Wheat Production
Advances in South America’s Colossus

The Gains from 20 Years of Brazilian/CIMMYT Research Collaboration
The gluten quality of Brazilian wheat is one concern of scientists such as Luiz Hermes Svoboda, head of the Wheat and Triticale Program for the Experimentation and Research Center (CEP) of the Rio Grande do Sul Federation of Wheat and Soybean Cooperatives (FECOTRIGO).
The Research Payoff - Golden Harvest Under the August Sun

In one direction, “rivers” of wheat flowed on the contoured land to the horizon; in another, adjacent fields made an interconnecting grid of quilt-like patches of green, yellow, and golden brown. This spectacle was my view at 8500 m above the Tibaji River Valley (see cover) as my jet approached the city of Londrina in the northern part of Paraná, Brazil’s top wheat producing state. I was well into a 2000-km winter trek through Brazil’s wheat areas that would dispel my “coffee-soybean” stereotype of the country.

During the first half of this journey, CIMMYT wheat specialist Man Mohan Kohli, a 10-year veteran in the Southern Cone of South America, acted as my guide. He was making a routine trip to help in screening material in the wheat plots of cooperating Brazilian institutions. I was along to visit these same institutions to gather information on Brazilian wheat research and production problems for this CIMMYT Today. Serving as my gracious host during my tour from western Paraná into Rio Grande do Sul was Benami Bacaltchuk, head of the technology transfer unit at the National Research Center for Wheat (CNPT) in Passo Fundo.

As we visited the various research institutions, Mohan Kohli made the observation that: “their combined energies and enthusiasm make the Brazilian wheat breeding effort one of the outstanding programs in the world today. It is at par with any developed country program in terms of its breeding network, screening of material, and developing varieties.” As I was to discover, this breeding program is complemented by equally aggressive research efforts in agronomy and plant pathology.

Many of the breeders, agronomists, and pathologists I visited (such as Luiz Hermes Svoboda at left) were among the wheat trainees and visiting scientists who have spent time at CIMMYT/Mexico since 1969. Many of these Brazilian researchers cite training and scientific visits at CIMMYT as important contributions to the advances in wheat production made over the last 20 years in Brazil.

Due to the advanced nature of the Brazilian national program, it is well-positioned to effectively participate in international agricultural research. A proposed breeding partnership between Brazil and CIMMYT that will capitalize on the special skills of Brazilian researchers is under discussion. This may result in a Brazil/CIMMYT International Acid Soils Tolerance Screening Nursery, which will benefit many countries throughout the world that have acid soil problems.

**The Brazilian wheat breeding effort is at par with any developed country program in terms of its breeding network, screening of material, and developing varieties.**

This CIMMYT Today presents the viewpoints of a cross-section of Brazil’s major players in wheat research and production. The narrative begins with some history and a description of the current wheat status. Also included are profiles of the research institutions working to improve wheat production in key areas and their working relationships with CIMMYT.

We go on to explore where and to what extent wheat production may expand. A number of Brazilian researchers and administrators point out that the advances in production technology, combined with the availability of vast tracts of unexploited arable land, suggest a huge potential for expanding the country’s wheat production. However, the general consensus appears to be that the question of long-term self-sufficiency is, as usually is the case, fundamentally economic and political in nature, rather than simply technical.

Many of the facts about early wheat research in Brazil have been gleaned from an English translation of The History of Wheat Improvement In Brazil by Mário Bastos Lagos, published in 1983 by the Instituto do Pesquisas Agronomicas in Rio Grande do Sul as Technical Bulletin No. 10.

G.P. Hettel
Science Writer/Editor—Wheat CIMMYT Information Services
Brazil, the fifth largest country in the world (8.5 million sq. km.), is not at all known for its wheat production; coffee, sugarcane, soybeans, and oranges more often come to mind. This South American colossus is second only to the United States in the export of agricultural commodities, but wheat is not one of them. Brazil produced 6.2 million metric tons (mmt) of wheat in 1987 on around 3.4 million ha, which supplied around 87% of the needs of its 138 million people. The preliminary production estimate for 1988 is 5.7 mmt on about the same hectarage. The 1987 production figure represented only 1.2% of the world’s total wheat production in that year and Brazil’s output was dwarfed by the wheat production of such giants as China (87.0 mmt), the Soviet Union (80.0 mmt), the United States (57.3 mmt), India (45.6 mmt), and Canada (26.3 mmt).
The Brazilian Institutions

There are numerous Brazilian institutions engaged in agricultural research. Support comes from the Federal government, state governments, and from farmer cooperatives.

The Brazilian Agricultural Research Enterprise (EMBRAPA), founded in 1974, has seven commodity centers—one of which is The National Research Center for Wheat (CNPT) in Passo Fundo, Rio Grande do Sul. Resource centers make up a second group of EMBRAPA institutions, such as the Cerrados Agricultural Research Center (CPAC), which work with crops, pastures, and livestock to develop an integrated agricultural system for a particular region.

EMBRAPA also has regional service centers that deal with germplasm conservation, chemical pesticide control, biotechnology, etc.

Virtually all Brazilian states have their own agricultural research institutions. In the states that have no research organizations, EMBRAPA has opened experimental units to do the research there. State institutions discussed in this CIMMYT Today include São Paulo’s Campinas Agronomic Institute (IAC), the Paraná Agronomic Institute Foundation (IAPAR), the Institute of Agriculture and Livestock Research for Rio Grande do Sul (IPAGRO), and the Minas Gerais Enterprise of Plant and Animal Research (EPAMIG). IAC, which celebrated the 100th anniversary of its founding in 1987, was the first truly successful research institute of its kind in Latin America.

Cooperative-supported institutions also play important research roles. Farmers contribute a certain percentage (usually 0.2 to 0.4%) of their income from soybean and wheat harvests. This money goes straight to the cooperatives’ research arms, such as the Experimentation and Research Center (CEP) of the Rio Grande do Sul Federation of Wheat and Soybean Cooperatives (FECOTRIGO) and the Eloy Gomes Research Center of the Organization of Paraná State Cooperatives (OCEPAR).
Wheat is grown primarily in Brazil's southern states of Paraná, Rio Grande do Sul, Mato Grosso do Sul, Santa Catarina, and São Paulo. Acid soils (see box on pages 8 and 9) and numerous diseases are the major production constraints in much of this region. Wheat was first introduced to Brazil in São Paulo by European immigrants in the 16th century. Rio Grande do Sul is considered to be Brazil's leading wheat-producing area. Around 10,000 ha of wheat are grown there today, virtually all under irrigation. Another area touted as having wheat production potential is the High São Francisco Valley region in the state of Bahia.

Brazilian breeders pioneered the development of wheat varieties having tolerance to aluminum toxicity—a major production constraint throughout the region.

Brazil has a rich tradition in wheat breeding efforts dating back to the early 1900s. The country's new generation of scientists, such as Carlos Riede, Francisco Franco, and Luiz Hermes Svoboda, give much of the credit for today's successes to pioneer breeders such as Benedicto Paiva, Ivar Beckman, and Carlos Gayer, as well as to those who came later such as Orlando Gomes Nobre, Milton Alcover, Mário Bastos Lagos, and Ady Raul da Silva. Many of these breeders pioneered the development of wheat varieties having tolerance to aluminum toxicity—a major production constraint throughout the region. Thumbing through CIMMYT's publication on the "Wheat Varieties of the Southern Cone" gives one a clear idea of the important role these and other early breeders played in Brazil's current wheat breeding successes. In addition, CIMMYT's Norman Borlaug, Glenn Anderson, John Gibler, and the bread wheat breeding team currently led by Sanjaya Rajaram have contributed to Brazilian wheat germplasm improvement.

The state of São Paulo, in southeastern Brazil, has some of the richest farmland in the country. Its farmers supply almost half of the nation's coffee, cotton, fruits, and vegetables and around 5% of Brazil's wheat—which still gives the state a fourth place ranking in wheat production. The fertile land is criss-crossed by an excellent system of railways and modern highways that efficiently get the harvests to the population centers of the region.

Wheat production in São Paulo has a checkered history. Portuguese immigrants brought wheat with them in the 1530s when the region was known as São Vicente. Although wheat was planted here first, its cultivation did not develop well in the early days due to disease problems, particularly stem rust.

Over the next 4 centuries, the area planted and the yields obtained fluctuated widely because imported varieties soon succumbed to rust. Also, many of these varieties required an extended period of cold
temperatures after germination (called vernalization) in order to develop seed, and this climatic requirement is seldom met in São Paulo. It was only after the introduction of the variety Frontana, bred by Iwar Beckman in Rio Grande do Sul in 1945, that wheat cultivation began to stabilize in the state.

According to João Carlos Felicio, wheat breeder at the Campinas Agronomic Institute (IAC), wheat research in São Paulo began to intensify in the 1940s and, by the early 1950s, wheat breeders were producing tangible results. In 1953, IAC relocated its wheat experimental station to Capão Bonito, an area in the southern part of the state more conducive to wheat production. It was here that the popular “IAC” varieties originated.

The most outstanding of these varieties was IAC 5-Maringá (Frontana/Kenya 58/Ponta Grossa 1) developed in 1966 by Milton Alcover, long-time IAC breeder. Between the end of the 1970s and early 1980s, IAC 5-Maringá was the most popular variety in the wheat-growing areas throughout Brazil. Although Maringá is still cultivated on a large-scale in Rio Grande do Sul and Paraná, area devoted to the variety is declining due to the appearance of new varieties with higher production potential and better resistance to diseases. Maringá has been used in the breeding programs at many of the Brazilian institutions and at CIMMYT in Mexico.

In the 1970s, São Paulo farmers began growing on nonacidic soils semidwarf varieties of Mexican origin that had better resistance to stem and leaf rusts. Early on, these varieties included Sonora 63 and Pitic 62. Later Mexican varieties such as Tobari 66, Inia 66, Jupateco 73, Cocaque 75, and Alondra 4546 were recommended to farmers. Today, another Mexican variety, Anahuac 75, is planted on about 45% of the São Paulo wheat areas (both irrigated and dryland) in soils without aluminum toxicity problems. A local, aluminum-tolerant, semidwarf variety (IAC 24), released in 1982, will likely soon catch the attention of farmers and eventually replace Anahuac 75.

Current wheat situation
In 1988 São Paulo farmers produced about 385,000 t of wheat on 180,000 ha. Average yield broke the 2-t/ha barrier for the first time. A substantial part of this wheat is rainfed in the west central part of the state where there are no serious acid soil problems. Rainfed wheat is grown in the southern part of the state—but the acid soils are a major constraint here. About 70% of the arable land in São Paulo has acid soils, but they are widely dispersed and vary in toxic levels of soluble aluminum, manganese, and iron. There is potential to expand rainfed area in the south an additional 200,000 ha with the use of aluminum-tolerant varieties.

Presently, some 20,000 ha of irrigated wheat are grown in the northeastern and central part of the state with yields in the 3.5-4.0 t/ha range. Anahuac 75, IAC 24, and Taiama do extremely well under irrigation. “If the economic
incentives were there, an additional 500,000 ha of irrigated wheat could be grown in this region of São Paulo," says Felicio. "However, irrigation equipment is in short supply and is very expensive. Farmers are afraid to make such a major investment because of uncertain wheat prices and credit availability."

**Prospects for increased cooperation with CIMMYT**

Although IAC annually plants several of CIMMYT’s international nurseries at both its Capão Bonito and Campinas stations, Felicio thinks his institution should take a more active role—perhaps getting involved in international shuttling of germplasm with CIMMYT in the same manner as some other Brazilian institutions (see pages 15 and 18). “Although Dr. Carlos Camargo (head IAC wheat breeder) visited Cd. Obregon, Mexico, in 1983 and I made the trip in 1986, we need to make more visits to Mexico for material selection,” says Felicio. “We are definitely interested in shuttle breeding.” IAC is hopeful that some of the lines and varieties coming out of the shuttle breeding pipeline in Paraná and Rio Grande do Sul will have adaptation to São Paulo’s acid soil areas.

Despite significant progress, there is still a great demand in the state for new, more productive varieties with stable resistance to diseases and adaptation to acid soils. High yielding, disease-resistant varieties that are also efficient in the uptake of phosphorus and nitrogen would suit well the existing cropping pattern and production techniques of the region.

**Rio Grande do Sul—“Brazil’s Barn”**

Rio Grande do Sul (RS), the southernmost state in Brazil, has had “boom and bust” cycles of wheat production. But even during the lean years, RS was always Brazil’s undisputed leader in wheat production—until around 1982 when the state of Paraná took the lead in area cultivated and production. In 1988 RS produced 1.5 mmt (about 26% of Brazil’s total) on about 1 million ha.

**Early history**

Native Indians grew wheat as early as 1627 in RS. The first Azorean settlers were so successful in producing the crop in the 1700-1710 period that the state was nicknamed “Brazil’s barn.” During the early 1800s, RS grew so much wheat that it annually exported thousands of tons of grain to neighboring Uruguay and Argentina.

“Southern Brazil has always been a hotbed for wheat diseases,” says Cantidio Alves de Sousa, a 1969 CIMMYT trainee and now breeder for the National Research Center for Wheat (CNPT) at Passo Fundo. “We have problems with leaf and stem rusts, septoria nodorum and septoria tritici blotches, fusarium head scab, spot blotch, powdery mildew, root rots, soilborne mosaic virus, and barley yellow dwarf virus.”

Rio Grande do Sul’s unpredictable climate, which produces severe frosts and prolonged periods of rainfall or drought, and its acid soil complex have been persistent problems from the beginning. However, the rust diseases were apparently responsible for ending RS’s “golden era” of wheat production around 1820.

Serious wheat breeding began in RS in 1919 with the creation of the Alfredo Chaves Experiment Station (Veranópolis Experimental Station from 1925 on)—a unit of the Brazilian Ministry of Agriculture at that time. Between 1920 and 1924, the Czechoslovakian agronomist Carlos Gayer developed what became known as the “Alfredo Chaves lines” by making crosses with the best land race varieties used by the early Italian immigrants. These lines are part of
the pedigree of almost all modern wheat varieties in Brazil. The Swedish plant breeder Ivar Beckman began his pioneering work at Veranópolis in 1925. The best of the many improved varieties he developed over the years was Frontana, also in the pedigree of most modern Brazilian varieties.

Frontana and related varieties such as Surpresa were used widely and successfully by breeders during the 1940s and 1950s as a source of leaf rust resistance in the USA, Canada, and Mexico. For example, one of the first improved rust-resistant wheat varieties distributed by the Office of Special Studies (CIMMYT's predecessor in Mexico) was Supremo 211 derived from the cross Surpresa/Hope/Mediterranean made by E.S. McFadden at Texas A&M and selected at Chapingo, Mexico by N.E. Borlaug and his associates.

The Julio de Castilhos Experimental Station (JCES), south of Cruz Alta in the middle plateau region of RS, is another important site in the history of southern Brazil's wheat breeding work. It was here in the 1940s that geneticist Benedito de Oliveira Paiva discovered that high acidity in the soil caused "crestamento"—a "burning" or "toasting" of wheat plants observed in the region for many years. Later it would be determined that aluminum toxicity associated with the acid soil complex was the real culprit. In the late 1960s, JCES would become the headquarters of a joint wheat breeding project between FECOTRIGO and the RS Secretariat of Agriculture. This project would eventually lead to Brazilian wheat breeders' first association with CIMMYT—thanks mainly to the original link with Mexico provided by Mário Bastos Lagos, a breeder, pathologist, and teacher, who trained at the Office of Special Studies in 1957.

Another important segment of the history of southern Brazil's wheat breeding efforts was the creation of the Southern Agronomical Institute (IAS) at Pelotas, RS in 1943. It was here that Ady Raul da Silva started utilizing the rust-resistant, semidwarf progenitors from the Mexican program in crosses with Brazilian germplasm. The efforts of his breeding team led to the development and release of more than 40 IAS varieties between 1955 and 1974—several of which (such as IAS 54, IAS 55, and Londrina) were some of the first released varieties derived from crosses between Brazilian and Mexican material and actually predated the start of germplasm exchange between FECOTRIGO and CIMMYT. After the creation of the Brazilian Agricultural Research Enterprise (EMBRAPA), Dr. Ady (as Brazilians call him) became the leading wheat researcher in the Cerrados region where he combined germplasm and soil management practices to demonstrate the vast potential of this region for wheat production.

Today, RS is the home of three premiere Brazilian research centers devoted to developing new and better wheat varieties—the National Research Center for Wheat (CNPT), a unit of EMBRAPA; the Experimentation and Research Center (CEP), the crop research arm of the Rio Grande do Sul Federation of Wheat and Soybean Cooperatives (FECOTRIGO); and the Institute of Agriculture and Livestock Research for Rio Grande do Sul (IPAGRO). These institutions have had a long history of cooperation with CIMMYT.
The Acid Soil Problem and Aluminum Laboratories in Brazil and Mexico

Soil acidity, is a major growth limiting factor for plants in many parts of the world. Approximately 1 billion ha in the tropics and subtropics are acidic. These areas include large parts of Brazil and other parts of South America, especially within the Amazon basin and vast areas in the llanos of the Orinoco, and substantial portions of the Andes. China, the Himalayas and the Deccan Plateau of the Indian Subcontinent, and vast areas of Central Africa also have soil acidity problems. Currently, many of these areas are either undeveloped for agriculture, or are cultivated but of very low productivity.

Growth limiting factors that have been associated with the acid soil complex include toxicities of aluminum and manganese and deficiencies of phosphorus, molybdenum, calcium, magnesium, potassium, and sulfur. These acid soil factors may act somewhat independently, but more often together, to negatively affect plant growth.

Aluminum and manganese toxicities (manganese to a lesser extent in area) are the two most important factors limiting the growth of crop plants in many acid soils of the world. Aluminum toxicity is particularly severe below pH 5.0. At this level it inhibits root growth by preventing cell division in the root apical meristem. The restricted root system makes the plant vulnerable to drought and unable to utilize normal levels of available essential plant nutrients. Above ground, aluminum toxicity symptoms are not easily identified on the foliage and often resemble those of some nutrient deficiencies.

Current approaches to solving the aluminum toxicity problem are raising the pH by adding lime and/or gypsum to the soil, improving management practices, and breeding plant varieties that are tolerant to the mineral. In the breeding efforts to develop tolerant plants, aluminum laboratories at IAC in Brazil and CIMMYT in Mexico are playing an important role.

Because toxic levels of soluble aluminum in the soil are a major constraint in much of São Paulo, IAC was a pioneer in laboratory screening of F2 and F3 generations for aluminum tolerance. When CIMMYT began setting up its own aluminum screening lab in the late 1970s, Evangelina Villegas, head of CIMMYT's general laboratories, visited Carlos E. Camargo, IAC's head wheat breeder, in his laboratory at Campinas. Camargo screens thousands of plants annually from both IAC and CIMMYT for aluminum tolerance and their ability to absorb phosphorus. His laboratory results on aluminum correlate well with field results. F2 populations are tested for tolerance to aluminum by the immersion of seedlings into nutrient solutions containing aluminum. Plants showing tolerance in the solutions are selected and transplanted in lime-corrected and fertilized soil. At maturity, spikes are selected, taking into consideration plant height, vegetative cycle, yield potential, and disease resistance. Camargo’s laboratory work has and
will continue to prove important in developing wheats for the warmer and more marginal environments.

In the CIMMYT aluminum laboratory at El Batan, Villegas, with the able assistance of technician Jaime Lopez-Cesati, has screened more than 15,000 segregating wheat lines for their tolerance to soluble aluminum. The CIMMYT process involves a visual evaluation of the continued growth of the primary roots of seedlings after immersion in a nutrient solution containing aluminum. After exposure to the aluminum solution, seedling roots are immersed in a hematoxylin solution, which stains the root tips black and makes it easy to observe continued root growth. Then the seedling roots are placed in aerated distilled water for 24 hours. Only the roots of aluminum-tolerant seedlings will continue to grow in the distilled water. Promising segregating materials identified by the laboratory screening procedure are sent to two locations in Rio Grande do Sul and to Paraná in Brazil for testing in acid soils and to Toluca and Cd. Obregon in Mexico for testing in nonacid soils.

The above-ground growth differences between the aluminum-tolerant line, CEP 8530 (left) and the susceptible line, Suzhoe F3#1 (right), growing in acid soil plots at Cruz Alta, are obvious to even the most casual observer. Below ground, retarded root growth is a further check for susceptibility (inset, right).
National Research Center for Wheat
In 1938, the Brazilian Federal Ministry of Agriculture created the Passo Fundo Experimental Station (PFES) located about 60 km from the city of Passo Fundo. With the creation of the IAS in Pelotas, PFES became a part of IAS. In 1969 PFES was transferred to a new and better site only 7 km from Passo Fundo.

"At this site in 1974, the PFES became the CNPT, the first commodity research center of the newly organized EMBRAPA," says Luiz Ricardo Pereira, CNPT head. "EMBRAPA's new national wheat center was located at Passo Fundo because of the excellent wheat work that was underway in already existing facilities. And at the time, RS was producing 90% of Brazil's wheat."

Cooperation with CIMMYT—In 1969 Dr. John W. Gibler, a former Rockefeller Foundation specialist, resigned his position as associate director of the CIMMYT Wheat Program and contracted with Massey Ferguson, the farm implement manufacturer, to work with FECOTRIGO and the RS Secretariat of Agriculture in a joint project called the Accelerated Wheat Breeding Program (PAT). Gibler started to bring Mexican materials to Passo Fundo (see box, p. 23) thus beginning CNPT’s long relationship with CIMMYT. Soon after that, Norman Borlaug visited Brazil and was impressed with the research progress being made.

The informal relationship between CNPT and CIMMYT grew stronger through the years as CIMMYT’s bread wheat research team continued to work closely with CNPT breeders such as Ottoni de Sousa Rosa, Cantidio Alves de Sousa, and others.

"The two most important factors in the CNPT/CIMMYT relationship have been the exchange of genetic material and the opportunity for

Experimental wheat plots at CNPT's Passo Fundo headquarters are critical to the success of germplasm shuttling activities between Mexico and Brazil.
our researchers to go to Mexico as visiting scientists and trainees,’” says Pereira. “Visits by CIMMYT researchers to see what is happening under Brazilian conditions have also been important. We think both institutions have gained in this exchange.’’

“When Dr. Gibler first started working with us, he thought it would be enough just to introduce Mexican materials into Brazil and we would have our own Green Revolution,” says Pereira. “But it didn’t work out that way. It is true that in areas without acid soils, the Mexican varieties do quite well, but in many RS soils, which have toxic levels of aluminum and/or manganese, the Mexican wheats simply died.” Because CNPT wanted the high-yield potential, semidwarf stature, and disease resistance of the Mexican germplasm, its breeders began crossing the material with their already well adapted Brazilian material.

Newly released CNPT varieties with CIMMYT germplasm in their pedigrees are definitely improving farmers’ yields in southern Brazil. BR 14-Thornbird (IAS 63/Alondra’S’ //Gaboto/Lagao Vermelha) is a good example. Released in 1985 by CNPT, it has already become the fourth most popular variety in RS. Truly aluminum tolerant, BR 14 has a yield potential that is 25% higher than the old Brazilian standbys, such as Maringá.

Cropping systems and technology transfer—The historical average wheat yield for southern Brazil has been around 900 kg/ha, but over the last 3 years, yields have increased substantially. The average yield for RS in 1988 was 1.5 t/ha. “This improvement is partially a result of production systems we have developed for the new varieties,” says Benami Bacaltchuk, head of CNPT’s technology transfer unit. “Farmers are always asking for better varieties, but I think we have seen improvements recently primarily because we have developed better cropping systems for these varieties.’’

The 1600-ha farm of two brothers, Vanderley and Altair Bassegio, is the best example of what improved technology can do for farmers.

“Over the last 10 years, we have helped some farmers overcome many of southern Brazil’s production constraints by combining genetic resistance to foliar diseases with the use of efficient fungicides and fertilizers and through crop rotation,” says Bacaltchuk. “Our major problem is that many small farmers are not adopting these technologies. They do not believe in using fertilizer and chemical control for diseases and worst of all—they do not believe in crop rotation.’’

RS farmers grow two crops each year—wheat (winter) and soybeans (summer). They could plant oats or rapeseed in the winter, but there is not much of a market currently for these crops. If the farmers are planting only wheat, it is recommended that the land be left fallow for one or two winters. “This is a practice that many small farmers are not easily convinced to do,’’ says Bacaltchuk, “even though in the long run their production would be greatly improved.’’

Experimentation and Research Center/FECOTRIGO

FECOTRIGO is a federation of 72 wheat and soybean cooperatives (see box on Cooperativa Triticola Erechim, p. 14) in RS. FECOTRIGO’s main goal is to help its member farmers get fair prices for their crops and credit so that they can continue operation. FECOTRIGO created the Experimentation and Research Center (CEP) in 1971 when the farmers decided they wanted their own research center for wheat and soybean breeding. “Farmers support us by contributing 0.2% of the market price of each bag of wheat they sell, says Luiz Hermes Svoboda, a 1972 CIMMYT trainee who is now head of the CEP Wheat and Triticale Program.

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Successful Farmers in Rio Grande do Sul Support Agricultural Research

In RS, farmers such as Sadi Zanella and Vanderley and Altair Bassegio support the research efforts of FECOTRIGO and EMBRAPA. Their efforts to make use of new technology are reflected in their successes.

Zanella, who farms 75 ha (15 ha of wheat) near Passo Fundo, belongs to Cooperativa Triticola Erechim, Ltda (COTREL). He contributes 0.2% of the income from his wheat harvest to COTREL where it is passed on to support the FECOTRIGO research program. "I think it is important that the farmers have an active role in supporting agricultural research," he says. Zanella believes that the new technology emanating from current research is needed for the region, but he adds, "the costs in utilizing some of these technologies that correct soil acidity and improve fertility are often difficult to afford."

Zanella treats his seed with fungicide and always plants his wheat in a different area every year, leaving some land fallow. "Using the rotation plan that EMBRAPA and COTREL recommend has provided good results for me," he says. "Over the last 2 years, I have averaged 2.7 t/ha."

The Bassegios' 1600-ha farm is one of the largest in the area. "We produce soybean and wheat seed for other farmers," says Vanderley, who is also a trained agronomist. "In 1988 we cultivated 1150 ha of soybeans in the summer and 300

Like many small-scale farmers in the Rio Grande do Sul, Sadi Zanella believes new technology is important, but he worries about the cost.
ha of wheat (850 ha left fallow) in winter. We rotate our wheat to a different area of the 1150 ha every winter.”

Altair points out the importance of leaving wheat land fallow over 2 years instead of one. “This year we planted a small area to wheat that had been fallow only 1 year,” he says. “This wheat is having much more of a problem with soilborne wheat mosaic virus than wheat in the area that was fallow for 2 years.” The brothers have also found that areas they have fertilized more have fewer disease problems.

Over the last 8 years, the Bassegios’ wheat yields have averaged 2.3 t/ha compared to an average 0.7 t/ha in the surrounding Passo Fundo area. They attribute their success to using good varieties, rotation, and new research information. “We want the latest information and are not shy about asking the researchers how we can grow our crops better,” says Vanderley. “We don’t wait for the researchers to come to us and say ‘do that.’ We go to EMBRAPA and ask for help because we want to be good farmers.”

The brothers feel the most important research for farms such as theirs is the development of varieties that can respond well to inputs, such as to fertilizer without lodging. They currently produce seed for varieties BR 14, BR 15, and BR 23.
The Cooperativa Triticola Erechim, Ltda (COTREL), one of 72 cooperatives in Rio Grande do Sul that financially supports the research of FECOTRIGO, helps its farmer members get credit and assists them in making planting decisions. The 24,000 RS farmers associated with COTREL have an average farm size of 12-15 ha, which is representative of the region.

Luiz Eduardo Sartor, COTREL administrator, thinks a serious problem for the small farmers in his cooperative is that agricultural research in Brazil is aimed mostly at larger high-tech farmers. “Wherever possible, we are assisting our member farmers to adopt new technology,” he says.

To encourage farmers to grow wheat during the winter, COTREL provides its members with seed. The farmers are required only to return the same amount of seed after harvest. COTREL provides a market for wheat and nearly everything else its members produce and transforms them into consumer products for selling in its cooperative stores.

‘COTREL members do not have to be landowners’ says Sartor, ‘but they must have a contract to use the land and they must sell their products (either the grain itself or the milk, eggs, or meat that result from its consumption) to the cooperative.’

COTREL cooperates with EMBRAPA in a number of regional experiments. ‘We work together in multiplying seed for the region, setting up demonstration plots, and providing communication links between researchers and farmers,’ says Sartor. ‘I think we have a very good relationship.’

Flour, milled from the wheat of COTREL member farmers, is available to Rio Grande do Sul consumers in COTREL cooperative stores.
CEP's CIMMYT connection—With the termination of the Accelerated Wheat Program and the creation of CEP, FECOTRIGO asked John Gibler to take on the task of initiating its breeding program at Cruz Alta. He transferred the genetic materials from the PAT program to Cruz Alta and set out to form a group of top-notch researchers at CEP.

Of the 24 Brazilian researchers who have undergone training at CIMMYT/Mexico, 11 have come from CEP/FECOTRIGO. Ricardo Matzenbacher, longtime CEP wheat breeder, was the first Brazilian trainee to come to CIMMYT in 1969 when he was still with the PAT. Luiz Svoboda spent 4 months at CIMMYT in 1972; Nelson Neto, a 1971 CIMMYT trainee and now CEP pathologist, spent 11 months at Cd. Obregon and Toluca. Gibler established masters degree programs for many CEP researchers to study abroad. “He believed that without well trained scientists, the breeding work would be inferior,” says Neto.

Over the years, CEP’s researchers have been melded into an interdisciplinary team. “If I am a plant pathologist,” says Svoboda, “it does not mean that I can’t go to the field and help make selections or plan crosses. The breeders, agronomists, and pathologists all work together here. This is very important and it is why we have been so successful.”

Germplasm exchange with CIMMYT—In the late 1960s and early 1970s, CEP became the first Brazilian institution to intensively exchange germplasm with CIMMYT. This soon led to the international shuttle breeding program that spread to other Brazilian institutions and that has been so successful in developing varieties with high yield potential, good agronomic type, disease resistance, and tolerance to aluminum toxicity.

“Segregating populations resulting from crosses made at CIMMYT between Brazilian and Mexican wheats are selected after undergoing screening in CIMMYT’s aluminum laboratory,” says Matzenbacher. “Lines surviving the laboratory screening are sent to Brazil for field selection in unlimed soil. F3 through F6 generations are then selected on an alternating basis at Cruz Alta and Cd. Obregon. We send back to CIMMYT only those lines that show aluminum tolerance; CIMMYT in turn selects for high yield and agronomic traits.”

(continued on page 18)
An “ocean” of wheat is harvested near Londrina, Paraná. Remnants of indigenous forests are being conserved in their
the native forest are visible in the distance. Larger areas of Paraná’s natural state by the Brazilian government.
Some lines at the same segregating stage are grown simultaneously at both Mexico and Brazil. For example, Matzenbacher would soon be taking notes in the CEP aluminum screening plots (late August). "We telex our notes to Sanjaya Rajaram, head of the CIMMYT bread wheat program, and his colleagues at Toluca, Mexico," says Matzenbacher. "CIMMYT breeders can make selections almost simultaneously with us, using data on how these same lines at the same segregating stage are performing in Brazil. I think this is very dynamic."

Each year CEP breeders test about 100 advanced lines from the shuttle program in preliminary yield trials. If these lines show good yield potential, they spend 3 more years in statistical tests before becoming eligible for varietal release. CEP has released nine wheat varieties and two triticales. Some have come about as a result of the germplasm exchange with CIMMYT. CEP varieties occupy about 35% of the wheat area of RS—the most popular being CEP 11 and CEP 14-Tapes, mainly because of their disease resistance. CEP 17-Itapua, a 1987 release, may soon become a farmer favorite as well.

About 30% of CIMMYT's bread wheat crosses now include Brazilian material—primarily for its aluminum tolerance and foliar disease resistance.

According to Rajaram, about 30% of CIMMYT's bread wheat crosses now include Brazilian material—primarily for its aluminum tolerance and foliar disease resistance. A few years ago, only about 10% of the material coming from Mexico showed tolerance to aluminum. Recently, however, the percentage of materials showing tolerance is dramatically increasing—in addition to having all the traits being selected for in Mexico.

The future—Matzenbacher, Svoboda, and Neto maintain that increasing yield potential in CEP varieties is their main goal because their state's average yield still hovers around 1 t/ha. "In some exceptional years our farmers can average 1.5 t/ha," says Svoboda. "I hope that as we approach the 21st century, farmers can produce an average of 2-2.5 t/ha through improvements resulting from breeding and crop management research. To accomplish this, we must have varieties that will respond to fertilizer, without lodging—which definitely means continuing the shuttle with CIMMYT to incorporate stronger straw and shorter height."

Wheat production in Paraná is a remarkable story. Twenty years ago, wheat was grown only in the southern Paraná and much of the nearly 2 million ha of land now producing wheat was still native forest in the west or planted to coffee in the north. This is difficult to imagine when viewing the spectacular "ocean" of wheat that "waves" to the horizon in the early August breeze in the northern and western parts of the state. Tracts of the original western forest that remain by government edict are proof enough of the dramatic change.

Soybeans help expand Paraná's wheat production During the November-February period of the Brazilian summer, soybeans fill the agricultural landscape. Farmers in northern Paraná replaced their frost-killed coffee plantations with soybeans. Soybeans also expanded to the western part of the state. The wisdom of such soybean expansion can be questioned because it replaced much of the native forest.
In any event, after the soybeans were firmly established, farmers needed something to grow during the winter season—and wheat fills the niche nicely. If soybeans had not been introduced to the northern and western regions, wheat may have remained only in southern Paraná where it has been a traditional crop for many years. The increase in area devoted to wheat (which paralleled the increase in soybean production) between 1962 and 1988 has been truly phenomenal. Land devoted to wheat production in Paraná increased, on the average, 76% per year during this period, while at the same time it was increasing 11.7% in RS and 17.2% in Brazil as a whole. In 1988, Paraná farmers produced 3.3 mmt of wheat on 1.7 million ha, representing 56% of Brazil’s total production and half of the area cultivated to wheat in the country. Average yield in 1988 nearly broke the 2-t/ha barrier at 1.9 t/ha.

Paraná Agronomic Institute Foundation
Since it started operation at Londrina in 1974, IAPAR has been involved in plant and animal research and natural resources management. “We are involved in about 20 different crop and livestock programs, including wheat, maize, coffee, dry beans, beef and dairy cattle, and swine,” says Osmar Muzilli, IAPAR scientist and former institution director. “We don’t work on soybeans because EMBRAPA’s soybean center is right next door. We integrate our work with EMBRAPA’s to avoid duplication of effort and waste of resources.” IAPAR’s soil scientists, breeders, agronomists, plant pathologists, and socio-economists work in interdisciplinary teams to solve the problems of Paraná’s constantly changing agriculture. “Our interdisciplinary teams plan projects designed to bring about maximum technical and economical solutions,” says Muzilli.

Three important events—The first commodity research program established at IAPAR was with wheat. Three important events occurred early on to get the breeding program started. First, Milton Alcover came over from IAC in São Paulo and introduced germplasm from several parts of Brazil to see how it would perform under Paraná conditions. Second, IAPAR’s first cooperation with CIMMYT started in 1975 through contacts established at FECOTRIGO, which arranged for the institution to start receiving seeds and nurseries from Mexico.

Early research
Paraná has not had an extensive history and tradition in wheat breeding. The state’s first wheat variety, PG 1, was selected at Ponta Grossa, in southeastern Paraná, in 1914. PG 1 was crossed with the already mentioned Alfredo Chaves lines in RS, which gave rise to a number of popular varieties.

Coinciding with Paraná’s rapid development in agriculture was the creation of two crop research centers almost at the same time in the early 1970s—one primarily state-supported, the Paraná Agronomic Institute Foundation (IAPAR), and one farmer-supported, the Organization of Paraná State Cooperatives (OCEPAR). Both of these institutions have cooperated with CIMMYT essentially from their beginnings.

In Sonora, Mexico, Luiz Alberto Campos, leader of the IAPAR wheat breeding team, carefully prepares wheat seed he selected in CIMMYT plots. The seed will subsequently be planted in Paraná.
And third, after Carlos Roberto Riede, IAPAR wheat breeder, came back from the 1976 training course at CIMMYT, IAPAR shifted its breeding practices based on what he learned in Mexico.

**Transition area**—Paraná is a transition area in terms of climate and soils and there are many wheat diseases. “We have to breed varieties for the different conditions across the state—acid and nonacid soils and drought and heat stress,” says Riede.

Helminthosporium diseases are prevalent in the state, especially *H. sativum*, which is of particular interest to CIMMYT in its new effort to develop wheats for the warmer and more marginal environments. Riede thinks IAPAR can help CIMMYT develop material that will be well suited to countries in the warmer regions that have helminthosporium problems.

**Use of Mexican material**—In the 48% of Paraná soils that are are relatively nonacid with low to medium levels of soluble aluminium, CIMMYT-derived varieties, such as Anahuac 75, adapt very well. In fact, Mexican germplasm of this type really opened up Paraná wheat production in the nonacid areas. For the acid soils with high levels of toxic aluminium, the wheat breeding team of Riede; Luiz Alberto Campos, team leader; and Y.R. Mehta, plant pathologist, is crossing adapted Brazilian materials with Mexican materials of high yield potential. They want to have better yielding material that is aluminum tolerant. Because their aluminum-tolerant varieties are very tall and often lodge, they also want to reduce plant heights.

IAPAR 18-Marumbi and IAPAR 22-Guaraúna, two varieties resulting from Brazilian/Mexican crosses, have been released and are recommended to farmers growing wheat in acid soils. A number of lines in the nursery and yield trial pipeline show great promise.

**Increased cooperation with CIMMYT**—IAPAR has not been as active in international shuttle breeding with CIMMYT as have CEP/FECOTRIGO, CNPT/EMBRAPA, and OCEPAR. However, since 1984, F₁ populations of Brazilian/Mexican crosses made at Londrina have been sent to Cd. Obregon, Mexico, to advance one generation in the selection process. Starting in 1988, seeds of F₃ populations originating from F₂ plants selected in acid soils with aluminum toxicity were sent to CIMMYT as a more intensive shuttle breeding effort is being developed between the two institutions.

**Strategy for acid soils**—“IAPAR’s strategy in high aluminum and/or manganese areas of the state is to grow tolerant plants in limed soil,” says Muzilli. “We can’t eliminate the problem by only having tolerant plants or only liming the soil. Our experiences show us that sensitive plants in limed acid soils will still have problems because lime penetrates only about 30 cm into the soil while the wheat roots penetrate much deeper. Tolerant plants yield much better in lime-corrected soil.”

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*Side-by-side comparison of IAPAR 6-Tapejara, at left, and IAC 5-Maringá. Maringá typifies an older Brazilian variety with superb aluminum tolerance, but without semidwarf genes and improved yield potential. Tapejara represents newer varieties with semidwarf genes and higher yield potential. The Tapejara here, planted only 1 week later than the adjacent Maringá, yielded about 600 kg/ha more.*
Other constraints—Along with the acid soil problem, adverse weather conditions, disease flare ups, and soil erosion and compacting constrain wheat production in Paraná. A 1987 rice blast epidemic in wheat depressed production about 5% in northern Paraná. Although this new disease in wheat also appeared in 1988, damage was not significant due to severe drought. In addition to IAPAR’s breeding and disease research, no-tillage or minimum tillage technology will help stabilize overall wheat production in the state.

Organization of Paraná State Cooperatives
OCEPAR is a political organization of Paraná’s numerous agricultural and nonagricultural cooperatives that, by law, exists to defend the interests of its members. About 80 agriculture and livestock cooperatives support OCEPAR’s agricultural research. The institution’s wheat research, which officially started in 1974 at Londrina, is now conducted at the Eloy Gomes Research Center at Cascavel in western Paraná, an area with medium levels of aluminum in the soil, and the Palotina Research Center, north of Cascavel, an area with low levels of aluminum. In 1987, additional work in soils with high levels of aluminum was started at Guarapuava in the south central region of the state.

Germplasm exchange with CIMMYT—OCEPAR’s wheat breeding program first received germplasm material from outside sources such as FECOTRIGO and CIMMYT in 1976. John Gibler came to Cascavel in 1977 as technical director to help organize OCEPAR’s breeding program and one of the first things he did was arrange for breeder Manoel Bassoi to go to CIMMYT as a visiting scientist as well as to bring back Mexican germplasm.

In 1970-71, another organization in Paraná, the Meridional Institute of Agricultural Research (IPEAME), introduced into the region through international nurseries the Mexican varieties Sonora 63, Sonora 64,
and Inia 66 for planting in the nonacid soils. They replaced the traditional low-yielding Brazilian varieties that often lodged. These Mexican varieties were also more resistant to the rusts than local varieties. “When we saw this, it became an OCEPAR objective to bring in a lot more Mexican germplasm for direct planting in our nonacid areas,” says Bassoi. “When I and other OCEPAR staff went to Mexico, our role was to identify germplasm adaptable to the nonacid soils.”

CIMMYT started working with Mexican/Brazilian crosses in 1974. The F₃s of these crosses were at Cd. Obregon when OCEPAR staff began their visits. They brought back to Brazil many segregating lines to see how they would do in the local acid soils. Further selection of this material in Paraná eventually led to the varieties OCEPAR 8-Macuco, OCEPAR 9-Perdiz, OCEPAR 10-Garça, and OCEPAR 11-Juriti—all recommended to farmers growing wheat in the moderately acid soil areas. In 1977 a very successful germplasm shuttle between OCEPAR and CIMMYT was established. Annual visits are made by OCEPAR staff to Mexico and CIMMYT staff make reciprocal visits to Paraná. Over the years this shuttle scheme has enabled OCEPAR to incorporate higher yield potential and high resistance to leaf rust and stem rust into its Brazilian varieties.

“We are attempting to bring our local germplasm up to the same yield potential as Mexico’s,” says Francisco Franco, OCEPAR wheat breeder. “That’s good for our farmers. As well, when Dr. Rajaram’s breeding team at CIMMYT receives our material to use in crosses, they won’t be sacrificing yield potential in the process.”

Roughly 65-70% of the wheats grown in Paraná now have a Mexican germplasm background. “Only in the very acid soils do farmers still grow varieties such as IAC 5-Maringá and BH 1146,” says Franco. “In the rest of Paraná with lime-corrected or nonacid soils, all the wheats are direct Mexican (primarily Anahua 75) or Mexican-derived varieties.”

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**Cultivars obtained through alternate selection at Brazil and Mexico and recommended for cultivation in several Brazilian states.**

<table>
<thead>
<tr>
<th>Cultivar</th>
<th>Pedigree</th>
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<tbody>
<tr>
<td>CEP 13-Guaiba</td>
<td>PAT 1/Alondra'S//Gaboilo/</td>
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<tr>
<td></td>
<td>Lagoa Vermelha</td>
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<tr>
<td></td>
<td>F11960F-500-800-3122-0A-0Y</td>
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<tr>
<td>MG 1</td>
<td>IAS 64/Aldan'S//CM 47207-16M-2Y-3F-704Y-700Y</td>
</tr>
<tr>
<td>IAPAR 18-Remumbi</td>
<td>PF73260//PF73261//PF7065/</td>
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<tr>
<td></td>
<td>Alondra'S</td>
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<tr>
<td>IAPAR 22-Guaraua</td>
<td>CNTB/Alondra'S</td>
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<tr>
<td>OCEPAR 8-Mucuco</td>
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<td>IAS 58/Bananaquit//CM 47971-4M-105PR-2T-0T</td>
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<tr>
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<td>IAC 5/3/Acaso 20/Pato B//</td>
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<td>Bluebird/INA</td>
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<td></td>
<td>B 14403-OM-1T-0T</td>
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<tr>
<td>Trigo BR 14</td>
<td>IAS 83/Alondra'S//Gaboilo/Lagoa Vermelha</td>
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<td>Mixture of the lines PF 79765, PF 79767 = Thornbird'S</td>
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<tr>
<td>Trigo BR 16-</td>
<td>PF 70402/Alondra'S//IAC 72160/Alondra'S//</td>
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<tr>
<td>Rio Verde</td>
<td>PAT 19/Blanco'S//PF7065//PF79765</td>
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<tr>
<td></td>
<td>Trigo BR 21</td>
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<td>Cajeme E71//PF 70653</td>
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Mexican and Brazilian locations involved in the shuttle breeding scheme.
Establishing Brazil’s Wheat Research Base

When Brazilians discuss the historical development of their country’s wheat research at FECOTRIGO, EMBRAPA, OCEPAR, IAPAR, and other institutions, a substantial list of names usually forms—including such pioneers as Ady Raul da Silva, Milton Alcover, Ivar Beckman, and Mario Bastos Lagos. On nearly everyone’s list is the name John Gibler. In 1969, Gibler resigned his position as associate director of the CIMMYT Wheat Program and joined Massey Ferguson, which sent him to Brazil to direct the Accelerated Wheat Breeding Program in Rio Grande do Sul and later the research staff development of CEP/FECOTRIGO and OCEPAR. The effects of his 10 years of whirlwind activity in Brazil are still being felt today.

Gibler is now semi-retired in California, but still keeps active as a part-time crop science consultant. He believes his greatest accomplishment during his stints as technical director of CEP and OCEPAR was his contribution to establishing a solid base of young wheat researchers in the country. Many of the young scientists for whom he arranged training at CIMMYT/Mexico and U.S. universities now are in positions of authority at CEP, OCEPAR, and IAPAR. “Now that these institutions have solid research staffs, there is real healthy competition between them,” says Gibler, “and it will keep them all on their toes.”

Another accomplishment was the initiation of germplasm exchange between Brazil and Colombia, Chile, and Mexico. “Germplasm exchange was and is important,” he says, “but training is the key. If a breeding program has only germplasm without trained people, it will stand still. As trainees at CIMMYT, our scientists learned how to handle the large amount of material being brought into Brazil. Instead of making 20 crosses a year and working those to death, we were able to go through large amounts of material and select only the cream.”

Shortly after Gibler arrived in Brazil, he quickly discovered that the dwarf wheats he knew from Mexico would not adapt to the areas with high-aluminum soils. However, there were tremendous results when lime was applied to these soils. After working out which amounts and rates of lime application were best, the next step was developing varieties for these amended soils. “That’s when the crossing of Brazilian materials with the Mexican dwarfs went into high gear,” says Gibler.

Another achievement Gibler points out with a smile is bringing about CIMMYT’s change of attitude toward Brazilian germplasm. “When I first arranged for our trainees to go to Mexico in the early 1970s, they would take Brazilian material along to cross with the Mexican material,” says Gibler. “Early on CIMMYT breeders ignored most of this material, but the trainees made selections, took them home, and eventually fed them back to Mexico. Soon, it dawned on the CIMMYT breeders that they should look more closely at this material because there was some valuable germplasm there—not just for tolerance to aluminum, but also resistance to helminthosporium and scab, which are big problems in Brazil.”

John Gibler, long-time consultant to Brazilian agricultural research institutions, reviews the index cards of his lifetime collection of some 25,000 wheat pedigrees from around the world.
Common objectives—According to Bassoi and Franco, OCEPAR’s collaboration with CIMMYT has evolved into much more than a mere exchange of germplasm between Mexico and Brazil. A common objective of OCEPAR and CIMMYT is to widen their respective germplasm bases and the shuttle has facilitated this process. The objectives of OCEPAR and CIMMYT have often become one and the same, such as with helminthosporium and scab resistance.

Even if 8 to 9 million ha were planted in the southern states, this area is literally dwarfed by the potential area in two virtually untapped regions of Brazil—the high São Francisco River Valley and the Cerrados.

Bassoi and Franco also pointed out that CIMMYT’s work is closely intertwined with many of the Brazilian institutions. “Material coming out of CIMMYT may have been crossed in Mexico (CIMMYT), Cascavel (OCEPAR), Passo Fundo (CNPT), or Cruz Alta (CEP),” Bassoi says.

Scientific collaboration—“In addition to germplasm improvement, information sharing and technical advice have been other advantages of our association with CIMMYT,” says Franco. “For example, Mohan Kohli visits us two or three times a year to look at our program, bring us new information, plan with us, and assist us in analyzing data and selecting material in the field plots. He leaves with information and impressions gathered here and passes that on to others. My OCEPAR colleagues go to Mexico to exchange information and discuss problems concerning research activities. I think the enrichment is evident at both institutions. In Paraná, the progress resulting from the scientific collaboration, when translated in terms of gains for the farmers, has been significant.”

The future—In terms of research, Bassoi and Franco believe that OCEPAR and indeed the other Brazilian wheat research institutions need to continue developing high yielding varieties. “The yields in Mexico and Europe are much higher than they are in Brazil,” says Bassoi. “A realistic goal would be to reach 60 to 70% of Mexico’s potential.”

“Poor agronomic practices are still too widespread in Brazil,” Franco says. “We need to have our various sets of varieties properly integrated with the appropriate agronomic practices before we can move up to the next yield level.”

Potential Areas for Wheat in Brazil

Close to 6 million ha of wheat were cultivated in 1988 in the states of Paraná, Rio Grande do Sul, Mato Grosso do Sul, São Paulo, and Santa Catarina. In some of these states, the dryland areas are not being utilized to their full potential because many farmers don’t see wheat as an economically viable crop at the moment. However, at best, area planted to wheat could increase another 2-3 million ha in these states and even if 8 to 9 million ha were planted in the southern states, this area is literally dwarfed by the potential area in two virtually untapped regions of Brazil—the High São Francisco River Valley Region (to some extent) and the immense Cerrados Region.

High São Francisco River Valley
The upstream region drained by the long and winding São Francisco River in the northeastern state of Bahia has the potential to add significant area to Brazil’s wheat cultivation. In the mid-1970s, the first experiments with irrigated...
wheat plantations were done at Bom Jesus da Lapa and the State Plant and Animal Experimentation and Research Unit (UEPAE). Yield results were promising.

Because of the huge successes at FECOTRIGO and OCEPAR, the governor of Bahia asked John Gibler to see what might be done regarding wheat in the region. "I could see that aluminum was no problem there," says Gibler, "so I brought a large number of Mexican wheats for planting and they did beautifully—at altitudes averaging 1000 m only about 12° south of the equator."

However, according to Gibler, there are a number of problems that will delay any significant wheat production for the immediate future in this region. "First there is a lack of money to set up the necessary irrigation equipment," he says. "And even if irrigation were set up tomorrow, how would the São Francisco River Valley farmers get their crop to the population centers? There are no roads—and dams on the river impede shipping."

The Cerrados
The Cerrados, the Brazilian term for wooded scrubby savanna, lies primarily in the states of Goiás, Minas Gerais, and Mato Grosso. It also has infrastructure problems similar to the São Francisco Region in Bahia. However, thanks to the location of the new national capital, Brasília, within the region, solutions to the problems of crop storage, marketing, and transportation are coming much sooner than in the São Francisco Valley. Also to help agriculture along in this vast wilderness, EMBRAPA, in 1975, established the Cerrados Agricultural Research Center (CPAC) at Planaltina outside Brasilia.

"Our mandate is to coordinate and promote the research necessary for a sustainable agriculture that is compatible with the region's environment," says Wenceslau Goedert, former CPAC director and eminent Brazilian soil scientist-agronomist. "We collaborate regionally and nationally with centers such as the Minas Gerais Enterprise of Plant and Animal Research (EPAMIG) and the Goiás Enterprise of Plant and Animal Research (EMGOPA) and internationally with CIMMYT."

A mere 10% of the estimated 100 million ha of arable land in the Cerrados is currently being intensively cropped. About half of this area is devoted to rice. Livestock has been the traditional agricultural commodity of the region.

Positive factors—There are a number of positive factors for agriculture in the Cerrados. Says Goedert: "The temperature range is excellent—between 17 and 27°C. There is an abundance of solar radiation and total rainfall (1500 mm annually) is quite good, although distribution is erratic. Topography and physical soil structure are excellent for intensive mechanization any time of the year. If you compare the savanna of Brazil with those of Venezuela, Colombia, and Africa, you will see that its infrastructure is quite good in terms of communications, roads, marketing, soil amendments, and..."
credit—everything you need for agriculture. The region has abundant sources of limestone and phosphate—two very important amendments for our very poor soils. And land is still cheap—about 1/10 the price of arable land in RS or Paraná. These factors are attracting many people here into the interior.”

Problems—The pronounced dry season (varying from 3 to 6 months depending on location) is a severe constraint to agriculture in most of the Cerrados. The soils are generally of low fertility, acidic with aluminum toxicity, and have localized deficiencies of zinc, nitrogen, potassium, calcium, and magnesium.

Potential for wheat—Currently, about 95% of the crops (upland rice, maize, cassava, black beans, and some wheat) are planted in October-November and harvested at the beginning of the dry season in April-May. “From CPAC’s beginning we foresaw a great potential to grow crops in the dry season—and this is where wheat enters the picture,” says Goedert. “If farmers irrigate and add fertilizer, they can grow about anything in the dry season, but wheat appears to be the best option because it is totally mechanized and there are varieties that do well under these conditions.”

About 12 years ago Ady Raul da Silva started a breeding program at CPAC using CIMMYT international nurseries. Says Goedert: “First we tried to improve wheats for the rainy season, but this cropping system has had a lot of problems (prolonged droughts within the rainy season, aluminum toxicity, and Helminthosporium) and yields

Pivot irrigation for agricultural crops (such as for wheat shown above at Cooperativa Agrícola Cotia near São Gotardo, Minas Gerais) is changing the face of a portion of the Brazilian savanna (inset). Currently, only a small part of the Cerrados’ arable land is devoted to such intensive agriculture.
Goedert sees irrigated wheat in the Cerrados as Brazil’s best chance to increase wheat production for domestic consumption. How fast will irrigated wheat expand in the Cerrados? Says Goedert: “It depends on how fast central irrigation pivots are set up. In 1986, some 500 units of central pivots were installed in the Cerrados—which means 50,000 additional hectares for potential wheat cultivation in the dry season.”

Cooperativa Agricola Cotia—A large Japanese cooperative, Cooperativa Agricola Cotia (CAC) has committed itself to agricultural production in the Cerrados with nearly 40,000 ha cultivated to various crops near Sao Gotardo, Minas Gerais. CAC grows both summer and winter wheat crops and in 1985 grew some 1500 ha under pivot irrigation during the dry season. CAC officials state that they are particularly interested in producing grain in the Cerrados, especially wheat. In 1987, agronomist Wilson Goto became the first CIMMYT trainee from CAC as well as the first Brazilian to take the CIMMYT production (agronomy) course—the 22 Brazilian trainees preceding him either took the improvement (breeding and pathology), cereal technology, or experiment station courses.

Osmar Muzilli (IAPAR)—“I don’t know if Brazil will ever be totally self-sufficient. In the southern part of the country (Parana and RS), we will continue to have these climatic and disease problems. The Cerrados region has a great potential, but the investment (for irrigation and fertilization) and economics of it all will make it very difficult to increase the area that much. It is difficult to talk in terms of self-sufficiency because of the high risk we have in the southern part of the country and major investments that will have to be made in the Cerrados. We can increase production, but I don’t think in terms of self-sufficiency—at least in this century.”

Wenceslau Goedert (EMBRAPA)—“For Brazil to have a chance at wheat self-sufficiency, irrigation expansion will have to continue in the Cerrados. However, for this to happen farmers will need incentives from the government in the form of firm market prices and available credit before they go to the great expense of installing irrigation equipment.”

Luiz Svoboda (CEP/FECOTRIGO)—“A lot depends on government policy. Presently, this policy is very unstable—so we don’t know what the future will bring. One possible way to reach self-sufficiency would be to use flour mixtures. Wheat is no longer subsidized so there is the possibility of using other flours. The demand for wheat would go down and perhaps the gap would close this way.”

(continued on page 29)
Although only about 30,000 ha of triticale were grown in Brazil (much of this in RS) in 1988, this is a substantial increase from the mere 30 ha commercially grown in the entire country in 1982 and practically double the 16,000 ha grown in 1986. According to Agusto C. Baier, head of EMBRAPA's triticale breeding program, work with the manmade crop has been underway in Brazil using CIMMYT introductions since 1969. Many of the lines evaluated in trials conducted in Paraná and RS have yielded well with acceptable test weights.

Recent triticale varieties—all with Mexican backgrounds—released in Brazil include BR 1, CEP 15-Batovi, IAPAR 13, IAPAR 23, OCEPAR 1, and OCEPAR 2. "These varieties show good adaptation to acid soils and high resistance to powdery mildew, septoria on leaves, stem rust, and leaf rust," says Baier. "The main problems for triticale development in Brazil are the head diseases (septoria, helminthosporium, and scab), sprouting, and low test weight."

Views of others on the potential of this crop in Brazil follow.

Luiz Pereira (CNPT/EMBRAPA)—"Triticale can produce more than wheat, especially in bad-weather, high-disease years—as much as 50% more—and it adapts very well to acid soils. However, as Brazil continues to produce wheat with better quality, triticale's inferior quality may hinder future expansion."

Carlos Riede (IAPAR)—"The complete triticales are doing much better than the substitute triticales in our trials. We have released one good yielding variety, IAPAR 23, which was developed from CIMMYT germplasm. Although triticale is not yet all that important in Paraná, farmers, particularly those having problems with wheat on marginal land, will be looking at triticae as a possible alternative."

Francisco Franco (OCEPAR)—"On our acid soils, triticale may provide a stop-gap until higher-yielding, aluminum-tolerant wheats are developed. For farmers able to afford technology (fertilization, liming, and chemical pest control), wheat will pay; farmers, who cannot afford or do not want to contend with the technology, may have success with triticale."

John Gibler—"I am convinced that bread making quality can be put into triticale. CIMMYT has come a long way on this already. As soon as the quality problem is solved, triticale will have a major impact on where and how much wheat is grown—particularly in the marginal acid soil areas of Paraná and RS."

Luiz Svoboda (CEP/FECOTRIGO)—"As the higher-quality CIMMYT-derived triticales have been released, farmer interest in the crop in Brazil has increased. I think the area planted to triticale will increase because it is more resistant than wheat to powdery mildew, leaf rust, and stem rust—and it can tolerate acid soils. And since the subsidy for wheat has been discontinued, there is no longer a marketing disadvantage to growing triticale."

Triticale, undergoing close scrutiny by wheat breeders Ricardo Matzenbacher (CEP/FECOTRIGO) and Ottoni de Sousa Rosa (CNPT/EMBRAPA), appears very promising for many marginal wheat-growing areas of Brazil.
Luiz Pereira (CNPT/EMBRAPA)—"If the government decides to push for self-sufficiency in wheat, we have the technical answers to achieve it. The biggest doubt that the government has is how much can we pay for imported wheat and how much will it cost to produce it locally. This is the only reason we are not self-sufficient now. At the moment, imported wheat is very inexpensive—but this situation may not continue forever. The government does not have a policy for self-sufficiency because it doesn't know if it is better—not because the country is not able (or does not have the technology) to be self-sufficient."

Manoel Bassoi (OCEPAR)—"It will depend a lot on where the politicians take us. Brazil is currently economically and politically unstable. We don’t know what will happen tomorrow—whether wheat and soybean production will increase or decrease. In many parts of the world, ecologists are promoting the production of crops in a more natural way, i.e., less fertilizer and chemicals. This is alright for an area such as Amazonia where land is plentiful and population is scarce. But to feed the inhabitants of massive metropolises such as the city of São Paulo with a population of 16 million people, modern agriculture with its high yielding crop varieties that respond to fertilizer and chemical pest control is an absolute necessity."

As implied by several above, economic factors will delay significant production increases through expansion of wheat area under cultivation in the near future. Opening more area to irrigation in the Cerrados, for example, would introduce double or triple cropping with wheat most likely being one of the crops. However, the possibility for expanding irrigated area for wheat alone is severely limited since the modest profitability of wheat per unit area simply does not justify investment in high-cost irrigation equipment. While it is certainly true that additional irrigation investment could eventually be induced if the producer price for wheat were supported at an extremely high level, this would require large subsidies from the government treasury. Such a policy does not seem justified, especially because abundant supplies of wheat are readily available on world markets, often at subsidized prices.

Brazil’s rapid increases in domestic wheat production and consumption, reflected in the graphs on page 2, have primarily been related to government subsidies. Recent changes in government policy are expected to reduce domestic consumption well below the current levels. For example, the May 1988 decision to eliminate the subsidy program under which wheat is provided to flour mills at prices sharply below levels guaranteed to farmers is expected to increase the price of wheat to mills by 60%, resulting in a 20% rise in retail prices for bread, pasta, and flour.

Because of the economic constraints, Brazilians need to remain realistic about their country’s wheat production potential. Perhaps self-sufficiency in wheat per se is not the right objective at this time. Even if long-term self-sufficiency appeared to be an attainable goal, an export-oriented strategy, at present, seems unlikely given the current supply of wheat on global markets and the relatively low levels of world prices.
Breeding Partnership between Brazil and CIMMYT

The advanced national agricultural research programs in Brazil and other developing countries have much to offer in the development of international wheat germplasm. CIMMYT believes that it has much to gain by joining with advanced national programs with expertise, capability, and interest in particular constraints. CIMMYT terms these joint efforts breeding partnerships.

The advanced national agricultural research programs in Brazil and other developing countries have much to offer in the development of wheat germplasm for the international scene.

“We see the concept of a breeding partnership as a mechanism to utilize special, perhaps unique, skills of researchers in a national program and to harness more energies to solve particular problems” says Art Klatt, former associate director of the CIMMYT Wheat Program and currently assistant dean for International Programs in Agriculture at Oklahoma State University. “A partnership will continue to rely upon the successful shuttle breeding system where two generations (one in Mexico and one in the partner country) are grown in a single year. The project will involve both CIMMYT and national program staff at all stages of varietal development. Both groups of scientists—each having special knowledge and experience—will work together in making decisions in regard to germplasm.”

In the proposed Brazilian partnership, Brazilian scientists will come to Mexico at the appropriate time to assist in the selection process. In the same manner, CIMMYT scientists will participate in Brazil. Brazilian and CIMMYT scientists will jointly decide which materials will be advanced. They will also discuss the direction of the program, including future crossing plans and objectives. A formalized partnership may eventually lead to a Brazil-CIMMYT International Acid Soils Tolerance Screening Nursery.

Such partnerships have already been set up with Turkey for winter wheat germplasm development, China for developing scab resistance and India for developing Karnal bunt resistance.

In addition to aluminum toxicity tolerance being combined with high yield potential, the proposed Brazilian partnership would work to incorporate resistance to the many diseases rampant in Brazil, such as the septorias, helminthosporium, scab, leaf rust, stem rust, etc. Other countries with these disease problems will also ultimately benefit from the exposure.

CIMMYT’s Sanjaya Rajaram believes that this proposed Brazilian-CIMMYT partnership will enhance the exposure of the excellent work done by the Brazilian institutions to the international community. Says Rajaram: “Once the partnership is underway, it will produce benefits far beyond Brazil. Germplasm will become available for such countries as Cameroon, Kenya, Malawi, Mozambique, Rwanda, Tanzania, Ecuador, and Paraguay where soil acidity also poses problems in wheat production.”
Acronyms

CAC—Cooperativa Agricola Cotia, Minas Gerais
CEP—Experimentation and Research Center of FECOTRIGO
CNPT—National Research Center for Wheat of EMBRAPA
COTREL—Cooperativa Triticola Erechim, Ltda, Rio Grande do Sul
CPAC—Cerrados Agricultural Research Center
EMBRAPA—Brazilian Agricultural Research Enterprise
EMGOPA—Goiás Enterprise of Plant and Animal Research
EPAMIG—Minas Gerais Enterprise of Plant and Animal Research
FECOTRIGO—Rio Grande do Sul Federation of Wheat and Soybean Cooperatives
IAC—Campinas Agronomic Institute, São Paulo State
IAPAR—Paraná Agronomic Institute Foundation
IAS—Southern Agronomical Institute, Pelotas, Rio Grande do Sul
IPAGRO—Institute of Agriculture and Livestock Research, Rio Grande do Sul
IPEAME—Merialional Institute of Agricultural Research, Paraná
JCES—Julio de Castilhos Experimental Station, Rio Grande do Sul
OCEPAR—Organization of Paraná State Cooperatives
PAT—Accelerated Wheat Breeding Program, Rio Grande do Sul
PFES—Passo Fundo Experimental Station
RS—State of Rio Grande do Sul, Brazil
UEPAE—State Plant and Animal Experimentation and Research Unit, Bahia
The International Maize and Wheat Improvement Center (CIMMYT) is an internationally funded, nonprofit scientific research and training organization. Headquartered in Mexico, the Center is engaged in a worldwide research program for maize, wheat, and triticale, with emphasis on food production in developing countries. It is one of 13 nonprofit international agricultural research and training centers supported by the Consultative Group on International Agricultural Research (CGIAR), which is sponsored by the Food and Agriculture Organization (FAO) of the United Nations, the International Bank for Reconstruction and Development (World Bank), and the United Nations Development Programme (UNDP). Donors to the CGIAR system are a combined group of 40 donor countries, international and regional organizations, and private foundations.

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