogen fixation, soil management and planting schedules. Stagnation should rather be correlated with inadequate soil conservation measures, in a context where operational costs and the impact of heavy mechanisation consistently erode gains from varietal and crop improvement practices.

In addition, by 1980 the frontier for soybeans in the southern States had been exhausted, and cultivation oscillated around 3 500 000 hectares throughout the decade. The occupation of the Cerrados in Brazil's central region was promoted by farmers and co-operatives from the southern States. EMBRAPA's national soybean research programme worked to develop new varieties based on the "long juvenile period" trait and obtained the first variety adapted to low latitudes, IAC2. Other varieties for the Cerrados were developed by EMBRAPA and the one private firm (Francisco Teresawa) active in varietal development of soybeans¹⁸. Further research into soil treatment and production schedules has allowed rapid expansion into new climatic regions, so that the new frontier now accounts for over 40 per cent of total national production, with productivity levels consistently above 2 000 kilos.

The national soybean research programme has also stimulated research on testing varieties and adapting crop practices to conditions in the North and the Northeast, and soybeans can now be cultivated throughout the country. While this is a major agronomic achievement, it has been argued that research should be concentrated on areas where the crop is most competitive. EMBRAPA would argue the need for geographical diversity to offset adverse climatic conditions.

The evolution of this research shows that no straight line links market signals to research priorities. A decline in crop prices may be more important than any increase in input prices and may lead simply to crop diversification. However, the modernisation of specific crop systems exhibits a high degree of irreversibility. Mechanisation may be the key to declining yields, but all alternatives point to modifications within the mechanised production system; labour is no longer interchangeable with machinery in this production system.

Biological alternatives to chemicals also present problems, because they tend to be pest-, product- and ecosystem-specific. A major research effort may provide a biological control mechanism for the soybean caterpillar, but it does not affect the *percevejo*. Biological nitrogen fixation can be increasingly applied to legumes, but grain and forage crops present greater difficulties. Microorganisms used for biological fixation are region-specific, and new strains need to be identified for the frontier region. Integrated pest management is more generic, but it implies a different level of managerial ability on the farmer's part.

4. EMBRAPA's research priorities

Priorities of the soybean programme are to maintain productivity in areas of traditional production, improve the conditions for expansion on the Cerrado frontier, and explore possibilities for adapting soybean production to other regions in Brazil.

Lowering overall costs and increasing yields are permanent goals as well, since they form the basis of the research effort's legitimacy and further financing.

Three other elements guide research activity. First, there is the search for solutions to problems which emerge in the course of the research activity itself. New varieties demand new cultivation practices, have different demands for inputs, and become susceptible in different ways to diseases and pests. The initial research trajectory therefore continually recreates its own research agenda.

Second, the desire for prestige among peers influences the direction of research. At present, this is reflected in tensions over the potential of advanced biotechnology research. It may also affect the promotion of effective multidisciplinary research. Individual research projects have an internal dynamic that does not adapt easily either to internal or external demands.

Third, public research institutes may wish to study issues of a societal nature. In the late 1980s, EMBRAPA's soybean research programme attached high priority to adapting soybeans for human consumption as a cheap protein substitute. There are strong agronomic arguments for such research. Smoother flavoured varieties have been identified, and protein levels have been significantly increased. Equally strong arguments can be adduced for developing cheaper vegetable protein as the basis of a viable nutritional strategy for developing countries. A project for developing soybeans for human food can be an important basis for co-operation in international soybean research¹⁹. Certainly, agro-industry seems to be more interested in the indirect incorporation of soybeans in the form of isolates and concentrates, and farmers concentrate on price guarantees. Nevertheless, this research is seen as an important goal and international financing is being negotiated. A contract for \$900 000 was recently signed between the University of Viçosa and Nestlé for the development of a smoother tasting variety of soybeans for the production of soybean milk. Viçosa has the most important university research programme in soybeans and has launched more than twenty varieties since the early 1970s²⁰.

5. The fiscal crisis and new orientations

Despite the importance of the crop, the National Soybean Research Centre received no preferential treatment in the allocation of funds. With 50 researchers in 1982 and 42 in 1988 the Soybean Centre is also somewhat smaller than other national product centres. Expenditures have not followed the increasing qualification of the research team. In addition, no extra resources seem to have been allocated for the recruitment of fifteen extra researchers in 1990. Informal estimates suggest that, as a result, research activity in the Centre is running at 70 per cent of normal functioning.

The impact of funding cuts is also difficult to estimate. The numbers of research projects held steady during the early 1980s but declined notably from 1986. Funding remains relatively stable with an important increase in the last year of the series. This stagnation becomes more serious when the aggressive postgraduate training policy, which led to an increased number of PhD researchers in the 1980s, is taken into account. Resources appear to have been increasingly concentrated in EMBRAPA's own research units, to the detriment of the associated research centres.

Thus, the Agronomic Institute of Parana, the most important public research institute in the State, has suffered a severe erosion of its research capacity due to reduced funding by EMBRAPA.

The depth of the crisis was not clearly recognised. Agro-industry showed great resilience; new export markets were conquered (orange juice, poultry) and production of soybeans and wheat doubled. The crisis was associated with the end of the military government, and the middle years of the decade were dominated by ideas of democracy, the revival of old aspirations (agrarian reform, priorities for domestic food production), and a commitment to growth. At the end of the New Republic's first government, however, the persistence and depth of the crisis became clear. Funding of agricultural research at State level dried up, and EMBRAPA was unable to serve the expansion of internal demand created by its training programme. As a result, its own research capacity began to suffer, and the effectiveness of the co-operative research structure was questioned.

Under the Collor government the watchwords became competitiveness, liberalisation, modernity, and privatisation, and the way out of the crisis appeared to require both a technological and institutional rupture with the past. This new posture represents a radical challenge to the public sector. EMBRAPA's research units are now undergoing a thorough review of their methods of operation. It is too soon to evaluate how the new views will affect public agricultural research.

The Soybean Centre is moving to a more systemic research methodology while preserving its profile as a centre of excellence for soybean research. However, budget restrictions block the greater institutional co-operation that is the keynote of EMBRAPA's new orientation. Alternative sources of funding are being actively explored, but they have been frustrated by bans on the hiring of new staff. The sale or licensing of technology is also being pursued, a notable case being the technology for the production of the anticarsia baculovirus. Because much of the Centre's research has the character of a public good, the potential for this form of funding is somewhat restricted. In recent debates the Centre has positioned itself firmly against plant protection legislation²¹.

6. Agricultural research and the co-operative system

Agricultural research centres have been established by the Federation of Co-operatives in both Parana and Rio Grande do Sul, the major soybean and wheat producers in the southern region. The Francisco Teresawa company, whose research team emerged following the reformulation of the Federal agricultural research system in the early 1970s, also has a large network of associated co-operatives. Recently, the powerful COTIA Co-operative has begun to develop plant improvement activity in soybeans²². The research programmes of both OCEPAR in Parana and FECOTRIGO in Rio Grande do Sul, begun in the 1970s, have plant breeding programmes at similar stages of maturity and are able to release new varieties each year.

The co-operative research institutes receive their main financing from a research fund managed by an organ of the Bank of Brazil that represents 0.4 per cent of the wheat marketed from each State. Other sources of funding include a

percentage of revenue from seeds produced by the research centre and marketed by affiliated co-operatives, revenue from the marketing of the centre's own seed production, from laboratory services on seed and soil quality, sale of technology, and the testing of industrial inputs and machinery for the private sector.

The co-operative research centres do applied research designed for immediate use by associates. OCEPAR decided not to establish a biotechnology research component after staff left after the training programme. Its research teams are relatively small but cover a complete range of traditional research activities: plant improvement, soil conservation, pest management, and weed control. The FECOTRIGO Centre has an overall research team of thirteen. The centres work simultaneously on all the crops involved in the production system dominated by wheat and soybeans.

There is significant convergence between the research agendas of the co-operatives and public research bodies. Both have expanded their activities into the areas of pest and soil management, with a view to reducing costs and environmental damage. FECOTRIGO and the OCEPAR produce inoculants and the anticarsia baculovirus on a large scale. FECOTRIGO has created the firm GERATEC-Biotecnologia Aplicada for the marketing of the inoculant *Rhizobium japonicum*.

The plant improvement programmes of these co-operatives have been very successful. To date FECOTRIGO has developed eleven varieties of wheat, seven of soybeans, three of triticale and one of maize, all of which have been recommended for planting in Rio Grande do Sul. The centre's research activity has also been important in the expansion of the soybean frontier to Matto Grosso. In the State of Parana, 45 per cent of the area is sown with OCEPAR's own varieties.

Each year in the different states and regions, the co-operatives, the state and federal public research centres and private breeders meet to determine "technical recommendations" for the coming harvest. These include recommendations on the varieties best suited for different regions and epochs and on varieties no longer to be recommended. Recommendations are also made for soil management, crop rotation, planting seasons, planting, weed control, pest management, and harvesting. It has been argued that productivity in soja is some 50 per cent of the potential achieved at experiment stations, whereas for maize, it is only 15 per cent²³.

It remains to be seen how this system will be affected by the implementation of plant protection/patent legislation. It is difficult to imagine that these levels of co-operation would survive the emergence of competitive seed markets for these products. On the other hand, the stability of soybean varieties and the lower incidence of disease has considerably increased the longevity of the leading varieties. Data on soybean seed demand in Rio Grande do Sul from 1989-91 show that virtually the whole area is planted to varieties released in the 1970s, but increased incidence of disease may begin to increase the attractiveness of more recent releases. The stability of varieties has tended to increase the importance of a systemic view of agricultural research programmes.

Both the co-operatives and the public sector give high priority to "non-embedded" technologies in the form of management practices. Studies dating from the early 1980s show that these were responsible for 15-30 per cent of productivity gains. Their importance has clearly increased with the emphasis on cost reduction, decreased use of fertilizer and chemicals, and increased adoption of pest and disease management practices. It is too early to evaluate how future legislation and the tendency to judge public sector research in terms of its ability to generate direct financial returns will affect the systemic research agenda. However, there are grounds for fearing that it will suffer in the transition to a private seed market structure.

The terms for co-operation with Argentina were already established in the Procisur Programme, which is now virtually at a standstill due to the loss of funding from the World Bank. International co-operation involves a project for a global network for soybean research based on the needs of tropical and semi-tropical agriculture. It was elaborated at the Fourth World Soybean Research Conference held in Argentina during 1989, and was based on recognition of the inadequacies of current networks for the needs of tropical and semi-tropical agriculture. The initiative involves consolidation of networks on a continental basis. The regional initiative of which the Procisur Programme was an example would be restructured into a "Latin American and Caribbean Regional Soybean Network". Given EMBRAPA's pioneering research, the National Soybean Centre would co-ordinate initiatives and would be expected to play a key role in the development of a global network involving Africa and Asia. A major priority of the programme would be to exploit plant breeding advances for the development of soybeans as a natural high protein food in Third World countries.

III. AGRICULTURAL RESEARCH AND DEVELOPMENT AND WHEAT IN BRAZIL

1. Introduction

The research agenda for wheat was set by the nature of the agronomic challenge, first to adapt wheat to highly acidic soils and later to introduce resistance traits to diseases stimulated by the humid climate. In the 1970s, important segments of domestic research were increasingly integrated into the international model of the CGIAR system, which promoted high productivity. Targeted Federal funding gave pride of place to the co-operative system, which provided the main support for the entry of CIMMYT germplasm and varieties.

Under EMBRAPA, the agricultural research system favoured the promotion of domestic wheat production, and this policy remained in force until the fiscal crisis of the late 1980s and regional integration in the Southern Cone. When EMBRAPA assumed the co-ordination of the National Wheat Research Programme, it had to take into account the following factors:

1. Guaranteed prices and guaranteed purchases. They stimulated production but subordinated industrial quality to agronomic performance.
2. Wheat expansion was also stimulated by being harnessed to the explosion of soybean production, as wheat expanded into new regions and adjusted to rotation with soybeans.
3. Research priorities would be elaborated in a climate which placed a premium on energy costs, which primarily affected fertilizer use.
4. Finally, the EMBRAPA system had to take into account a mature research body, particularly in the areas of plant breeding and soil analysis.

Research capacity at EMBRAPA's national wheat centre increased from 52 to 62 during the 1980s, with the largest increase at the PhD level (from seven to sixteen). Funding climbed steadily in the 1970s and early 1980s, trailed off in the mid-1980s and declined abruptly in 1989. However, both the soybean and wheat centres benefited from large new installations financed by the Interamerican Development Bank in the late 1980s.

EMBRAPA's distinctive contribution to wheat research includes the following factors:

1. Its training programme developed important capacity in new areas of phytopathology and entomology. This allowed for more sophisticated plant breeding programmes geared to the incorporation of resistance traits. It also made possible new lines of research related to biological control of pests and diseases. The broadening of research capacity leads towards an increasingly multidisciplinary methodology, but the higher levels of qualification also point to greater specialisation.
2. The Centre's plant breeding built on the earlier programmes of the Experimental Station at Passo Fundo, which concentrated on domestic germplasm and genetic stock and developing resistance by the incorporation of foreign genetic material. The Centre exchanges germplasm with the CIMMYT, but CIMMYT varieties and germplasm are not used for research on plant improvement.
3. Advanced techniques were incorporated, e.g. anther culture, a technique developed through a technology transfer programme with the University of Paris begun in 1979. It accelerates the development of new varieties by up to four years. In addition, the Centre accumulated important research capacity for developing elite germplasm through interspecific crosses that can broaden the genetic base.
4. Collaborative research activity between State institutes and EMBRAPA units was emphasized for adapting wheat varieties to new regions opened up by the advance of soybeans in the Centre-South and the Cerrados.

The Wheat Centre's research has somewhat turned away from chemical control and towards studying the epidemiology of the principal diseases. It is also carrying out important research on biological control. Its fundamental objective is to reduce the use of chemical products to the strict minimum²⁴.

The EMBRAPA model seeks to lower pollution and health risks and to increase sustainability. It situates plant improvement within an integrated programme devoted to soil management, chemical and biological controls, crop practices and crop systems. It can be argued, and the EMBRAPA researchers would certainly argue, that this combined research activity, rather than the yield increases of particular varieties, has been primarily responsible for the sharp upward movement in productivity in the mid-1980s. But the model is ill-adapted to the patterns of accountability that apply in the private sector.

The trend during the 1980s towards a more systemic approach raised questions about the "individual product" orientation. Repeated cultivation of wheat led to the proliferation of diseases and to declining productivity. Although the Centre's research had in fact always extended to alternative winter crops (barley, triticale, oats, tremoco, rape-seed, ervilhaca), issues of crop rotation were seen to require a more systemic view. In particular, wheat research had to take into account the summer planting of soybeans. Research was not only required on soil nutrients, diseases and pests, it also had to develop varieties with a cycle appropriate for combination with soybeans.

As a result, research into each crop was begun in the centre of the other. In addition, the combination of crop and cattle raising is also being studied.

The Centre's plant improvement programme had an early commitment to biotechnology, and significant work was done in the area of cytogenetics. Studies were undertaken, in conjunction with the University of Rio Grande do Sul (UFRGS), to identify chromosome instability, a key factor in lack of varietal uniformity. As a result, a series of recommendations were given to plant breeders in Brazil, and also in Argentina and Uruguay. Gene mapping techniques were developed, again in conjunction with the UFRGS, to identify resistance to aluminium toxicity in the BH1146 variety which was widely planted in the late 1970s and early 1980s.

The culture of immature embryos made possible interspecific transfer of useful characteristics, such as resistance to different types of rust disease and to the "oidio" fungus. A method for transferring useful characteristics directly to susceptible commercial cultivars has placed the Centre in a leading position in the field.

The first variety based on anther culture (BR43) has been launched, four years earlier than the normal time scale would demand. Anther culture is also used to hybridise related species for the transfer of valuable traits. In Brazil, this work may represent the most successful integration of biotechnology into plant breeding programmes, and it points to a crucial issue in seed research. At present, research places a premium on the capacity to integrate advanced biotechnology tools into plant breeding programmes.

Within EMBRAPA, biotechnology was concentrated at the CENARGEM, which is responsible for germplasm collections. The time may have come to integrate biotechnology expertise into the various agricultural research programmes.

Although priority was given to research on disease resistance and efficiency traits, the EMBRAPA system and the Wheat Centre have been responsible for the continuous release of new varieties. Some 46 recommended varieties were released up to 1989, and eight new varieties have been released since. For recommendation, the cultivar must demonstrate at least 5 per cent increased yield in relation to existing varieties, in addition to any new useful trait. Among the qualities incorporated into these new varieties are soil and disease resistance and adaptation to irrigation.

2. The co-operative research system

Private co-operative research began with a collaborative project between the State Experiment Station Julio Castilhos and the CIMMYT, which later became the Accelerated Wheat Programme (PAT) co-ordinated by John Gibler. It was later transferred to the Experiment and Research Centre (CEP) at Cruz Alta²⁵. From the outset, the Centre adopted a production systems approach, as did the Parana Co-operative Research Centre (OCEPAR). Research was undertaken on alternative winter crops (flax, rapeseed), on the principal rotation summer crops (soybeans and maize), and on alternative diversification options, particularly cattle. Research on soybeans and maize was emphasized.

Although the co-operative research capacity is small (13 researchers as against 62 at the EMBRAPA Wheat Centre), its activity is not limited to plant improvement. Research is done on entomology, phytosanitary projects, direct planting methods, weed control, crop practices, soil fertility, seed production, soil management and conservation, and quality control of cereals. The centre's keynote is "applied research whose results can be immediately adopted by farmers". It undertakes seed and soil analysis, contributes to efforts to reduce fertilizer applications, and has an industrial unit that produces inoculants for nitrogen fixation in soybeans. It has developed and diffused biological pest control systems and promoted more rational use of insecticides. It has also evolved crop management practices that offer means to reduce the use of herbicides.

The Centre's plant improvement programme for wheat is primarily based on the development of Mexican germplasm introduced within the framework of the PAT Programme, as is that of the Parana co-operative research programme, which is funded from a portion of the levy on wheat marketed under the control of the Banco do Brasil. These funds were initially directed entirely to Rio Grande do Sul, and the allocations to Parana reflect the growing importance of wheat production in Parana, which accounted on average for over 50 per cent of national production during the 1980s.

In Rio Grande do Sul, the Co-operative Research Centre took over a major State wheat programme, the Julio Castilhos Experiment Station. Together with the EMBRAPA National Centre, it ensures the small share of State research in adapted varieties. In Parana, the State research centre IAPAR also developed an important wheat research programme based on Mexican germplasm and established a leading position in the field. As a result, the presence of EMBRAPA varieties in Parana is very limited.

The OCEPAR follows a pattern similar to that of the FUNDACEP of the FECOTRIGO. It takes a production systems approach and covers plant improvement for maize, soybeans and wheat. It also studies soil management, crop practices, weed and pest control together with the production and promotion of biological control systems. Its research capacity is smaller than that of either the FUNDACEP or EMBRAPA, and its plant breeding programme began later. However, its 1990 annual report states that 51 per cent of the area planted to wheat in Parana is based on "varieties created or introduced by the OCEPAR".

3. The research institutes and the adoption of plant varieties

The OCEPAR has published data on the principal wheat varieties grown in Parana since the mid-1970s which show the importance of varieties from CIMMYT in the expansion of trigo in Parana. Two factors are of particular note here. Mexican varieties enter abruptly and strongly in 1977 (Inia F66, Tanori F71, Jupateco), and there is a progressive reduction in the number of varieties widely planted. At the end of the 1980s two varieties -- Anahuac, introduced by OCEPAR, and Tapejara, introduced by IAPAR -- are of CIMMYT origin and account for almost 70 per cent of the cultivated area. EMBRAPA's IAC-5 variety now only accounts for 5 per cent.

The situation is very different in Rio Grande do Sul, where, according to EMBRAPA, the area cultivated in 1989 was evenly divided between a small number of FUNDACEP and EMBRAPA varieties. EMBRAPA's BR23 variety is responsible for the largest share of area cultivated. In 1990, the FUNDACEP increased its share to around 60 per cent, but serious diseases affected its major varieties. As a result, the FUNDACEP's share will decline considerably, and new varieties will have to be developed at a time when the Centre is facing grave financial problems which threaten to compromise its research capacity. EMBRAPA therefore expects to increase its share substantially in the coming period and thereby justify the resources dedicated to developing resistant varieties.

In Mato Grosso, EMBRAPA leads with almost 40 per cent, and is followed by the Agronomic Institutes of Belo Horizonte and Campinas. CIMMYT has somewhat over 10 per cent and is followed by IAPAR; both FUNDACEP and OCEPAR have a negligible presence. CIMMYT varieties are particularly important in the irrigated areas²⁶.

A comparison of the small number of varieties which dominate production with the number of varieties recommended each year shows the high costs of plant breeding programmes. Some 24 varieties were recommended for the 1991 harvest in Rio Grande do Sul, and 50 for 1990 in Parana. While all programmes share a high mortality rate, the diffusion of evidently superior varieties also depends on an effective seed production system²⁷.

4. Changing economic conditions and agricultural research priorities

Stimulated by the support for import substitution and carried forward in the wake of soybean expansion, wheat production almost matched domestic demand in 1986, reaching 6.2 million tonnes for a projected domestic demand of 6.7 million tonnes. From 1977 to 1987 productivity almost doubled with a slight *decline* in planted area. According to EMBRAPA, these were the fruits of mature systemic agricultural research programmes. Others would place greater weight on the introduction of new Mexican varieties and the shift in production areas. Whatever the cause, there was an average annual productivity growth of 6.03 per cent from 1976 to 1990. Only cotton was higher, with 7.02 per cent, and mamona placed third place, with only 3.23²⁸.

When the EMBRAPA research structure was established, crop area planted to wheat in Rio Grande do Sul was declining sharply but still represented some 70 per cent of national production. By the late 1980s, Parana had more than doubled its share of national production and reached a high of 62 per cent in 1985 with an average productivity of over 2 tonnes per hectare. By this time, Mato Grosso had also increased its share to some 10 per cent. With the expansion of the frontier, farm structures became more heterogeneous, and the regional base of wheat production increased. This made possible different responses to the more austere wheat policy that began when the Brazil-Argentina Protocols were signed in July 1986. The second and third dealt directly with wheat and proposed "an integrated project for the production, storage, transport and supply of wheat". The strategy of self-sufficiency

was abruptly halted by integration with Brazil's principal source of wheat imports and its commitment to increasing levels of imports²⁹.

Debate centred on subsidies, whose levels had not changed with economic conditions, and the subsidies were finally eliminated in 1988. At the same time, pressures were exerted on wheat producers via a progressive reduction in guaranteed prices from \$248 in 1985 to \$115 in early 1989. In addition, Bank of Brasil credit was reduced drastically in 1990 and 1991. Production levels reached a plateau in 1986, but in the last two harvests production has declined by some 30 per cent.

The cycle of reform measures was completed in 1991 with the privatisation of wheat marketing, which was accompanied initially by a policy liberating wheat imports. The latter measure has now been modified, with the imposition of a 25 per cent tariff which will be progressively reduced over a five year period³⁰.

The research community agrees that the new wheat policy will have a major impact on the structure of wheat production. Greater flexibility with regard to imports and declining support prices will tend to establish new productivity thresholds. A simplified view would suggest that wheat production will now only be viable in the new areas, where farm units are larger and there is greater scope for the use of the high yielding Mexican varieties.

EMBRAPA points instead to the major increase in yields in Rio Grande do Sul during the last five years to argue that an important segment of the wheat producing sector can survive in the more competitive environment of the 1990s. EMBRAPA is considering a target of 2.5 to 3.5 tonnes per hectare. To achieve it, EMBRAPA would give equal importance to high-performing varieties and the package of crop practices which have been perfected over the last fifteen years. It argues that, with existing technologies, average national productivity of over 2.3 tonnes per hectare is possible. However, tens of thousands of farmers in Rio Grande do Sul, in Santa Catarina and in the South of Parana will become uncompetitive in this new context and will have to diversify out of grains if they are to remain in business.

The shift to higher levels of productivity is not seen to represent in itself a new challenge to the research structure, but it is crucial to maintain and strengthen research capacity, given the continuous emergence of new diseases and pests and the critical degradation of soil fertility. The Rio Grande do Sul Miller's Association is currently campaigning for a large-scale programme of soil recuperation, which it sees as necessary for maintaining the region's competitiveness³¹.

On the other hand, the privatisation of wheat marketing is likely to have a decisive influence on the research agenda. In the past, due to the guaranteed purchasing structure, quality did not influence planting decisions. Nor was quality an issue for the milling sector, because the wheat market was relatively unsophisticated, and because the poor quality of domestic wheat could be compensated by blending with imported wheats as long as consumption outstripped domestic production.

The move towards self-sufficiency coincided with a diversification of demand for more varied and higher quality wheat flour. With the expansion of wheat into more

fertile soils and the use of Mexican varieties, the problem of quality could be solved by mixing wheats from the different domestic regions. However, with the disappearance of guaranteed purchase, it is likely that much wheat will have difficulty finding a market. While different varieties are suited to different industrial processes, quality is also greatly affected by climatic conditions. The milling associations are already organising their purchasing strategies on the basis of on-line harvest information.

It is clear, therefore, that the issue of industrial quality will have to be incorporated into plant breeding programmes, and meetings between EMBRAPA and the Milling Association are already underway. This year's plant variety recommendations already include details on industrial quality, giving "superior", "medium" or "inferior" grades for pH levels, flour yield, and milling quality. The most popular B23 variety fares poorly: it is superior in pH, but inferior in both flour yield and milling quality. EMBRAPA's National Wheat Programme currently has 57 projects relating to agronomic features, and industrial quality will now have to be integrated into plant improvement³².

The industrial property legislation and the adoption of a more entrepreneurial posture within the public research structure would suggest a strengthened private sector. However, the privatisation of wheat marketing has placed the co-operative research structure in considerable difficulty. While situated within the private sector, the co-operative research structure has been financed primarily by the levy on wheat imposed by the Bank of Brazil. For the OCEPAR research centre, this was the source of 42 per cent of total receipts in 1989. Privatisation will affect inefficient wheat-producing areas, and farmers can now bypass the co-operative and sell directly to millers and/or the animal feed industry. Furthermore, it is not clear that individual co-operatives are prepared to assume the administration of the research levy.

The private entrepreneurial sector is virtually non-existent in wheat, but the public sector research system has prepared the ground for a private plant breeding sector. The Francisco Teresawa company, which is active in soybeans, is now developing wheat varieties that are being tested by the Parana Agronomic Institute (IAPAR). Like the Francisco Teresawa company, the Ottoni Rosa company, which produces wheat varieties in Rio Grande do Sul, has moved from the public to the private sector. Its varieties are now in official trials and should be launched within two years.

Private firms would have a place in wheat because the economic crisis and a more bureaucratic rhythm tends to make plant breeding inefficient in the public sector. Advances in research have now led to an efficient production system based on mature plant variety programmes, efficient use of fungicides and crop rotation systems. In this context, a private firm concentrating on high yielding varieties would have good market opportunities; the Ottoni Rosa company's strategy is closer to the high yields/high inputs breeding programme associated with the CIMMYT than to EMBRAPA's effort to diminish industrial inputs.

It is too early to assess the potential for the emergence of a private seed sector in wheat if plant variety or patent protection legislation is enacted. While much

research is being undertaken, there is considerable controversy over the potential of hybrids in wheat.

The high incidence of disease and the difficult soil conditions, in addition to the greater intrinsic instability of wheat varieties, make for a high mortality rate in new varieties. In light of the further doubts over wheat's viability in the new climate favouring the liberation of imports and regional integration with Argentina, a strong private sector is unlikely to emerge rapidly. In addition, EMBRAPA's research programme places it in a strong competitive position, particularly for the development of the elite resistant germplasm which will be at a premium as new diseases proliferate. For all these reasons, it is perhaps not surprising that the National Wheat Centre has adopted a relatively neutral position on the issue of plant variety legislation.

Regional co-operation in wheat research has existed for some years within the framework of the Procisur Programme and involves exchange of germplasm, training programmes, and regional trials of plant varieties. While cost-benefit analysis has indicated high rates of return on Brazil's participation, there was little evidence of priority being given to the Programme, and with the end of funding from the World Bank the programme is virtually at a standstill. The National Wheat Centre would rather see itself as a point of reference for global wheat research, particularly for tropical and semi-tropical conditions. Co-operation with Africa, where Brazilian varieties are already being used, would be a major priority. This would be part of the restructuring of the international agricultural research system and would involve a redefinition of the role of CIMMYT³³.

IV. AGRICULTURAL RESEARCH AND THE SUGAR-ALCOHOL COMPLEX

1. Introduction

Agricultural research geared to the sugar-alcohol complex is very different from the two areas previously considered, and it is not co-ordinated by EMBRAPA. Although a formal protocol was signed in 1974 between EMBRAPA and the National Programme for the Improvement of Sugar Cane (PLANALSUCAR) for integrated sugar cane research in Brazil, it simply ratified the executive role of the PLANALSUCAR in sugar cane research. Like the other traditional export crops (coffee, cocoa), the sugar-alcohol sector has specific institutional arrangements that also encompass agricultural research. Its regulating organism was the Institute for Sugar and Alcohol (IAA), which was abolished in 1990.

The restructuring of this sector involves a major reorientation out of food and into the energy complex. The future of this agro-industrial sector therefore depends primarily on the role of fuel alcohol in Brazil's energy matrix. The evolution of sugar markets can nevertheless have a significant influence on policy and competitive strategy.

The two major agricultural research institutions for the sugar-alcohol sector were established prior to the Proalcohol Programme, launched in 1975. The PLANALSUCAR, created in 1971, was an offshoot of the 1965 4870 Law, one of whose provisions was for a levy on exports to finance the modernisation of the sector. The Copersucar Technology Centre (CTC), established in 1969, is the research arm of the leading co-operative in the sector, Copersucar. Its funding also derived from a marketing levy supervised by the Institute of Sugar and Alcohol (IAA). As for wheat, the principal private sector active in research was thus highly vulnerable to institutional transformations in the public sector, particularly those involving the liberalisation of marketing from State monopoly and quota systems.

A report, prepared in 1966 at the request of the IAA by Albert J. Mangelsdorf, ex-head of the Hawaii Sugar Cane Experimental Station, proposed a major long-term research programme for improved yields. When the IAA did not act quickly on it, Mangelsdorf accepted Copersucar's invitation to supervise the establishment of a research programme for the development of new varieties and which became the CTC. One result has been a lack of integration if not outright competition between the public and private sectors in the area of plant breeding. Copersucar's initiative may be attributable to dissatisfaction with bureaucratic sluggishness, but the identification of the IAA with Northeastern or non-Sao Paulo interests was probably at least as important. In any case, when the PLANALSUCAR was launched, Sao Paulo sugar

processors were already committed to funding a private agricultural research programme, and the PLANALSUCAR was closely tied to the fortunes of the IAA.

Both programmes developed research programmes based on the Mangelsdorf report³⁴. The PLANALSUCAR was an ambitious long-term national programme that envisaged results at the end of a ten-year period. In the climate of optimism created by the high yielding Green Revolution varieties, the IAA committed itself to major infrastructural and human resource investments. The goal of plant improvement was motivated by the very low productivity levels in Brazil, around 42 tonnes per hectare and by the low costs to the farmer, since no new machinery or inputs would be required. As a result, the programme was seen as a distributive programme geared to the interests of the sugar cane suppliers and to less developed regions.

The Copersucar plant improvement programme was of a magnitude similar to that of the PLANALSUCAR. The critical state of the genetic material pointed to the urgency of such research, given the increasing importance of exports and the need to compete with other exporting countries whose yields (80 tonnes per hectare) were double the Brazilian average.

The fact that short-term economic returns tend to dominate private research raises questions about the lack of safeguards in introducing foreign germplasm and in releasing varieties whose resistance to major diseases and pests was doubtful. For example, Copersucar released the SP70.1143 variety, which is probably the most widely planted in Sao Paulo and is susceptible to the rust disease. The varieties of PLANALSUCAR and the IAA are all resistant to this disease.

In the division of labour between public and private research, the PLANALSUCAR has emphasized cost-cutting biological control systems, while Copersucar's programme quickly expanded to incorporate a wide range of issues regarding industrial processes, instruments and machinery which gain in importance with the shift to alcohol production. Its activity is determined less by individual factor substitution than by efforts to increase overall productivity through continuous wide-ranging improvements. This challenge was soon reoriented by the shift from sugar to alcohol production in the mid-1970s³⁵.

2. The Proalcohol Programme and the reorganisation of the sugar cane complex

The sugar industry's modernisation programme in the 1970s coincided with a period of sharp rise and fall in international sugar prices, and resulted at the end of the decade in marked overcapacity. At the same time, the oil crisis led to sharply increased petroleum prices. Since Brazil then imported 80 per cent of its gasoline requirements, the price increase pushed up the share of this item in total imports from 12 to 22 per cent. What was perhaps unexpected was the size of the Proalcohol Programme, and the speed of implementation, since it met with substantial resistance from the car and capital goods industry and from the influential Petrobras and Ministry for Industry and Commerce. The sugar lobby was crucial, but it was aided by concerns about the balance of payments. Also, the World Bank agreed to finance investment in alcohol distilleries.

The launching of the 1975 Proalcohol Programme involved the creation of a special body, the National Alcohol Executive Commission (CENAL), which was responsible for the analysis and approval of investments in distilleries. In addition the National Petroleum Council and Petrobras jointly assumed charge of alcohol distribution, thereby depriving the IAA of a fundamental source of income and power³⁶.

The first five-year plan established a target of three billion litres of alcohol to be mixed with gasoline, a target which demanded new industrial investment and an increase in planted area. Favourable prices, guaranteed purchase, 100 per cent subsidised loans for industrial and agricultural investment credit, and special working credit conditions ensured that targets were reached. Industrial investment was primarily directed to the modernisation and construction of distilleries annexed to the sugar mills.

The end of the first targeted period saw an unprecedented increase in petroleum prices from \$12 to around \$30 a barrel, with petroleum accounting for 30 per cent of total imports. At the same time commodity prices entered a period of decline, and the prime interest rate soared from 7 to 21 per cent. For this reason, the Proalcohol Programme embarked on a more ambitious project, the complete substitution of gasoline.

By the end of the second five-year period, major problems appeared. Surpluses began to be a financial burden for Petrobras, but the principal problem was the decline in gasoline consumption. By 1985 gasoline exports amounted to almost 40 per cent of total production and, given the difference between internal and export prices, represented a loss of around \$1 billion per year. The production of gasoline could not be reduced since it was a byproduct of diesel production which was the key to the petroleum fuel matrix. In addition, the decline in gasoline revenue made it more difficult to maintain subsidised prices for diesel and domestic gas.

In 1989 the supply of alcohol collapsed, and 29 distilleries stopped production. The decline in real prices from 1985 led to stagnating production, while consumption was still increasing at a rate of 11 per cent per year due to growing numbers of alcohol-fuelled cars. The alcohol in gasoline was reduced from 22 to 12 per cent, and alcohol-fuelled cars were readapted to gasoline. A government proposal to reduce the proportion of alcohol-fuelled cars to 50 per cent was overtaken by loss of public support, and production quickly dropped to 10 per cent.

It is likely that the 1990s will see increased competition in the sugar alcohol sector. Lobbying power was a key factor in the approval of investment projects and the allocation of production quotas. Levels of technical and managerial efficiency therefore vary widely. Distillery yields in Sao Paulo vary between 3 625 and 7 045 litres per hectare, and production costs in the less efficient plants are as much as 20 per cent higher. Given the government's declining real price strategy for sugar and alcohol, the sector is likely to see considerable shakeout. Given the anti-subsidy policy, a premium will probably be increasingly put on productivity and technological efficiency³⁷.

3. The PLANALSUCAR and the context created by the Proalcohol Programme

The PLANALSUCAR had from the outset a problem of client identity. Effectively excluded from the dynamic centre of sugar-alcohol production in Sao Paulo (although its headquarters were there) and identified with the increasingly marginalised northeastern base of the IAA to which it was entirely subordinated, the PLANALSUCAR attempted to define its national mandate in terms of the new producing sectors and new regions brought into sugar production in the wake of the Proalcohol Programme. However, the client base was too diffuse, both regionally and institutionally, to provide an autonomous base.

The institutional subordination of the PLANALSUCAR to the IAA came to assume crippling proportions, and in 1987 the Superintendency launched a campaign to transform the PLANALSUCAR into a Foundation with organisational flexibility and financial autonomy. It argued that the Programme would otherwise collapse³⁸. The proposal contained a substantial list of achievements: a major plant improvement programme, effective biological control systems for the most serious pests, the technical means to set prices according to saccharose content, and a range of technologies for adapting sugar cane production to the demands of the Proalcohol programme³⁹.

Negotiations to incorporate the PLANALSUCAR into EMBRAPA were begun, but the latter's resources no longer cover its own needs. The experimental stations and laboratories have been abandoned, along with the plant improvement programme. PLANALSUCAR staff in Sao Paulo have been absorbed by the university structure, but are without resources for research.

Thus, the PLANALSUCAR, based on the premise that private research was unable to guarantee either a broad national perspective or adequate quality criteria, disappeared in a political climate favourable to the dismantling of interventionist organs such as the Sugar and Alcohol Institute, whose increasing irrelevance only served to highlight its subordination to vested interests.

4. The Copersucar Technology Centre in the 1980s and into the 1990s

Copersucar's plant breeding programme was reaching maturity when it combined with its industrial analysis laboratory to form the Copersucar Technology Centre in 1979. The first generation of SP varieties were launched in 1981, and they progressively dominated the area cultivated by Copersucar's associates. A national comparison (excluding the two important States of Pernambuco and Alagoas) of the dissemination of PLANALSUCAR and Copersucar varieties in 1990 is highly favourable to the latter. The Copersucar programme thus dominates the centre-south and centre-west where some 70 per cent of total production is concentrated. A second generation of varieties was released in 1988 and a third in 1991 for a total of 25 releases in all.

Modern techniques of micropropagation, tissue culture, and more recently genetic engineering have been integrated into the breeding programme through

collaboration with Cornell University. The centre has accumulated a large germplasm bank and has effective quarantine facilities. While this might suggest that the Copersucar breeding programme has adequately compensated for the demise of the PLANALSUCAR, doubts remain about the resistance of SP varieties to the rust disease which is beginning to present a serious threat.

The resources and activities of the CTC grew strongly through the 1980s. Copersucar itself expanded considerably. It led the conversion to alcohol and moved into sugar refining (over 50 per cent of national production) and coffee (8 per cent of the domestic market). The research budget rose from \$7 million to over \$20 million between 1983 and 1989 and represented 1 per cent of gross sales, an extremely high commitment.

During the 1980s, Copersucar embarked upon a wide range of research in biological controls, alternative uses for vinasse and bagasse, crop diversification (food crops and cattle fattening), and the improvement of biological controls.

Like that of the EMBRAPA centres, the research agenda of the CTC is constantly redefined in function of the problems and side-effects associated with rapid monocultural modernisation in semi-tropical conditions. In the past, sugar cane was grown on the rich soils of the coast, but thanks to a plant improvement programme for adapting sugar cane to low fertility soils it can apparently be grown like any grassland crop.

A major problem in these soils is the proliferation of soil insects (nematodes), which affects all crops in the Cerrados region, so that crop rotation practices become an important component of continued productivity. Monitoring systems have been developed for detecting the areas of greatest infestation; this makes it possible to apply control techniques more economically.

A more systemic and multidisciplinary approach, with an increasing integration of biological controls, has been taken by the CTC research programme in response to tighter legislation on the use of chemical compounds, the increased costs of such use, and the limited efficiency of agrochemicals for a whole range of pests prevalent in sugar cane production. Thus, biological control methods have been developed, due to the ban on the use of chlorinated organic compounds; they have been successfully adopted for the sugar borer, and many sugar mills now have their own insect nursery for multiplying natural parasites.

Thus, both the EMBRAPA centres and the CTC have progressively adopted a more holistic and systemic approach, giving increased emphasis to crop rotation, integrated management and biological controls. In EMBRAPA, research projects undergo a primarily scientific vetting process which may allow for a higher proportion of basic research activity. In the CTC, instead, the research programme is submitted for approval to a Consultative Council with three representatives from sugar mills dealing with agricultural research and three for industrial processes. They are elected to a four-year term, and they tend to define the research agenda more pragmatically. According to a research head at the CTC, however, the weakness of basic research

in the universities and the lack of interest in sugar cane in the industrialised countries forces it into more basic research.

With the demise of the PLANALSUCAR, the CTC is left without competitors, since the Agronomic Institute of Campinas has also stopped its sugar cane research activities. There is no evidence of private seed firms in sugar. This broadens the demand for the CTC's technical services, for which non-associates pay. This opens up an important source of non-budget funding. But dependence on a single plant breeding programme is potentially dangerous, given the more limited genetic base for new variety releases. This is particularly important if the SP varieties prove in fact to be susceptible to rust disease.

In addition, the CTC is geared specifically to the priorities of its members located in the Sao Paulo region, and it is therefore no substitute for a national programme. But because there are no agronomic reasons that prevent the expansion of SP varieties into the new frontier areas or the traditional northeastern region, it is likely that the CTC will expand the geographical reach of its activities. It is unlikely that it will replace the national network involving over 30 experimental stations established by the PLANALSUCAR.

Although it lies in the private sector, the co-operative structure depends greatly on government intervention and its role as intermediary of subsidised credit. As for wheat, trading in sugar was based on a quota system, and a key to Copersucar's growth has been its capacity to monopolise marketing activities. In the wake of the demise of the IAA, market liberalisation has been extended to the sugar sector, and individual sugar mills are now free to market their own production. The impact on Copersucar has been dramatic. The number of affiliates has declined from 67 to 47, and the defectors are primarily the major mills.

As a result, the CTC budget, which was based on a percentage of the co-operative's marketing revenue, has suffered major cuts. Three thousand hectares of field trial lands have been sold, and the number of seedlings used for the plant breeding programme has been reduced from over two million to 600 000. The reduction in funding is of the order of 40-50 per cent. This very recent development is likely to have a major impact on the plant breeding programme, which, when added to the fate of the PLANALSUCAR and the demise of the Campinas Institute programme, calls the future of sugar cane research into question.

It is not surprising that the CTC is a strong defender of plant protection legislation. It is calculated that if intellectual property led to returns of \$5 a hectare, the Centre would receive over \$7.5 million. This would compensate for the current cuts in funding. Initial moves in this direction have already been taken with the Union of Sugar producers of Alagoas, which has committed itself to a payment of the equivalent of 300 kilos of sugar cane per hectare over a five-year period.

CONCLUSION

The different public sector agricultural R&D institutions in Brazil have been diversely affected by the crisis and policy reorientations of the 1980s. The public R&D programme in sugar cane, independently of any evaluation of its merits, was a victim of the marginalisation and subsequent abolishment of the Sugar and Alcohol Institute. In wheat and soybeans, the federal bodies have tended to survive by dismantling State research institutes. EMBRAPA's current budget crisis, with funding apparently cut by as much as 50 per cent, may suggest a similar future for the federal research structure.

The public sector agricultural research structure is also responsive to changes in factor prices. Research here should probably have as a principal objective overall cost reduction through a decrease in dependence on industrial inputs. Such targets are not easily distinguishable from a more structural preoccupation with the impact of monocultural modernisation. They shift the research agenda from the individual product to the production systems, on the basis of a methodology that is increasingly systemic rather than oriented to a specific discipline.

This approach better fits ecological objectives and the preference for biological solutions. This is clear in the case of fertilizer use. The nascent private seed sector seems to give priority to varietal development based on the efficient use of industrial fertilizer inputs. In the public sector different forms of biological nitrogen fixation clearly predominate.

A privatising ideology might emphasize the bureaucratic and inefficient character of public sector activity and its tendency towards academic rather than applied research. It might attribute this to the lack of accountability to a client base. However, the vocation of the public research community is tied, to a significant extent, to perceived societal objectives, and this orientation is arguably a positive consequence of the lack of a specific clientele. Thus, the Soybean Research Centre currently accords considerable priority to developing new protein-rich soybean varieties suitable for immediate non-industrial consumption.

There is no simple public-private division of labour in agricultural R&D. Private sector R&D has been overwhelmingly dominated by the co-operative system, which has proved very vulnerable to liberalisation, as it has been largely financed by levies from State marketing quota systems. The few small private firms seem backwards in comparison with the systemic R&D methodology increasingly adopted by EMBRAPA, and there is as yet no sign of interest on the part of leading players in the seed industry.

Public sector agricultural research in Brazil first sought to develop an institutional capacity for adaptive research, permitting rapid agricultural modernisation using imported technology packages. Its ambitious training programme resulted in a body of researchers able to accomplish original research, particularly in plant improvement and biological controls, e.g. the development of soybean varieties incorporating the "juvenile gene" and adaptable to low latitudes. The wheat research programme's efforts to develop varieties based on domestic germplasm, together with its work on resistance traits, biological fixation and biological controls, have given the Brazilian public agricultural research system a strategic position with regard to tropical and semi-tropical agricultural systems. The potential of this system should therefore be taken into consideration in an analysis of new patterns of international research co-operation.

While the demands of the new technology paradigm are apparent to all, a new training programme comparable with that of the late 1970s is unlikely to materialise in the current economic context. Yet competence is acutely lacking in the fields of information technology and biotechnology. There are also serious difficulties in improving established skills, particularly in plant breeding. The 1980s have shown the need to integrate molecular biology into the traditional practices of plant breeding; but young researchers are attracted to biotechnology, and the population of plant breeders is ageing. This may reflect more than the impact of the crisis on recruitment: it may indicate a serious decline in supply.

The public sector research system recognises that research must take a more entrepreneurial approach, both for mobilising resources and for creating more clearly identified and accountable client relations. In part it is the EMBRAPA's current "non-accountability" that makes it vulnerable in a time of acute crisis. Present restructuring proposals recognise the inter-institutional dependence of research and the need to reflect articulated societal demands.

The need to rethink the role of public agricultural research is recognised both inside and outside the sector. Research methodology, training priorities, accountability, and funding are all in question, but the severity of the current crisis may make survival the first priority. The present study has shown that public sector research made important advances in the 1980s in spite of the crisis. It has also pointed to the complexity of defining new frontiers for public and private competence. Private sector research is fragile and has depended heavily on public funding; it is not clear that it can replace the public research system. And while autonomy may lead to excessively academic goals and bureaucratic procedures, it also allows resources to be mobilised for strategic societal goals.

The present study has argued that in Brazil there is no direct relation between economic crisis and structural reform/liberalisation, nor between the latter and the dynamics of the agricultural research system. The economic crisis has been largely interpreted in the light of the transition from a military to a democratic regime, and national economic growth strategies have been offered as the means to overcome it. Very recently, a new view has emerged. It gives priority to orthodox fiscal adjustment, to international competitiveness accompanied by international institutional alignment

as the precondition for growth, and to a programme of privatisation for the State-controlled industrial sector.

It is too early to judge the impact of these measures on agricultural research in Brazil. Given the complexity of the balance between the public and the private sector, the current priority accorded structural adjustment and liberalising policies must be situated within the context of the demands for competitiveness implied by the current technological and organisational revolution in economic activity. Given the fragility of the private agricultural research sector in Brazil and uncertainty as regards the perspectives for foreign investment, the new international context may well demand a substantial strengthening of the public agricultural research system.

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