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Rice production and research in Latin America and the Caribbean (LAC): A comparison of temperate and tropical regions

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Summary

There are sharp contrasts between temperate and tropical rice-growing environments in LAC. In the former, growing conditions are less diverse; production is higher and more stable; cropping systems are more technically sophisticated; producers have greater access to external markets; research institutes are more effective; and there are fewer biotic and abiotic constraints. National programs serving both types of environments rely heavily on varietal improvement to overcome production constraints. But they also generate valuable information on high-priority problems in crop management. This paper gives an overview of rice research institutes in the region, of cropping systems and production constraints, and of research highlights.

Introduction

Rice is of strategic value in LAC. All 25 countries in the region grow and consume this staple food. In 1989-1991 the crop was planted to a total of around 7 million hectares (with production at about 18 million tons), ranging from 5 million hectares in Brazil to roughly a thousand each in Belize and Jamaica. Regional per capita consumption is 43 kg/yr of paddy rice, ranging from 4 or 5 kg in Guatemala and Mexico to 109 kg in Guyana and 147 kg in Suriname (CIAT, 1993).

LAC contributes 3.9% of the world's total rice production and contains 5.5% of its total rice area. Since the late 1960s, when varieties with improved plant type were introduced in the region, production has grown at an annual rate of 2.8%, resulting in a two-fold increase over the last decade (an average of 9.9 million tons in 1966-68, compared to 18.4 million in 1988-90). Average yield grew more rapidly (1.7%) than cultivated area (1.1%). Even so, at 2.5 t/ha, average rice yield is lower in LAC than in any other part of the world, except Africa (Sanint, 1992). This is the result of low-yielding upland rice, which is subject to severe climatic stresses. Upland environments (concentrated mainly in Brazil) account for 57% of the region's total rice area and 28% of its production.

In the temperate subregion, production of paddy rice grew at an annual rate of 3.2% during 1981-1991, area at 2.4%, and yield at 0.8%. This rate of increase in production was 4.6% lower than in 1971-1981 and that for area 4.2% lower. However, the rate for yield was 0.4% higher. In the tropical subregion, a similar pattern prevailed, with the rate of expansion in production declining from 3.9% to 1.0% and that for area from 1.0% to -1.2%. Average yields, on the other hand, showed a more dramatic increase than in temperate areas, rising from 0.9% in 1971-1981 to 3.0% in 1981-1991.

Although LAC as a whole is self-sufficient in rice production, most subregions are not. The Caribbean countries produce only 63% of the rice they consume and Central America and tropical South America just 75%. Surinam and Guyana are the only net exporters in the tropical subregion. The rest of the deficit is supplied by the temperate area.

Rice is grown in a wide range of ecosystems, from upland areas completely dependent on rainfall (e.g., the acid-soil savannas in Brazil, Colombia, and Venezuela) to fully irrigated areas (as in Colombia, Peru, Venezuela, and other countries). The crop is also found in arid zones (such as the north coast of Peru), temperate areas (the Southern Cone), and the tropics.

To get an overview of production constraints as well as research capabilities and results, it is convenient to compare LAC's temperate and tropical subregions. The former is located below 29° south latitude and includes Argentina, Uruguay, Chile, and southern Brazil (specifically the state of Rio Grande do Sul). This subregion contains about 1.1 million hectares or 15.8% of LAC's total rice area and accounts for almost 30% of its production. Yields in this environment, obtained largely under irrigation, are high and stable, ranging from 4.1 to 4.9 t/ha (Table 1).

Most of the rice grown in the tropical subregion is planted under upland conditions in the acid-soil savannas of Brazil. In 1989 the total rice area in that environment was about 3.9 million hectares. Average yields are low (1.2 t/ha) and unstable, because of extreme variability in the weather (Steinmetz and Forest, 1986). The remainder of the rice area in tropical America is irrigated or rainfed lowlands.

As indicated in Table 2, the tropical area planted to rice, excluding Brazil, accounts for 21.3% of the total area in LAC and for roughly 38% of its production. Average yields are just below 3.0 t/ha in Central America (ranging from 2.1 t/ha for Panama to 4.0 t/ha for El Salvador) and nearly 4.0 t/ha for South America (with a low of 2.1 t/ha for Bolivia and a high of 5.2 t/ha for Peru).

Table 1. Rice statistics for the temperate areas of LAC, 1989-1991.

Region	Area (1000 ha)	Percentage of total LAC area (%)	Production (1000 t)	Percentage of total LAC production (%)	Average yield (kg/ha)	Per capita consumption (kg)
Argentina	103.0	1.55	428	2.45	4.2	6
Chile	35.3	0.53	146	0.84	4.1	9
Uruguay	108.3	1.63	531	3.04	4.9	24
South Brazil	804.0	12.09	3,953	22.62	4.9	43
Total	1,050.6	15.80	5,058	28.95	-	-

Sources CIAT, (1993). FIBGE, Levantamento Sistematico da Produção Agricola, Jan/90.

Table 2. Rice statistics for tropical areas of LAC, excluding Brazil, 1989-1991.

Region	Area (1000 ha)	Percentage of total LAC area (%)	Production (1000 t)	Percentage of total LAC production (%)	Average yield (kg/ha)	Per capita consumption (kg)
South America	976.4	12.23	4,485	25.66	3.81	32
Central America	259.4	3.25	679	3.89	2.84	21
Caribbean	467.8	5.86	1,425	8.15	3.36	43
Total	1,703.6	21.34	6,589	37.70	-	-

Sources CIAT (1993). FIBGE, Levantamento Sistematico da Produção Agricola, Jan/90.

Research capabilities

The public sector has a strong presence in rice research in LAC. Almost all countries in the region have a national rice research institute. Government's role is to provide scientific personnel, financial support, infrastructure, and so on. With the recent trend toward liberalization of national economies, the private sector has found new opportunities to get involved in research. As a result, the institutional environment of rice research is rapidly changing in almost all countries of the region.

The situation varies somewhat between temperate and tropical areas, as is evident from the following examples.

In the temperate area, the Instituto Rio Grandense do Arroz (IRGA) in Brazil is supported by taxes on rice production (about 1%). Although the scientific personnel and administration (a president and three directors) are employed by government, their decisions must be approved by a council composed of farmers and other segments of the private sector. Funds obtained through the tax cover not only biophysical research but also socioeconomic studies as well as administration, maintenance of research stations, and other operational costs.

Argentina's Instituto Nacional de Tecnologia Agricola (INTA) is organized similarly. The institute receives 90% of its financial support from a 1.5% tax on all agricultural exports. It obtains the remaining 10% through special projects and by selling property rights to the private sector for varieties and technologies developed by INTA. In the last three years, the institute's rice program has received substantial financial support from the private sector (farmers, millers, and agronomists associations) through an organization called PROARROZ. Currently, the nation's legislators are working on a law that will make contributions based on rice sales mandatory. INTA's administration has representatives from both the private and public sectors, allowing research beneficiaries to participate meaningfully in the establishment of priorities (INTA, 1991).

A key rice research institute in the tropics is Brazil's Centro Nacional de Pesquisa de Arroz e Feijão (CNPAF/EMBRAPA), which coordinates all the country's rice research and is funded entirely by the government. Research priorities are set in consultation with state institutions and extension agencies.

The Instituto Colombiano Agropecuario (ICA) is currently trying to adjust to difficult new financial realities. The institute used to have rice scientists in all the country's production areas. But now it has just two or three multidisciplinary teams concentrating on the most important regions. Until 1992, ICA was fully supported by the state. But in response to financial difficulties, the government created CORPOICA (Corporación Colombiana de Investigación Agropecuaria) a mixed enterprise, with the aim of attracting extra funds.

The Instituto Nacional de Investigación Agraria y Agroindustrial (INIAA) in Peru is representative of the research system in LAC. It has a central administration and experiment stations in the most important rice-growing areas. In 1992, because of a financial crisis in the central government, INIAA passed over administration of its experiment stations (those located in the most developed areas) to farmers' cooperatives. Since then research has been organized and sponsored by farmers and carried out by scientists on the government payroll (Sáenz, 199?).

Finally, there is the Centro Internacional de Agricultura Tropical (CIAT), which is funded by the international community through the Consultative Group on International Agricultural Research (CGIAR). Rice is one of four commodities on which the Center conducts research. In rice germplasm development, it concentrates on two major tasks: 1) broadening the genetic base and increasing the yield potential of irrigated rice (mainly in the tropics) and 2) providing suitable materials for acid-soil savannas (CIAT, 1992). Recent institutional changes call for the establishment of a new international rice program coordinated and funded by countries in the region, either directly or through the private sector. CIAT's Rice Program will be phased out.

In 1987 and 1989, CIAT conducted a survey of the region's human resources in rice research. The results indicated that in LAC more researchers are working in agronomy (44.1%) than in breeding (30.2%) (Zeigler and Cuevas-Pérez, 1989), but most agronomists spend time conducting yield trials in preparation for varietal release. In general, the scientists working in LAC are very experienced. Nearly 29% have been involved in rice research for more than 10 years, and 34.9% have at least a master's degree.

According to CIAT's Rice Program database, 30.7% of the 52 scientists surveyed in the temperate subregion have at least a master's degree, compared to 41.2% of 347 respondents in the tropics. In the temperate subregion, significant proportions of rice scientists concentrate on breeding and weed problems (18.5% for each), followed by soil fertility (16.7%). In the tropics breeders are prevalent (28.1%), followed by those working on weed problems (14.1%) and soil fertility (10.1%).

Cropping systems and major constraints

The temperate subregion is more homogeneous than the tropical rice-growing environment. The planting period is restricted to October and the first two weeks of November because of the high probability, with later planting, of low temperatures at flowering time. Production is in general highly mechanized, and most farmers sow dry seed, drilling or broadcasting it on dry or wet soil. Lately, farmers have begun to use minimum tillage after a winter annual pasture, mainly to overcome weed problems, such as red rice. Producers in Chile are an exception to the norm, sowing pregerminated seed in cold water (14-16°C). Farmers in the temperate area generally adopt new technology rapidly, assuming that it shows promise for improving their cropping system.

In the tropical subregion, there is no single major cropping system. Practices vary by country and by region within countries¾from fully irrigated lowland to rainfed upland production. Nevertheless, in contrast with the temperate subregion, most rice-growing countries in the tropics have two cropping seasons: a wet season from March-April to August-September and a dry season from October-November to February-March. Normally, it takes a lot of extension work for any new technology to be diffused and adopted.

Following is a brief description of production systems in some of the major rice-growing areas of tropical LAC. In the state of Santa Catarina, Brazil, some farmers use much the same system as in Chile, with reasonably good water management. But on part of the state's rice area, mainly small-scale farmers sow dry seed in dry soil. In the central area of Brazil, upland rice is grown in acid-soil savannas under rainfed conditions; drought is common. Production is highly mechanized, and rice farmers have large holdings (more than 100 ha).

Central America's 239,300 ha of rice are grown under rainfed lowland conditions, except in Nicaragua (45,700 ha), which grows 60% of this region's irrigated rice. Small-scale farmers and manual operations predominate in the area.

The Caribbean countries, mainly Cuba, Guyana, and the Dominican Republic, grow 424,200 ha of rice under irrigation, using dry seed and soil. In general, producers grow rice on a small scale without mechanization. A notable exception is the Dominican Republic (with 93,000 ha), where rice growers use transplanting and ratooning.

In Portuguesa and Guarico, the main rice-growing areas of Venezuela (118,700 ha), farmers have adopted the puddling system, with wet seeding and a high degree of mechanization. In Colombia (462,700 ha), producers in the Tolima Valley use dry seed and soil, following a system of flush irrigation. In the country's LLanos Orientales, rice is sown under favorable upland and irrigated conditions with dry seed and soil. In Ecuador the crop is transplanted on a significant portion of the country's rice area (266,300 ha), using a unique system, called *poza veranera*, by which farmers cultivate rice along rivers in soil deposited during flooding (INIAP, 1987). In the coastal area of Peru, farmers transplant rice with continuous irrigation (water level at 10-15 cm), using water that accumulates in the mountains during winter.

Priorities in research on crop management depend to a certain extent on the land tenure system, which in turn affects farmers' time frame. In the temperate subregion, 38% of the rice farmers in the state of Rio Grande do Sul, Brazil, own the land and 62% are renters (IBGE, 1987). In Argentina and Uruguay, a greater percentage of rice growers own the land they farm, but the area planted in these two countries (103,000 and 108,300 ha, respectively) represents only 20% of the Southern Cone's total. In the tropical subregion, 58% of Colombian rice growers are landowners, while 42% rent (FEDEARROZ, 1990). In Venezuela about 80% of rice growers are landowners (one of the highest proportions in LAC). In Ecuador they account for 65% of all growers (INIAP, 1987). If these ratios are weighted by the area planted to rice in each country, one can estimate that in the tropical subregion as a whole 63% of rice farmers are landowners and 37% renters.

The temperate area is more uniform than the rest of LAC in terms of research capabilities. All programs in this area are well structured and staffed and have long traditions of rice research. Although breeding is a major item on their research agendas, they also concentrate on crop management, diseases, and insects.

Even though cropping systems vary greatly in LAC, research priorities do not. Terres *et al.* (1989) and Carmona (1989) note that in the state of Rio Grande do Sul, a temperate area of Brazil, the major biotic constraints are blast (*Pyricularia grisea* Sacc.), poor grain quality, and red rice; the abiotic problems are low temperature and iron toxicity. Stem rot (*Nakataea sigmoideum/Esclerotium oryzae*) is apparently growing in importance in late-sowing areas of Argentina and Uruguay. Chile has no problems with diseases or insects, but cold weather and poor grain quality are major constraints (Alvarado, 1989). Chebataroff and Deambrosi (1989) point out that in Uruguay low temperature and reduced solar radiation during the critical period of plant development are limiting factors. Blast is also a constraint, mainly because of continuous cultivation of just one variety (Bluebelle). In the entire subregion, sheath blight is mentioned as a problem of increasing importance. Haure (1989), in describing the objectives of Argentina's breeding program for the temperate area, mentions tolerance to low temperature, high grain quality (to meet the standards of external markets), and resistance to blast.

In all four countries of the Southern Cone, high yield potential is a main breeding objective, to which improvement for resistance to biotic and abiotic constraints is believed to contribute. Nevertheless, Carmona (1989) points out that the genetic base of the released varieties is very narrow and that new sources of breeding materials are needed to increase yield potential. Cuevas-Pérez et al. (1992a) came to much the same conclusion for the whole LAC region.

In southern Brazil high priority is given to controlling red rice. This problem is not found in Uruguay, Argentina, or Chile but is present in other tropical countries, including Cuba. Antigua and Garcia (1992) note that in 1990 75% of Cuba's rice area was infested by red rice, which caused an estimated loss of 45,000 t of paddy rice. These same authors also comment that chemical control was very efficient in reducing the number of red rice plants in the crop and that certain crop management practices, such as mechanical weeding and sowing pregerminated seed, also gave positive results. Fischer and Ramirez (1993) indicate that herbicide application is an economically feasible alternative, and this accounts for widespread dependence on herbicides for red rice control. An important challenge is to improve the availability of seed free of red rice and thus prevent continuous reinfestation.

The tropical subregion is characterized by high relative humidity, mean temperatures between 25 and 28°C, and precipitation of 2500 to 2800 mm/yr. These conditions, combined with continuous planting, high seeding rates, and high nitrogen application, are favorable for disease development. Consequently, high priority is given to research on blast, followed by *Tagosodes orysicolus* (Muir), rice hoja blanca virus (RHBV), grain discoloration, and sheath blight. Several management practices, some of them described by Nieto and Farah (1993), have been developed to control these diseases and insects. Many farmers engaged in modernized production know about and use those practices. But most national institutes combat abiotic stresses mainly through a strategy based on varietal resistance, with the development of blast resistant germplasm receiving top priority.

Although insects are not generally a major constraint in LAC, Peru, Ecuador, Colombia, Venezuela, Cuba, and the countries of Central America have an insect problem that is unique to the region. This is *T. oryzicolus*, which causes mechanical damage during feeding and is also responsible for transmission of RHBV (Galvez, 1968). The main strategy for addressing this problem is breeding of varieties with resistance to the insect and virus.

Since most of the tropical rice planted under upland conditions is grown in Brazil's acid-soil savannas, any problem in this system receives high priority. CNPAF/EMBRAPA has been doing research on tolerance to drought, a major constraint in this environment, with the objectives of elucidating mechanisms of drought tolerance and identifying parental material to be used in breeding programs. Pinheiro et al. (1989) describe the strategy for identifying and developing tolerant germplasm.

Research highlights

As mentioned above, breeding is the national programs' preferred approach for tackling production constraints. From 1975 to 1993, 194 varieties were released in LAC for the various rice-growing ecosystems, giving an average of 8.1 varieties per year or 0.32 varieties per year per country (one variety is released every 3 yr in each of the 25 countries in LAC). As indicated in Table 3, 88.1% of these varieties are released in the tropical subregion and 11.9% in the tropics. This is to be expected, since less diversity is present in the temperate area and it takes longer to release varieties there. Cuevas-Perez *et al.* (1992b) mention that from 1986 to 1990 breeding programs in the temperate area took 17.2 yr to go from crossing to varietal release, whereas during the same period in the tropics these steps required only 12.5 yr.

In the upland, acid-soil savannas of central Brazil, the release of varieties like Guarani, Rio Paranaiba, and Araguaia, has helped increase the national average yield. In general, this improved germplasm has better disease resistance and drought tolerance than traditional varieties. In regional yield trials, Guimarães (1993) observed a 17.3% yield increase in the area. In Colombia, the release of Oryzica Sabana 6 has allowed farmers in the Llanos Orientales to adopt a sustainable cropping system involving rice with pastures (Vera *et al.* 1992). The same system is under evaluation in Venezuela, and a similar one is already used extensively in Brazil (Kluthcouski *et al.* 1991).

National programs are trying by various means to broaden the narrow genetic base of varieties released in LAC. In Uruguay, Chebataroff and Deambrosi (1989) have been using materials of tropical background (crossed and backcrossed to temperate germplasm). In Chile the national program and CIAT are collaborating in the use of anther culture to overcome sterility barriers to wide crosses (Chilean material/upland dwarf//temperate line), as described by

Martínez (1988). In 1992 the variety BULI-INIA, which has good grain quality and tolerance to low temperature, was developed through this process (Alvarado *et al.* 1992).

Table 3. Number of varieties released in tropical and temperate regions of Latin America and the Caribbean, 1975 to 1993.

Country	Tropical		Temperate
	Irrigated	Upland	
Argentina	0	0	3
Brazil	31	26	11
Chile	0	0	3
Uruguay	0	0	6
Colombia	12	2	0
Peru	11	0	0
Venezuela	7	1	0
Others	81	1	0
Total	142	29	23
Percentage	73.2	14.9	11.9

In 1989 a workshop was held in Brazil to analyze the genetic variability used in breeding programs in the temperate area. One of the conclusions, as summarized by Cuevas-Pérez (1989), was that international centers, including CIAT, should concentrate on medium- to long-term germplasm enhancement, using methods like recurrent selection. The products of this work should be improved populations with a broad genetic base, which can then be made available to national programs for line extraction. CIAT has made some progress in moving toward such an approach.

Blast is an important problem in both subregions. Management practices aimed at controlling this disease emphasize the combination of low sowing density and nitrogen application with the use of resistant varieties. Nevertheless, because of the high variability of the pathogen, genetic resistance breaks down shortly after new varieties are released, especially in the tropics. National programs and the international centers are trying to cope with this problem through germplasm improvement. Based on extensive research in Colombia, Levy *et al.* (1991, 1993) suggest that pathogen races can be grouped in lineages, based on the results of DNA "fingerprinting," and that genes conferring resistance to these lineages can be combined to provide a more durable type of resistance. Factors that distinguish lineages from one another are postulated to be more "conserved" traits (in an evolutionary sense), making it more difficult for the pathogen to overcome resistance. An example is Oryzica LLanos 5, which was released in Colombia in 1988, is now planted on more than 40,000 ha in a blast-prone area, and remains resistant (Correa-Victoria and Zeigler, 1993). The fingerprinting technique may also be used to forecast the emergence of new virulence groups in a particular region.

Sheath blight (*Rhizoctnia solani* K.) is one of the problems for which germplasm improvement apparently does not offer a solution. At IRRI and in LAC, thousands of lines have been tested in search of resistance sources, but so far not a single line has proved immune to the disease. Some partially resistant materials are available, but no national institute in LAC is using them in its breeding program. The disease can be controlled effectively through management practices, such as low seed density, low nitrogen fertilization, appropriate planting date and land preparation, good water management, and control of the initial inoculum (Correa-Victoria and Zeigler, 1991). IRRI and CIAT are attempting to develop resistance through transformation (with ribosome inactivating protein or RIP), using resistance genes from barley.

In the Southern cone, farmers deal with red rice by means of two distinct strategies. This problem is especially serious in Rio Grande do Sul, where more than 15% of the planted area is infested. Since most rice producers are renting land, they pay little attention to the problem and are not inclined to spend much money on its control. If their fields get heavily infested, they just move to another location. A further problem is that seed production policy allows one grain of red rice per 500 g of seed. Because of the combination of these two factors, the problem remains unsolved. On the other hand, in Uruguay, where a higher percentage of rice growers own their land and seed production standards are stricter (no red rice seed is allowed), the problem is minimal.

Management practices for controlling red rice, such as crop rotation, roguing, herbicide application, planting methods, are described in the literature and are effective. In Rio Grande do Sul, direct sowing and minimum tillage have proved to be the most successful methods for overcoming the problem. In 1993 it was estimated that these practices were applied on 25% of the state's rice area.

Genetic studies have shown that resistance to *T. oryzicolus* and RHBV is simply inherited and that the genes come mainly from single sources, such as Colombia 1 for the virus and Makalioka for the insect (Zeigler *et al.* 1988). CIAT is attempting to diversify the resistance sources, using transformation with viral coat protein and antisense RNA genes. The problem can be controlled through management practices aimed at reducing insect populations. Nonetheless, farmers planting susceptible varieties tend to rely on heavy insecticide applications.

Scientists working in the temperate subregion note that the continuous flow of data generated by research institutes has led to several improvements in farmers' crop management. Among these are improved land leveling, planting at optimum dates, more appropriate seeding rates, improved fertilization and water management, better timing of herbicide applications, and use of crop rotations. Noteworthy improvements have taken place in the tropics as well, but the rate of adoption has been much lower and varies from one country to another.

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