Perspective

A New Agricultural Frontier

PHILIP H. ABELSON AND
JAMES W. ROWE

BRAZIL IS BECOMING A SUBSTANTIAL NET EXPORTER OF food; these exports will impact on world commodity prices. In the past, this South American country exported mainly coffee and sugar, and imported substantial quantities of wheat and other temperate-zone products. In recent years, Brazil has become more nearly self-sufficient in wheat production and an increasingly important exporter of soybeans. Further expansion in the growth of both temperate-zone and tropical crops is under way. The key to the change in Brazil's role is increased competence in agricultural research and exploitation of a huge region, the Campo Cerrado, which was considered of little value before the early 1970s.

The Cerrado, with its 200 million hectares (500 million acres), is comparable in area to 12 U.S. midwestern farm states. The region lies south of the Amazon Basin between latitudes 6°S and 20°S, and most of it is in the states of Goiás, Mato Grosso, Mato Grosso do Sul, and Minas Gerais. Much of the Cerrado is a plateau ranging in altitude between 1100 and 1300 meters. Rainfall during the wet season (from about October to April) ranges between 1000 millimeters in the north and 2000 millimeters in the south. The virgin soil is acid (*p*H 5 or lower), has aluminum toxicity, and is practically devoid of phosphate in an available form. Deficiencies of such cations as calcium, magnesium, potassium, and essential trace elements are common. Before the early 1970s, the Cerrado was mainly used as pasture. But vegetation was so sparse and poor that 5 hectares were required to support one cow. Now, through experimentation and practice, it has been shown that with the addition of limestone, phosphate, and other fertilizers, many different crops can be grown with excellent results. Estimates of the extent of the arable land in the Cerrado range from 50 million to 110 million hectares. In most of the remaining area, slopes are such that tilling would lead to excessive erosion. However, the land could be improved for pasture or growth of tree crops and other perennials. In those areas where irrigation is feasible, it is possible to obtain 2½ crops per year.

In 1970, about 3.6 million hectares in the Cerrado (*1*) were devoted mainly to the cultivation of upland rice, corn, and beans, but yields were poor. Only 9000 metric tons of soybeans were produced that year in the states of Goiás, Mato Grosso, Mato Grosso do Sul, and Minas Gerais. By 1980, the area tilled had expanded to about 5.9 million hectares, and 2.185 million metric tons of soybeans were harvested. During the next 5 years, production of soybeans increased further. In 1985, the four states produced more than 6 million metric tons of soybeans (*2*), about one-third of the total Brazilian production. Prospects for increased and sustained production seem excellent. Only about 3 million hectares were required to produce the 6 million metric tons. When a larger fraction of the Cerrado is farmed, production could become comparable to that of the United States, which in 1983 was about 43 million metric tons.

The expanded use of the Cerrado in the past decade resulted from a combination of factors. One of them was the development of an infrastructure that provided roads and markets. This occurred after the establishment of Brasília, which is located near the center of the Cerrado region. Another factor was a policy decision by the Brazilian government to substantially expand the nation's competence in agricultural research. A Cooperative System of Agricultural Research was structured and initiated in 1973 under the mandate of the Empresa Brasileira de Pesquisa Agropecuaria (EMBRAPA). This organization coordinates all national research programs designed to increase agricultural productivity and maintains research stations in various regions of the country. In 1972, the government employed in the Ministry of Agriculture a staff of 872, of whom only three held the Ph.D. degree; most of the research staff held no degree higher than the B.S. degree. Since 1974, more than 1000 students have gone abroad for advanced study in agriculture, and now more than 225 Ph.D.'s are employed in government-supported agricultural research.

Another aspect of the increased utilization of the Cerrado was the establishment near Brasília in 1975 of EMBRAPA's Agricultural Research Center of the Cerrados (CPAC), which was staffed with competent people, many of whom had studied in the United States. An additional factor was the friendly cooperation of a number of agronomists of North America, including experts in tropical soils at Cornell University and North Carolina State University. They participated in the early crucial experiments that identified the requirements for the effective exploitation of the Cerrado soils.

The in-migration of farmers from the south of Brazil also contributed to the development of the Cerrado. These people were accustomed to using machines and state-of-the-art agricultural practices. They found that they could sell their established, high-priced land in the south and then buy and develop much more land in the Cerrado. They have adapted well to the new management techniques developed at CPAC.

Experiments at CPAC and application of the results of research conducted elsewhere enabled researchers to identify the levels of additives necessary to correct deficiencies of the soils of the Cerrado. For example, experiments with different applications of limestone showed that aluminum toxicity and low *p*H could be minimized by the addition of about 4 metric tons of limestone per hectare (*3*). If the limestone were plowed into the top 30 centimeters of the soil, roots of plants could tap moisture to that depth. The effect of applying limestone is not permanent, however. Gradually the *p*H level drops, and after several years additional applications are needed. The Brazilians have adequate supplies of limestone deposits at sites in the Cerrado region. Experiments with various levels of phosphate demonstrated the necessity for additions of substantial amounts of this fertilizer when growing grain crops such as maize. When no phosphate was added, crop growth was a complete failure. Good yields were obtained when an initial 320 kilograms of P_2O_5 per hectare were broadcast on the land, followed by annual additions of 80 kilograms of P_2O_5 per hectare. It was also necessary to add about 100 kilograms of potassium per hectare per year as well as some fixed nitrogen in amounts dependent on the cultivar and previous cropping practice. Sulfur may be provided as a constituent of phosphate fertilizers or in the form of $CaSO_4$. In summary, the research demonstrated the efficacy of additives, the level of requirements, and how and when to place them.

Considerable successful research conducted at CPAC, and elsewhere, has been designed to select the varieties of crops suitable for the Cerrado. As indicated, notable success has been achieved with

P. H. Abelson is science adviser, AAAS, and J. W. Rowe is director, Western Hemisphere Cooperation Program, AAAS, Washington, DC 20005.

soybeans. This crop was reputed to be sensitive to the length of day; therefore, it had been widely held that soybeans could prosper only in the temperate zones. However, varieties are now available that can flourish in the Cerrado.

One of the problems overcome in some soils was the presence of an actinomyces that released an antibiotic detrimental to the rhizobia, which are essential to nitrogen fixation by legumes. The development of resistant strains resolved this problem. Inocula of these strains are now commercially available. The advances in productivity in the Cerrado have largely been obtained by using conventional agricultural techniques. Researchers at CPAC emphasize that additional advances can be accomplished through selection leading to improved varieties. They have also been successful in finding varieties with enhanced tolerance of aluminum. They point out that the techniques and varieties must be chosen to suit each particular locality.

Agricultural practice in the Cerrado has been influenced by economic realities and by Brazil's need to minimize imports of fertilizers and pesticides. Thus soybeans are becoming a key crop because of their nitrogen-fixation capability and their export potential. Experimentation has demonstrated the remarkable value of green manures in the Cerrado. One legume, mucuna, when plowed under, furnished fixed nitrogen for at least two succeeding maize crops. It also acts to suppress the proliferation of nematodes.

In the tropics, insects and other pests pose serious problems. Brazil has made substantial progress in achieving biological control of some major pests and is widely considered to have achieved competency in this area. For example, the two major pests of soybeans in the Cerrado are a caterpillar and a beetle. The caterpillar is subject to a viral disease. Large quantities of the virus have been produced and used successfully as a control measure. The beetle is controlled by a small parasitic wasp. The general policy is to avoid chemical insecticides as much as possible. Experiments are also being conducted to find and develop insect-resistant species. Another problem for farmers in the Cerrado is the occurrence of dry spells during the rainy season, which vary in length and in some years cause substantial damage to crops.

Thus far, there has been little research in Brazil involving recombinant DNA techniques or monoclonal antibodies; however, at EMBRAPA's laboratories in Brasília, work has recently begun in this field. Tissue culture is being used successfully, and its use will likely proliferate. At BioPlanta, a private venture near Campinas in São Paulo state, commercial quantities of virus-free mini seed potatoes and superior strawberry plants are being produced and sold. Cultures of a number of other plants are being developed. In addition, spores of strains of endomycorrhizae that lend excellent performance to lemon seedlings have been isolated. Among researchers in Brazil, there is general awareness of the value of mycorrhizae in promoting uptake of phosphorus, and much work is progressing in this area.

Just as in the early days of agricultural advancement in the United States, scientists in Brazil need to make the technology available to farmers. Brazil has a substantial system for accomplishing such a transfer with some 15,000 extension agents. In addition, 30,000 salesmen with seed and fertilizer companies contribute to spreading knowledge of new technological advances. Scientists at CPAC make considerable efforts to educate leaders among the farmers, extension agents, and salesmen. They also interact with bankers who have a vested interest in making loans to those farmers who are using the best practices.

Scientists at CPAC are optimistic about the future of the Cerrado. Yields of soybeans obtained by farmers in the Cerrado are increasing and are now close to 2 metric tons per hectare. From 1983 through 1985, average yields in Illinois and Iowa were about 2.3 metric tons. The scientists at CPAC say that a wide range of crops which have now been tested at the station have performed very well. They believe that in addition to grain crops, cassava, sugar cane, and many vegetables, plus perennial fruit crops such as oranges, tangerines, avocados, mangoes, pineapples, and papayas, as well as forestry species including pine and eucalyptus can be grown on the Cerrado. They also project that slightly hilly areas of the Cerrado can be improved for cattle raising. Although these broad-ranging research results are encouraging, much still remains to be done in the area of economic analysis of these results to ensure that experimental practices are indeed economic at the farm level.

In light of present achievements and future prospects for the Cerrado, the question naturally arises as to prospects for agricultural development in Amazonia. The Brazilian government is responding to success in the Cerrado by de-emphasizing efforts in the Amazon region. Circumstances in the Cerrado are far more favorable for agriculture than those in most of Amazonia. In the Cerrado, the texture of the soil, the climate, and the infrastructure are superior. The Cerrado soils are about half clay or silt and half sand; they are well drained and tend to be resistant to compaction, permitting the use of machinery. Amazonian soils are largely clay and are easily compacted, making the use of machinery undesirable. The climate of the Cerrado is mild. The average temperature is 21°C, and maximum temperatures are usually no more than 28°C. In the dry season adult insect pests tend to diminish, and there is a respite from unwanted weed growth. The problems of creating and maintaining roads in the Cerrado are simple in contrast to the situation in Amazonia.

However, essential basic research aimed at utilizing lands of the moist tropics continues; EMBRAPA has centers at Belém, Pôrto Velho, and Manaus. Sanchez and co-workers from North Carolina State University have had considerable success with efforts in continuous cropping at Yurimaguas in eastern Peru in the Amazon Basin (*4*). As in the Cerrado, the key to success lies in suppressing aluminum toxicity, determining what levels of nutrients to supply, and coping with insects and other pests. Much of what is learned in Brazil will be applicable elsewhere in the tropics. Brazil has already sent agronomists to provide technical assistance to other former Portuguese colonies. In addition, African agronomists who attended a recent symposium in Brazil found there was much to be gained by cooperation with their Brazilian counterparts. Brazilian agronomists are also interacting with scientists in other tropical regions.

Research, development, and extension services are beginning to open up vast areas of the tropics for highly productive agriculture. During the next few decades, Brazil seems destined to achieve a considerable measure of leadership, both in international agricultural research and as a contributor to the global food supply.

REFERENCES

1. E. Wagner, *Policy of Occupation and Utilization of the "Cerrados"* (Empresa Brasileira de Pesquisa Agropecuaria, Departamento de Informacão e Documentacão, Brasília, 1981).
2. International Agricultural Statistics of the Foreign Agricultural Service, U.S. Department of Agriculture, personal communication (Washington, DC, November 1986).
3. W. J. Goedert, *J. Soil Sci.* **34**, 405 (1983).
4. P. A. Sanchez, D. E. Bandy, J. H. Villachica, J. J. Nicholaides, *Science* **216**, 821 (1982).

ADDITIONAL READING

M. A. C. de Miranda, E. A. Bulisani, H. A. A. Mascarenhas, *Soybean Situation in Brazil* (Ministry of Agriculture, Forestry and Fisheries, Tropical Agriculture Research Center, Japan, March 1984).

D. J. Lathwell, Ed., "Phosphorus response on oxisols and ultisols," *Cornell Int. Agric. Bull. 33* (January 1979).

———, "Crop response to liming of ultisols and oxisols," *Cornell Int. Agric. Bull. 35* (January 1979).

N. Caudle, *TropSoils: The First Three Years* (Department of Agricultural Communications, North Carolina State University, Raleigh, NC).