Closing the yield gap in rice production in Uruguay: impact of technological changes

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Uruguay, located between 30 and 35° L south, produces only one rice crop a year. Commercial rice cultivation started in 1931, and the crop area has increased since then. In the 2010−11 crop season, the rice-growing area is estimated to be 190,000 ha. About 90% of the rice produced is exported, accounting for 6.2% of national export value. Rice production is highly mechanized, with an average crop area of approximately 300 ha per farmer. The crop is grown in rotation with pasture for cattle grazing, typically 2 years of rice and 3−4 years of pasture. The rice crop season extends from October to April; the average minimum and maximum temperatures are 13.9 and 26.2° C, respectively. Optimum sowing date is in October, and crops planted after November 15 have less solar radiation during the reproductive phase, with increased risk of low-temperature damage.

Tillage operations, land leveling, sowing, and postemergence weed control are done with nonflooded soil, and rice grows as an upland crop until it is flooded at the four- to five-leaf stage. About 90% of the crop is drill-seeded, and, of this area, 10% is sown with no tillage and 15% with minimum tillage. The whole crop area is fertilized at sowing with N and P_2O_5 (about 15 and 60 kg ha^{-1}, respectively), and K_2O (25 kg ha^{-1}) is applied to about 35% of the area. One or two N topdressings are applied, generally before flooding or at panicle initiation, making a total of 45 kg ha^{-1} for N topdressings. Average total N (sowing + topdressing) is 60 kg ha^{-1}. About 97% of the rice area is treated with selective herbicides for barnyard grass control; 75% is sprayed with fungicides, mainly for control of fungal diseases affecting rice stems (even though rice blast pressure has increased in the last two seasons); and only 4-9% was treated with insecticides.

About 90% of the area is sown with certified seed,almost all long-grained varieties. Three high-yielding varieties released by the local breeding program account for 92% of the rice area: El Paso 144 (58%), INIA Olimar (19%), and INIA Tacuarí (15%). The first two are indica ecotypes and the last one is a tropical japonica. This paper presents the changes in rice cultivation technology that had resulted in significant yield increases and thereby closed the yield gap.

Research and technology transfer

The rice production chain is a highly integrated system. The Rice Growers Association and the Rice Millers Association play important roles. Much of the rice research is conducted by the national rice research institute (INIA), doing studies on breeding, weeds, pest and disease management, irrigation, physiology, nutrition, soil management, as well as sustainability of rice cropping systems. INIA discusses research needs and priorities with farmers and industry and conducts activities to ensure dissemination of results. There is no public extension service and most technology transfer is done through the industry's technical advisory departments; private consultants and farmer groups also play an important role.

Technological changes

In the last 40 years, adoption of high-yielding varieties, improved soil management practices (anticipated tillage, land leveling, and reduced tillage), early weed control, irrigation, adjustments in fertilization, and disease control has resulted in important yield increases. To study the technological changes in rice production, we gathered information from the production database of the largest milling company in the country, SAMAN, which processes about 60% of the rice produced and which has detailed records of farmers' cultural practices.

Between 1971 and 1990, production was based on an introduced variety, Bluebelle, which replaced several introduced medium- and short-grained varieties. The Bluebelle area declined rapidly in the early 1990s because of the adoption of the abovementioned local high-yielding varieties (these have 20−30% higher yield potential than Bluebelle).

Among SAMAN farmers, the use of a land plane increased from 10% of the area in the early 80s to 92% in 2010; drill sowing increased from 10 to 95% in the same period. The use of glyphosate herbicide to minimize tillage operations increased from 3% in 1991 to 94% in 2009, resulting in reduced costs. Anticipated tillage, in the summer previous to the rice crop, followed by glyphosate application and minimum tillage (or no tillage) previous to rice sowing in the spring enabled sowing of a larger area at the recommended dates, ensuring that the reproductive phase occurs under the most favorable climatic conditions. Crop area fertilized with N and P at sowing, as well as the area with N topdressing, increased sharply from 15% and 10% in the early 1970s to 100% and 97%, respectively, in 2010. Topdressing N rate also increased from 26 to 45 kg ha^{-1} in the same period. In the last decade, farmers established irrigation earlier, as indicated by the significantly increasing area being flooded. The area treated with herbicides increased from 4 to 97% between 1973 and 2010, while that treated with fungicides showed a sharp increase after 1997, from 9 to 79%.

Impact on grain yield

Between 1931 and 1970, grain yield was relatively low and stable, averaging 3.25 t ha^{-1}. As a result of the adoption of improved varieties and cultural practices, grain yield has been increasing since 1970. Average grain yield of the country (moving average for 5 years) increased at the rate of 90 kg ha^{-1} per year between 1970 and 2010 (Fig. 1) and at 142 kg ha^{-1} per year between 1990 and 2010. Between 1971 and 1990, there was a 36% yield increase driven by the adoption of Bluebelle and mainly by following improved cultural practices. The replacement of Bluebelle by high-yielding varieties El Paso 144, INIA Tacuarí, and INIA Olimar and further improvement in cultural practices resulted in a 63% yield increase between 1990 and 2010.

Yield gap among farmers

Grain yield distribution among all farmers (SAMAN) in 5-year periods for each decade between 1970 and 2010 (harvest years: 1975-79, 1985-89, 1995-99, and 2005-09) were analyzed using a quintile box plot analysis and t Student´s separation of means. JMP IN V4, SAS Institute, Inc. 2001 was used. The software grouped the yield data of all farmers in quintiles: minimum, 10%, 25%, median, 75%, 90% and maximum, estimating grain yield for each one. The means of the analyzed periods were significantly different (P = 0.05), indicating yield improvement across years. The maximum yield obtained by the top farmers leveled to slightly higher than 12 t ha^{-1} in the last 2 decades. However, the grain yield of the other quintiles continued to increase, suggesting a reduction in yield gap among farmers (Fig. 2). In the 1990s, 50% of the farmers (between quintiles 25 and 75%) had yields between 4.8 and 7 t ha-1 (median 6 t ha-1), whereas in the current decade, their yields were between 6.9 and 8.8 t ha-1 (median 8 t ha-1). The coefficient of variation was reduced from 31.0% in 1980s to 16.0% in the 2000s. However, in spite of the large gains in closing the yield gap, there is still much room for improvement. As shown in Figure 2, 25% of the rice growers have yields of less than 6.5 t ha-1, approximately 50% of the top farmers. The remaining task is to expand the use of improved crop management practices to farmers with noncompetitive yields.

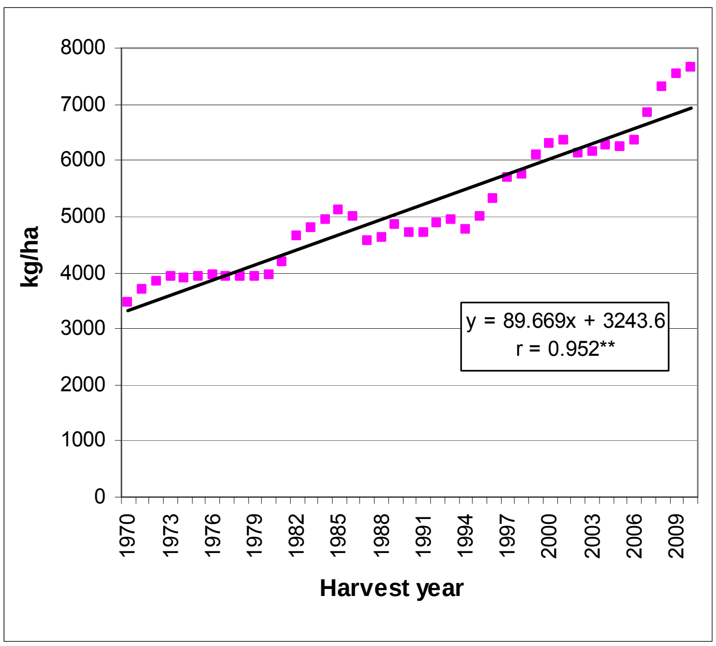

Fig. 1. Grain yield in Uruguay (moving average for 5 years) between 1970 and 2010 (harvest year). Equation for 1990-2010: y = 142.17x + 4389.2, r = 0.962**. Sources: Statistics Dept., Ministry of Agriculture (DIEA) and Rice Farmers Association.

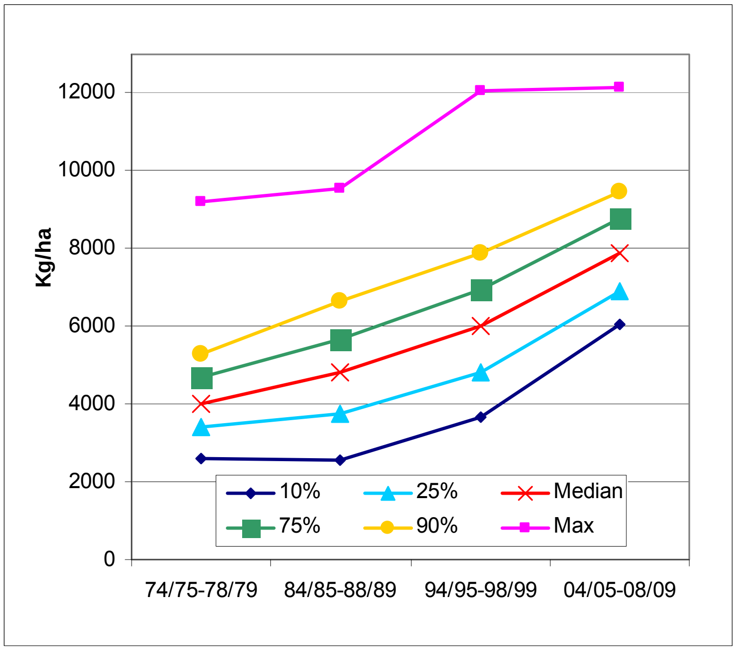

Fig. 2. Grain yields in SAMAN farms, classified into different quintiles during 5-year periods for each decade between 1970 and 2010. Quintiles: 10%, 25%, median, 75%, 90% and maximum.

Acknowledgments

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