# Conclusions on
# Improving the Competitiveness of Rice in Latin America by Narrowing the Yield Gap

Proceedings of a Workshop

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Research Program on Rice
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CGIAR

CIAT
International Center for Tropical Agriculture
Since 1967 / *Science to cultivate change*

FLAR

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International Center for Tropical Agriculture (CIAT)
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## Executive Summary

A workshop was held with experts from different countries to discuss narrowing the yield gaps in rice production in Latin America by mass adoption of technologies. In this event, successful cases from Brazil (Rio Grande do Sul) and Uruguay were presented, together with the experiences of the National Federation of Rice Growers (FEDEARROZ, its Spanish acronym) of Colombia and of FLAR's Agronomy Program. Two aspects were analyzed: the reasons for why improved management was not widely adopted in the tropics, and the role that different actors should play to facilitate the mass adoption of technology.

## Introduction

Narrowing the yield gap is the safest option for increasing rice production in Latin America. Yield gap is defined as the difference between the potential yield of a rice variety when cultivated in an environment to which it is adapted, without constraints of climate, soil fertility, or pests and diseases and the yield obtained by farmers. Pulver, in 2003, estimated the yield gaps (in t ha$^{-1}$) for the temperate zones to be:

| | | | |
|---|---|---|---|
| Santa Catarina (Brazil) | 1.2 | Argentina | 2.0 |
| Rio Grande do Sul (Brazil) | 1.3 | Chile | 2.0 |
| Uruguay | 1.3 | | |

In the tropics, the yield gaps (in t ha$^{-1}$) were estimated by the same author as:

| | | | |
|---|---|---|---|
| Colombia | 0.9 | Costa Rica | 2.5 |
| Venezuela | 1.5 | Panama | 3.5 |
| Guatemala | 2.1 | Cuba | 3.6 |
| Nicaragua | 2.1 | | |

In the temperate zones, except for Chile, all the countries began programs that focused on narrowing these gaps. Ten years later, the yields (in t ha$^{-1}$), estimated as being possible on-farm, had been attained and surpassed:

| Area | Projected yield | Yield in (year 2013) |
|---|---|---|
| Rio Grande do Sul (Brazil) | 6.5 | 7.49 |
| Santa Catarina (Brazil) | 6.9 | 7.10 |
| Argentina | 7.0 | 6.90 |
| Uruguay | 7.0 | 7.85 |

These increases in yield enabled considerable increase in rice production, particularly for Brazil's Rio Grande do Sul where total production grew 60% over 12 harvests. In Uruguay, 10% of small farmers are obtaining yields that are very close to the potential of the most widely planted varieties.

In contrast, in the tropics, yields (in t $ha^{-1}$) have not increased, with the yield gaps continuing, as follows:

| Area | Projected yield | Yield in (year 2013) |
|---|---|---|
| Colombia | 6.3 | 5.20 |
| Costa Rica | 6.0 | 4.78 |
| Panama | 6.0 | 4.50 |
| Venezuela | 5.9 | 4.25 |
| Nicaragua | 5.0 | 4.80 |

Any increases in rice production resulted from increases in planting area. In the Caribbean, yields also remained stagnant and, again, production increased because of increased planting area. However, the experiences of both FLAR and FEDEARROZ suggested that, under tropical irrigated or favorable upland conditions, rice crops can produce and surpass the potential yields mentioned by Pulver (2003).

The difficulty in attaining higher yields is not for lack of knowledge and technology. As FAO (2004) suggested, the factors responsible for the continuation of yield gaps may be classified as follows:

- Biophysical, which include variations in climate and soils, lack of irrigation, biotic and abiotic stresses, and inadequate post-harvest handling.
- Agronomic crop management, including plot preparation and conditioning; selection of variety; management practices governing irrigation, nutrient supply, and weed-pest-and-disease control; and post-harvest handling.
- Socio-economic such as farmers' educational levels, traditions, and capacity to invest.
- Institutional involvement and policies such as governmental policies on credit, rice prices, access to machinery and inputs, land tenure, access to stable and transparent markets, development and access to new technologies.
- Technology transfer, including the competence of extension workers; integration between research, development, and extension; economic advantages and risks of new technologies.

In the Latin American tropics, agronomy programs have concentrated principally on agronomic management and technology transfer, tending to ignore other factors, whether biophysical, policies and institutions, or socio-economic. This limited focus has hampered the narrowing of yield gaps in this region.

## Background

Rice is a highly significant staple in Latin America, being not only essential in this region's diet but also a generator of income and employment for many people. Lately, rice in Latin America has experienced a major increase in both yield per hectare and total production (Table 1), which largely results from focusing on improving the crop's agronomy. Growth trends in yield and production appear only in South America and not in either Central America or the Caribbean (Table 1).

**Table 1. Growth rates and current status of the rice crop's planting area, production, and yield in the Caribbean, Central America, and South America.**

| Region | Annual growth rate (%, 2000–2012) | | | Current status (average, 2010–2012) | | |
|---|---|---|---|---|---|---|
| | Area | Production | Yield | Area (ha x $10^3$) | Production (tons x $10^3$) | Yield (t.$ha^{-1}$) |
| Caribbean | 1.77 | 0.91 | -0.88 | 450 | 1,508 | 3.4 |
| Central America | 0.71 | 1.50 | 0.79 | 302 | 1,059 | 3.5 |
| South America | -0.93 | 1.70 | 2.60 | 4,750 | 23,759 | 5.0 |

SOURCES: Adapted from http://apps.fas.usda.gov/psdonline/psdQuery.aspx (accessed in October 2013).

Meanwhile, in South America, a wide difference in growth exists between the South Cone countries (e.g., Uruguay, Rio Grande do Sul of Brazil, and Argentina) and the countries in the tropics, except for Peru (Table 2). The lack of growth has a negative impact on the competitiveness of the Latin American rice sector, putting at risk the economic activity of many people who live off the crop and, at the same time, reducing the region's food security and increasing pressure on using land for this crop.

**Table 2. Growth rates and current status of planting area, production, and yield of the rice crop in some Latin American countries.**

| Country | Annual growth rate (%, 2000–2012)[a] | | | Current status (average, 2010–2012) | | |
|---|---|---|---|---|---|---|
| | Area | Production | Yield | Area (ha x $10^3$) | Production (tons x $10^3$) | Yield (t.$ha^{-1}$) |
| Uruguay | 0.28 | 2.70 | 2.41* | 173.33 | 1,390 | 8.01 |
| Peru | 2.59* | 3.55* | 0.97* | 375.33 | 2,708 | 7.21 |
| Rio Grande do Sul (Brazil) | 1.34* | 4.45* | 3.10* | 1,083.85 | 7,808.33 | 7.19 |
| Argentina | 4.70* | 5.83* | 1.13 | 230.67 | 1,557 | 6.76 |
| Dominican Rep. | 3.36* | 3.53 | 0.18 | 183.67 | 904 | 4.92 |
| Brazil (national) | -2.68* | 1.26 | 3.95* | 2,560 | 8,449.33 | 4.86 |
| Colombia | -0.57 | -0.78 | -0.22 | 446.67 | 2,129.67 | 4.77 |
| Nicaragua | -0.55 | 3.59* | 4.14* | 89.67 | 391.33 | 4.37 |
| Guyana | 1.40 | 2.48* | 1.07 | 141 | 601.33 | 4.26 |
| Venezuela | 2.52 | 0.94 | -1.58 | 140 | 551.67 | 3.94 |
| Suriname | 1.97 | 2.06* | 0.08 | 55.67 | 212.33 | 3.81 |
| Costa Rica | 2.70 | 2.08 | -0.63 | 77.33 | 266 | 3.44 |
| Ecuador | 1.47 | -0.74 | -2.21 | 365 | 1,123.67 | 3.07 |
| Bolivia | 0.59 | 3.37 | 2.80 | 152 | 455.67 | 3.00 |

Values followed by * indicate that the model's regression coefficient explains more than 50% of variation observed in the data and that the regression coefficient is significantly different to zero, according to the Student's *t*-test ($P < 0.05$).

SOURCE: Adapted from http://apps.fas.usda.gov/psdonline/psdQuery.aspx (accessed in October, 2013).

## Examples of gaps narrowed in Latin American countries

### Rio Grande do Sul-Brasil

In Rio Grande do Sul, Brazil, average yield grew in an accelerated manner during the decade of the 2000s as a result of several technologies being applied. Figure 1 shows this accelerated growth.

**Cropping of modern varieties in RS (1980/81 to 2012/13, or 33 seasons)**

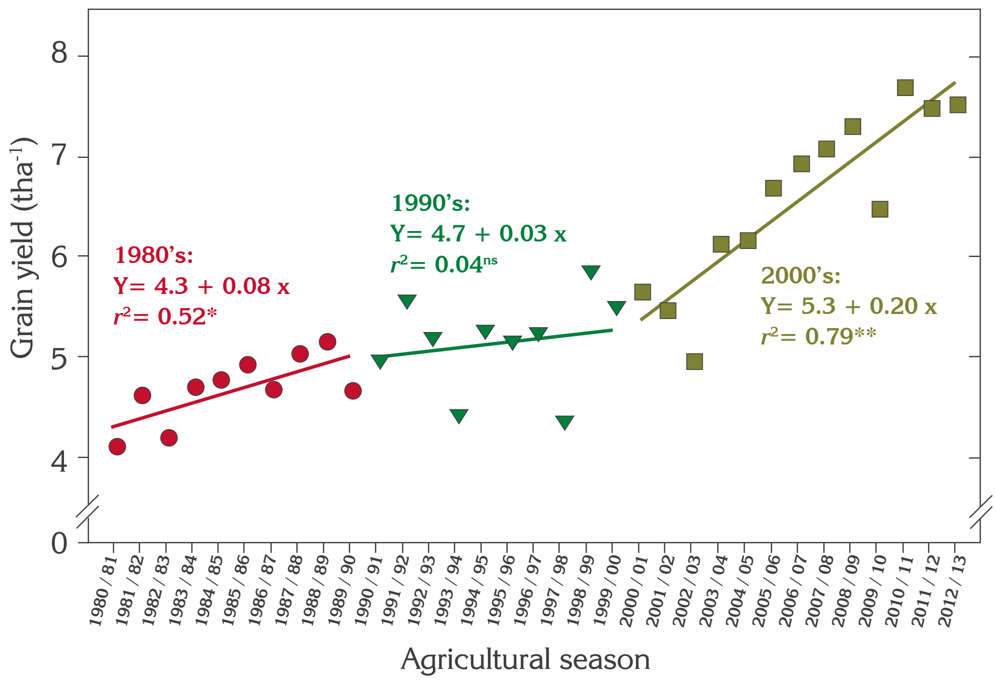


**Figure 1. Evolution of irrigated-rice yields in Rio Grande do Sul, Brazil. (where * or ** indicate that the $r^2$ is significantly different from zero)**

SOURCE: IRGA (results presented during this meeting).

During this period, growth in rice production was extraordinary as, over 12 harvests, it grew by 61%, of which yield contributed 42%, whereas planting area increased by only 15%. The programs for improved management had proposed changes in the production system, shifting from conventional preparation to early preparation, which allowed planting in the appropriate season. The programs also promoted the following practices:

- Using broad-based mud levees to allow planting along their tops and so take advantage of the entire planting area
- Using low planting densities to ensure plants are healthy and vigorous
- Planting in a timely season to totally exploit the luminosity offer
- Controlling weeds with very early applications of herbicides to reduce plant toxicity and improve weed control
- Early entry of paddy water
- Improving the management of fertilizer applications, with changes in the seasons of application, dosages, and methods of application

These changes were the product of two projects: one was the FLAR–CFC Project called, "Narrowing the yield gap in Rio Grande do Sul, Brazil".

It was financed by the Common Fund for Commodities (CFC) and was executed by the Instituto Rio Grandense do Arroz (IRGA) and FLAR in Rio Grande do Sul. The other project was Project 10 of IRGA.

In terms of genetic improvement, two fundamental contributions were made: the incorporation of resistance to herbicides, which enabled control over red rice; and the development of cultivars which had both an intermediate cycle (permitting exploitation of the entire cropping season) and higher production potential.

As well as improved management, the way new technology was transferred was fundamental: a “farmer to farmer” system of technology transfer was developed. It was based on the idea that farmers adopt those technologies that they see as functioning in the fields of leading farmers who have wide credibility in the sector. Instead of relying on chats by technicians in auditoriums, the farmers learn by doing.

Training at all levels (technicians, farmers, field workers, and irrigators, among others) is made available. For this training, demonstration plots, used to show proposed improved management practices, are large, allowing farmers to carry out field days at critical stages (e.g., planting time, flowering, and harvest). Other training events include technical tours for visiting other areas where a given technology has been implemented, and discussion meetings to evaluate and diffuse results, and plan new activities. Above all, the system is based on the idea of living the experience, and exchanging and sharing knowledge.

Also fundamental was the existence of a body of well-trained and highly motivated technical assistants to lead the transfer process and support those farmers implementing new technologies.

The need to be more competitive has obliged IRGA to seek new alternatives for stabilizing the progress made on narrowing yield gaps. This is because increased production and the presence of seasonal peaks in harvesting forces prices downwards. Paradoxically, narrowing the yield gap has negative effects on farmers’ income if no adequate strategy exists to manage the higher production. In addition, poor use of resistance to herbicides can cause the appearance of red rice and other weeds with resistance to these herbicides.

The solution that IRGA found was to promote crop rotation with soy and maize, using the technology of resistance to herbicides. There was even a highly promising alternative of rotating rice with pastures, a common system in Uruguay. These solutions imposed new challenges on research as these crops were not adapted to the soil conditions under which rice is normally cropped in Brazil. Thus, new soy and maize cultivars that tolerate waterlogging had to be developed, as well as technologies for planting and harvesting these crops in heavy soils. At the same time, technologies for drying and storing rice on-farm had to be developed so that farmers were not obliged to sell their product when prices were low.

## Uruguay

The rice yield in Uruguay has increased in recent years to a much higher rate (Figure 2), bringing the country not only to first place for yield on the continent, but also to one of the highest in the world. According to data presented during this meeting by the National Institute for Agricultural Research (INIA, its Spanish acronym), yield at farm level has grown linearly at a rate of 90 kg $ha^{-1}$ per year. This growth is principally due to non-genetic factors as, according to Blanco and collaborators (unpublished), the varieties most planted are 'El Paso 144' (released in 1987) and 'INIA Tacuarí' (released in 1992), although new varieties such as 'INIA Olimar' (released in 2004) and 'Parao' (released in 2011) have recently been gaining space.

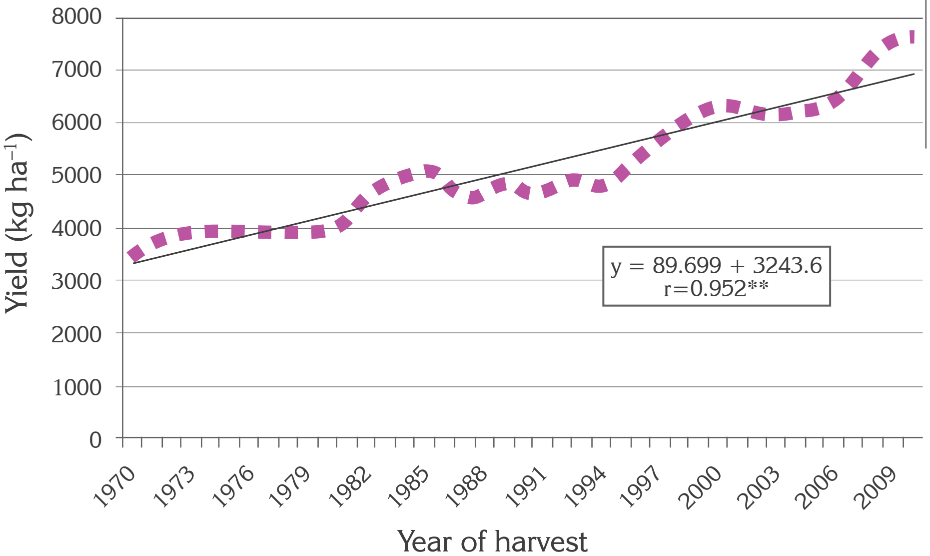


**Figure 2. Evolution of rice yield in Uruguay, 1970–2009.**

SOURCE: INIA (results presented during this meeting).

The rice production system in Uruguay presents unique particularities that enable it to be more productive. The number of farmers is reduced to about 520, planting an average of 320 ha. Most (70%) rent, are associates of the Rice Growers Association (ACA, its Spanish acronym), and hold fixed contracts with mills. The crop is integrated with livestock production and rotated with the soy crop. Production is destined for the export market, with a focus on product quality, which is as important as high production standards. Moreover, farmers are included in discussions on research plans, conduct early validations of varieties, and develop projects together with other farmers, mills, universities, and governmental ministries.

Yield had increased through a conjunction of factors such as agronomic management and marketing. In Uruguay, the principal changes occurring recently in agronomic management included early land preparation, that is, in advance of the planting date, and changes to applications of fertilizers. Recently, increased importance has been given to rotation with the soy crop, which has also helped improve yields.

No technology transfer model similar to that of IRGA's Project 10 or of FLAR's exists. However, the integration between mills and farmers, together with INIA and ACA, has been key to technology transfer. Moreover, the need to compete with international prices has been decisive in improving crop management and encouraging technology adoption.

Moreover, transparency in prices, achieved through agreements between ACA and the milling industry, has resulted in greater market stability. Finally, focus on the export market has obliged compliance with quality standards and best management practices, resulting in a product suitable for the market.

## FLAR's Agronomy Program

FLAR's Agronomy Program had its beginnings in the 1999 studies of Drs Peter Jennings and Edward Pulver in various Latin American countries. Between 2001 and 2006, the FLAR–CFC Project was executed in Venezuela and Brazil. From 2006 onwards, FLAR's partners began financing a program to provide partners with technical support in agronomy and technology transfer. This program uses a scheme similar to that proposed in the FLAR–CFC Project, focusing on key points of management and on the "farmer to farmer" strategy of technology transfer. The strategy involves intensive training, the use of well-trained leading farmers who establish demonstration plots in large areas, the accompaniment of farmers on technical tours, and field days. All these activities are directed by an extension specialist who provides technical support.

This program has extended to several countries—Bolivia, Chile, Costa Rica, Dominican Republic, Mexico, Nicaragua, Panama, and Venezuela—with irrigated and upland ecosystems. The main technologies promoted by the program are:

- Irrigation to reduce drought stress, nutritional deficiencies, and diseases. Water harvesting or construction of irrigation systems is fostered.

- Key points of management include planting date to capture the best environmental offer, improved fertilizer applications (dosage, times, and methods of application), low planting densities, seed treatment, early weed control, and early establishment of paddy water.

- Minimal tilling or early preparation to enable timely planting and reduce costs in weed control, especially red rice.

- Systematization of land with broad-based mud levees that can be planted and land leveling to reduce plant losses and improve efficiency in irrigation.

- Use of planters adapted for sowing in minimal tilling fields.

- Rotation of crops to break pest cycles, change predominant weeds, improve soil conditions (physical, chemical, and biological), and prevent surplus production.

According to the results given by FLAR during this workshop, the following was achieved:

- Increases in yield of between 1 and 4 tons above that of conventional management, in both temperate and tropical zones.
- Production costs reduced by as much as 35%.
- Water consumption reduced by as much as 25%.
- Reduced emission of greenhouse gases (not quantified).

Despite the benefits demonstrated by this system, adoption has not been widespread in the tropics.

## FEDEARROZ's AMTEC program

In Colombia, two phenomena appeared simultaneously that had the rice sector concerned: one was a drop in prices to farmers, and the other was a decline in yield as a result of climatic variability. The reduction in prices was provoked principally by the Free Trade Treaty with USA coming into force, which pressured prices downwards, and also by the implementation of an agreement with industries on price ranges.

However, changes in the historical levels of climatic variables (maximum and minimum temperatures, luminosity, rainfall distribution, and relative humidity) and the presence of pathogens have considerably reduced yields. Moreover, neither have the high prices in the rice sector contributed to technology adoption. Instead, they have sustained the high production costs that have reduced the competitiveness of Colombian rice.

Seeing the need to increase competitiveness, FEDEARROZ proposed a program for the Mass Adoption of Technology (AMTEC, its Spanish acronym). This program is described as a model for technology transfer that aims to implement production technologies that help increase yields and reduce production costs and, at the same time, foster best cropping practices to preserve the environment. Concretely, the program aims to recover the highest yields that had been achieved in the specific region and reduce production costs to less than 20%. The AMTEC Program is based on principles such as:

- Diagnosis: analyses of historical information, farm production processes, and economics.
- Planning: economic, financial, and agronomic.
- Agronomic management:
  - Planting times and selection of varieties suitable for season and site.
  - Soil analyses that include the study of physical, chemical, and biological components.

– Soil preparation and conditioning, emphasizing leveling, use of mud levees, and drainage construction.
– Construction of reservoirs and storage canals or ditches, irrigation, drainage, and rational water use.
– Establishing the crop, using planters for minimal tilling, low planting densities, and monitoring populations.
– Timely and balanced nutrition, including incorporation before planting.
– Phytosanitary monitoring and management, involving analyses of initial weed populations and early control with highly selective products; and management of phytophagous insects and diseases through biological controls, monitoring during key seasons to establish population levels, and chemical control based on action thresholds.
– Crop rotation and management of crop residues.

Nevertheless, the technology transfer model is based on the "farmer to farmer" concept. It also has a strong training component for both technical assistants and farmers and their field workers.

Results to date (Table 3) indicate that, in the pilot plots, yield had increased, on the average, by 1.27 t $ha^{-1}$ (+23%) and costs had dropped by 26% or US$119 $ha^{-1}$. These results demonstrate that the program is successful and is expected to be quickly adopted.

**Table 3. Results from demonstration plots of FEDEARROZ's AMTEC Program in different zones of Colombia, 2012 and 2013.**

| Year | Zone | AMTEC | | Farmer | | Difference (AMTEC - Producer) | |
|---|---|---|---|---|---|---|---|
| | | (t $ha^{-1}$) | (US$ $t^{-1}$)[a] | (t $ha^{-1}$) | (US$ $t^{-1}$)[a] | t $ha^{-1}$ | US$/t $ha^{-1}$ |
| 2012 | El Juncal | 6.50 | 417 | 5.30 | 614 | 1.20 | -197 |
| 2012 | Ibagué | 7.96 | 338 | 6.90 | 456 | 1.06 | -118 |
| 2012 | Norte Tolima | 7.48 | 366 | 6.29 | 485 | 1.19 | -119 |
| 2012 | Montería | 6.38 | 323 | 4.68 | 470 | 1.70 | -147 |
| 2012 | Zulia | 6.56 | 328 | 5.79 | 370 | 0.77 | -42 |
| 2012 | Pompeya | 5.70 | 309 | 4.30 | 503 | 1.40 | -194 |
| 2012 | María La Baja | 8.75 | 248 | 6.13 | 333 | 2.62 | -85 |
| 2013 | Pompeya | 4.30 | 475 | 3.36 | 600 | 0.94 | -125 |
| 2013 | Ibagué | 8.66 | 322 | 7.23 | 406 | 1.43 | -84 |
| 2013 | Fundación | 6.53 | 299 | 5.60 | 384 | 0.93 | -85 |
| 2013 | Casanare | 5.90 | 319 | 5.20 | 434 | 0.70 | -115 |
| | | | | | | | |
| | Average | 6.79 | 340 | 5.52 | 459 | 1.27 | -119 |

a. Rounded to the nearest dollar

SOURCE: FEDEARROZ (information presented during this meeting).

After this initial phase, FEDEARROZ began a series of activities towards overcoming the constraints that prevented the program from expanding, for example:

- Acquisition of equipment for different farming activities, including levee builders, levelers, and planters, as demonstration materials.
- Financing the acquisition of equipment.
- Increased number of technical assistants for both public and private programs.

- Training operators, including for machinery and irrigation.
- Investments in infrastructure: irrigation districts, reservoirs, dams, and access roads.
- Policy of low-cost credit.
- Research and development.

## Discussions on constraints to adoption of closing the yield gap concept

Once the positive results of improved crop management to close the yield gap were confirmed, Workshop participants formed working groups and were given a set of four questions (Appendix 2). The first question dealt with constraints to mass adoption of those technologies that help narrow yield gaps by improving the crop. A plenary session was then held, at which the conclusions of each group were discussed. Seven conclusions on the main constraints were arrived at by consensus:

- **Lack of institutionalism:** A major constraint to the mass adoption of technology is the non-existence of either public–private alliances or of strong and representative farmer associations that can take up leadership of projects to improve crop management and encourage the promotion of technological changes. Successful programs have shown that leadership by organizations able to conduct research and transfer is essential if a given program is to be successful (as in the cases of IRGA, INIA–Uruguay, and FEDEARROZ). In contrast, in those countries where no internal support is provided by organizations with, for example, resources and technical personnel, then programs such as FLAR's have limited success.

- **Lack of state policies that support the farming sector:** The governments of each country must foster policies that facilitate production. To narrow the yield gap, the key is to invest in infrastructure such as irrigation systems, access roads, financing for acquiring machinery and equipment, facilities for acquiring or adapting technologies, and policies to encourage efficient production.

- **Specialized technical training:** Achieving mass adoption of technologies requires training of personnel such as extension workers and technicians, farmers, and field operators in improved crop management. Moreover, universities also need to train agronomists to have an integrated approach to the concept of narrowing yield gaps. Agricultural research must be attractive to upcoming researchers because a lack of generational succession will impede increased adoption of new technologies.

- **Markets:** The market is the force that moves progress in a crop: if there are no buyers for the product then there are no incentives to invest, much less adopt technologies. The free market drives the search for competitiveness and technology adoption, particularly as competition obliges the production of "more with less". For example, a lack of markets for rotational crops limits the possibilities for adopting the practice of rotation. Likewise, a transparent rice market and suitable mechanisms for establishing prices will ensure investment by farmers.

- **Land tenure:** A high percentage of cultivated areas are in the "hands" of small farmers. Their lack of organization prevents them from accessing new technologies. Moreover, those renting land to produce rice are limited in carrying out practices that imply high investment such as the construction of dams or working uncropped land for early preparation or crop rotation.

- **Companies:** Generally, companies selling agrochemicals or other inputs for rice production have technical assistance services that provide advice to the farmers. However, such companies are more oriented towards promoting and selling their products and less towards adequate crop management. Such orientation limits the possibility of reducing costs and of making decisions based on tools such as damage thresholds.

- **Non adequate policies on subsidies and price protection:** Poor subsidy policies that are directed towards price protection but do not take into account competitiveness allow inefficiencies to enter the system. Farmers are therefore not motivated, even if their farms are highly productive. If deficiencies in their management are covered by high prices, then farmers do not see the need to adopt technologies that enable them to produce more for less.

## Discussions on the role of different actors

Workshop participants were divided in groups and then charged with discussing the role of different actors in improving technology adoption. The group concluded the following, that:

### Farmer organizations need to:

- Be strengthened as representative institutions of the rice sector and to have the capacity to lead programs for improving crop management.
- Focus on farmers' needs and avoid becoming political actors beyond the defense of common interests.
- Have strategies for adequate communication.
- Work towards integrating the chain as, without the collaboration of counterparts who process raw materials, a common front cannot be formed.
- Seek common objectives, particularly with new technologies that benefit farmers.
- Foster strategic partnerships among actors to create schemes that benefit all on a "win-win" basis.
- When submitting proposals before a government, have a proactive role with positive proposals that indicate solutions to problems.
- Promote sustainable mechanisms that ensure investment in research to develop new technologies.

### Companies could:

- Significantly promote improved crop management, particularly mills, by offering farmers financial and technical assistance that is focused on improved agronomic management.
- Design transparent mechanisms for determining product prices.
- Encourage clean production practices that foster rice cropping that is environmentally friendly and safe to consume.

### Governments could:

- Implement public policies directed towards improving the sector's competitiveness, especially in the construction of dams and irrigation districts, purchase of machinery and equipment, and tax benefits for technologies.
- Facilitate the integration of product's value chain.
- Stimulate institutional consolidation for the chain through public policies for each link.
- Respect the autonomy of the chain's representative institutions.
- Propitiate authentic leadership in each sector.
- Establish sustainable mechanisms for financing the research and development of new technologies.

### National research centers could:

- Together with the production chain, determine research priorities, audit the research, and define mechanisms for supporting research.
- Focus on field problems, and on strategies for effective communication.
- Ensure generational succession.
- Measure the success of research in terms of impact generated.
- Be more open to farmers' needs and increase diffusion of technologies and information generated.

### International centers could:

- Provide advanced technologies.
- Serve as bridges between countries and the international community to transfer novel technologies.
- Maintain a key role in training new personnel and training per se.
- Propitiate increased involvement with the production sector.

## Conclusions

The main constraints to the adoption of new technologies that narrow yield gaps and increase competitiveness are:

- Weak national institutions that cannot organize and support technology transfer programs that follow the "farmer to farmer" model.

- Land tenure that limit tenants in carrying out medium- or long-term investments such as early preparation or leveling because of the cost and competition for land with other tenants.

- Price protection. A clear relationship exists between price protection and subsidies and the lack of competitiveness—farmers do not feel the need to adopt new technologies and be more competitive. Hence, any policy aimed at price protection must be accompanied by a mechanism that favors the most efficient.

- A weak product chain that is either scattered or in permanent confrontation. For the crop to be competitive, its value chain must be integrated and all its actors must work together in seeking common objectives with creditability and establishing prices by using transparent mechanisms. The mills must also be significant actors in technology transfer, given that they need to assure their supplies of raw materials and thus require reliable suppliers with adequate standards of quality.

- Governmental policies. The role of governments is to ensure a free market with clear regulations that make it transparent. Other essential contributions are to develop infrastructure, roads, and irrigation projects; charge low taxes for importing machinery and technology; provide access to agricultural credit; regulate agrochemical sales; and pass laws on intellectual property that ensure investment in genetic improvement, and laws to support research programs through obligatory contributions from farmers.

- Training. There is urgent need to train new agronomists in technical assistance for the rice crop and technology transfer, using the “farmer to farmer” system. In most countries, transfer is achieved through agents whose interests are centered more on sales than on helping farmers.

- Instability of prices and overproduction. The challenge is not only to produce more rice but also to sell it at a fair price. Overproduction as a result of improved yield should therefore be carefully avoided as it will negatively affect technology adoption. To prevent this, strategies must be developed such as rotating crops to stabilize planting areas and exploiting upland farming systems to ensure that sales of products are not concentrated in one period.

- Free trade acts in favor of technology adoption, encouraging countries to become more competitive and thus avoid the threat of importing rice. However, the transition to free trade should be gradual, as a sector cannot be obliged to compete when, for many years, it has been protected and is inefficient. Free trade treaties may well reduce the number of rice farmers and the area planted to rice but, in the end, a new and more competitive sector will emerge, capable of producing more with fewer costs. At the same time, transition must be prevented from becoming a catastrophe that eliminates the rice sector.

- What should also be taken into account as acting against both technology adoption and the narrowing of yield gaps is the extreme climatic variability that has been seen in recent years. This variability reduces the effects the environment has in minimizing climatic variability by increasing night temperatures, the frequency of short dry periods, and pest and disease pressure; and fostering the appearance of new diseases.

## Appendixes

**Appendix 1.** List of participants at the workshop on “Mejorando la Competitividad del Arroz en América Latina mediante el Cierre de Brechas de Rendimiento” [Improving the Competitiveness of Rice in Latin America by Narrowing the Yield Gap], held at Hotel Barceló, San José, Costa Rica, 6 November 2013.

| Name | Occupation | Organization | Country of HQ |
|---|---|---|---|
| Alfredo Marín | Researcher–Production | Instituto Nacional de Tecnología Agropecuaria (INTA) | Argentina |
| Amílcar Sánchez | Farmer | Tuparroz | Panama |
| Claudio Batata Pereira | Agronomist | Instituto Rio Grandense do Arroz (IRGA) | Brazil |
| Edgar A. Torres | Plant Breeder | CIAT | Colombia |
| Eduardo Graterol | Agronomist/Researcher | FLAR | Colombia |
| Eduardo Reyes | Industrialist–Production | Semillas del Nuevo Milenio S.A. (SENUMISA) | Costa Rica |
| Ernesto Stirling | Agronomist | Asociación Cultivadores de Arroz (ACA) | Uruguay |
| Everardo Sandoval | Farmer | Molino Tempisque | Guatemala |
| Francisco Hurtado | Farmer | Conagro S.A. | Panama |
| Gilberto M. Dotto | Agricultural Technician | FLAR | Brazil |
| Gonzalo Zorrilla | Rice Program | Instituto Nacional de Investigación Agropecuaria (INIA) | Uruguay |
| Hernán Zorrilla | Agronomist–Rice | Asociación Cultivadores de Arroz (ACA) | Uruguay |
| Ivan Tio P. | Chairman | Federación Nacional de Productores de Arroz (FENARROZ) | Dominican Republic |
| José Antonio Martínez | Executive Director | Asociación Nacional de Industriales del Sector Arrocero (ANINSA) | Costa Rica |
| Juan Merino S. | Plantation Director | Instituto Nacional de Investigaciones Agropecuarias (INIAP) | Ecuador |
| Luciano Carmona | Agronomist | FLAR | Brazil |
| Luis Bueno T. | Industrialist | Consejo del Arroz | Mexico |
| Manuel Leonardo | Farmer | Genética del Arroz (GENARROZ) | Dominican Republic |
| Marvin Vargas S. | Agronomist | Corporación Arrocera Nacional (CONARROZ) | Costa Rica |
| Minor Cruz | Director–Operations | Corporación Arrocera Nacional (CONARROZ) | Costa Rica |
| Mynor Barboza | Executive Director | Corporación Arrocera Nacional (CONARROZ) | Costa Rica |
| Natalia Camacho | Collaborator | Semillas del Nuevo Milenio S.A. (SENUMISA) | Costa Rica |
| Néstor Gutiérrez | Economist | Federación Nacional de Arroceros (FEDEARROZ) | Colombia |
| Normán Oviedo | Manager | Semillas del Nuevo Milenio S.A. (SENUMISA) | Costa Rica |
| Oliverio Espailla T. | Farmer | Federación Nacional de Productores de Arroz (FENARROZ) | Dominican Republic |
| Patricia Guzmán | Technical Sub-Manager | Federación Nacional de Arroceros (FEDEARROZ) | Colombia |
| Pedro A. Díaz Hartz | Farmer | Consejo Nacional de Productores de Arroz (CONAPAMEX) | Mexico |
| Pedro Luis Cordero | Agronomist–Production | Fundación Nacional del Arroz (FUNDARROZ) | Venezuela |
| Roger Madriz | Technician | Corporación Arrocera Nacional (CONARROZ) | Costa Rica |
| Salomé Tupa | Farmer | Federación Nacional de Cultivadores de Arroz (FENCA) | Bolivia |
| Sergio Gindri Lopes | Agronomist/Researcher | Instituto Rio Grandense do Arroz (IRGA) | Brazil |
| Viviana Palmiori | Specialist–Innovation | Inter-American Institute for Cooperation on Agriculture (IICA) | Costa Rica |
| Wilfredo Bejarano | Farmer | Asociación Nicaragüense de Arroceros (ANAR) | Nicaragua |

**Appendix 2.** Work program for the workshop on "Mejorando la Competitividad del Arroz en América Latina mediante el Cierre de Brechas de Rendimiento" [Improving the Competitiveness of Rice in Latin America by Narrowing the Yield Gap], held at Hotel Barceló, San José, Costa Rica, 6 November 2013.

**Moderator:** **Edgar Torres**

| Hour | Activity | Person in charge |
|---|---|---|
| 8:00 | Welcome | |
| 8:30 | Challenges of the rice sector in Latin America and the Caribbean | Invited guest speaker: Alvaro Durant |
| 9:00 | Panel: Successful experiences / Limiting factors in improving agronomic management | |
| 9:00 | Narrowing the yield gap in Rio Grande do Sul, Brazil | Sérgio Iraçu Gindri Lopes, IRGA, Brazil |
| 9:30 | Narrowing the yield gap in Uruguay | Ernesto Stirling, ACA, Uruguay |
| **10:00** | **Refreshments** | |
| 10:15 | Effects of trade aperture in Mexico on rice production | Luis Bueno, C.M. Arroz, Mexico |
| 10:45 | Narrowing production gaps in Colombia | Patricia Guzmán, FEDEARROZ, Colombia |
| 11:15 | Strategies for narrowing the yield gap in tropical regions | Luciano Carmona, FLAR |
| 11:45 | Experiences in technology transfer in Rio Grande do Sul, Brazil | Gilberto Dotto, FLAR |
| **12:30** | **Lunch** | |
| 14:00 | Working groups for answering the following questions: | Simone Staiger-Rivas, CIAT |
| | 1. What are the constraints to mass adoption of technologies that help narrow yield gaps through improving crop management? | |
| | 2. For the mass adoption of these technologies, what are the respective roles of farmers, industry, government, national institutes, and international centers? | |
| | 3. What actions must be considered in a strategy to make improvements in agronomic management widely available? | |
| | 4. Define the resources needed and suggest where they can be obtained from. | |
| **15:30** | **Refreshments** | |
| 15:50 | The moderator presents results from the working groups | |
| 17:00 | Conclusions | |
| 19:00 | Dinner and Closure of the Workshop | |

## References

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