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UPLAND RICE COMPOSITE POPULATION BREEDING AND SELECTION OF PROMISING LINES FOR COLOMBIAN SAVANNAH ECOSYSTEM[1]

Marc Châtel[2], Yolima Ospina[2], Francisco Rodriguez[2],
Victor Hugo Lozano[2], Hermando Delgado[3]

RESUMO

MELHORAMENTO POPULACIONAL DE ARROZ DE TERRAS ALTAS E SELEÇÃO DE LINHAGENS PROMISSORAS PARA AS CONDIÇÕES DE SAVANA DA COLÔMBIA

Em colaboração, desde 1996, CIRAD (Centre de Coopération Internacionale en Recherche Agronomique pour le Développment) e CIAT (Centro Internacional de Agricultura Tropical) desenvolvem atividades de melhoramento intra-populacional, para ampliar a base genética do arroz cultivado. O desenvolvimento de populações base (compostos) de arroz de terras altas, por meio de seleção recorrente, compõem as novas estratégias para se alcançar esse objetivo. Usando-se um gene recessivo de macho-esterilidade (ms), essas populações têm sido desenvolvidas facilmente. Na Colômbia, essas populações de arroz têm sido melhoradas por dois procedimentos de seleção recorrente: seleção massal e de progênies S_2. Em cada ciclo de seleção, plantas férteis são selecionadas para o desenvolvimento de linhagens segregantes e para a seleção de progênies, usando-se o método convencional de pedigree. As linhagens avançadas são avaliadas em ensaios de rendimento, com apoio do projeto e em colaboração com a empresa colombiana de pesquisa – Corpoica Regional 8, em Villavicencio, Colômbia. Linhagens promissoras de boa adaptação a solos ácidos foram identificadas. Uma destas linhagens, extraída a partir do primeiro ciclo de seleção recorrente da população base PCT-4, mostra alto potencial de produtividade e mesmo nível de precocidade da melhor testemunha comercial (Línea 30), desenvolvida por melhoramento convencional.

PALAVRAS-CHAVE: *Oryza sativa*; arroz de terras altas; seleção recorrente; composto; população base.

ABSTRACT

Since 1996, the collaborative project between CIRAD (Agricultural Research Centre for International Development) and CIAT (Centro Internacional de Agricultura Tropical) has gradually phased out intra-specific tropical japonica conventional crossbreeding activities and concentrated on rice genetic base broadening. The development and enhancement by recurrent selection of upland rice composite populations are the new breeding strategies. Using a recessive male-sterile gene (ms), the development of rice population was made easier. In Colombia, upland basic composite populations were enhanced using two recurrent selection-breeding methods: mass recurrent selection and S_2 progenies evaluation. At each enhancement cycle, fertile plants are selected for the development of segregating lines and progeny selection using the conventional pedigree method. The most advanced lines are evaluated in yield trials by the project and in collaboration with the Colombian research organization – Corpoica Regional 8, in Villavicencio, Colombia. Promising lines having good adaptation to acid soils were identified. One promising line, extracted from the first cycle of recurrent selection of the composite population PCT-4, shows a higher yield potential with the same earliness of the best commercial check (Línea 30), developed by conventional crossbreeding.

KEY-WORDS: *Oryza sativa*; upland rice; recurrent selection; composite population; promising line.

INTRODUCTION

Conventional crossbreeding projects of the "Centro Internacional de Agricultura Tropical" (CIAT, Colombia) and the collaborative rice breeding project between the "Centre de Coopération Internationale en Recherche Agronomique pour le Développement" (CIRAD, France) and CIAT have been, and still are, a source for the release of new varieties in Latin America countries, such as Bolivia, Brazil and Colombia (Inger 1991). But the released lines present some narrow genetic base, which needs to be broadened for the development of new varieties (Cuevas-Pérez et al. 1992, Rangel et al. 1996, Montalván et al. 1998). It is the responsibility of international centers like CIAT and CIRAD to join

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2. Centre de Coopération Internacionale en Recherche Agronomique pour le Développment (CIRAD) / Consultative Group on International Agricultural Research (CGIAR) – Projeto colaborativo no Centro Internacional de Agricultura Tropical (CIAT). Apartado Aéreo 6713. Cali, Colômbia. E-mail: m.chatel@cgiar.org; y.ospina@cgiar.org
3. Corporación Colombiana de Investigación Agropecuaria – Corpoica Regional 8. Villavicencio, Meta, Colômbia.

forces to propose and implement new breeding tools for creation and future release to rice growers of germplasm with different genetic backgrounds.

The creation of populations with broad genetic base (Châtel & Guimarães 1998), and their breeding through recurrent selection, is a new breeding method proposed and implemented by the CIAT/CIRAD rice project.

Since 1996, the project concentrates in the development and enhancement of upland rice gene pools (*Oryza sativa* L., Tropical Japonica type) (Châtel et al. 2001). By using a recessive male-sterile gene (ms), from a mutant of IR36 (Singh & Ikehashi 1981), rice population development and enhancement were eased. The basic populations were enhanced using two recurrent selection-breeding methods.

The main purpose of a breeding project is the creation of variability and the development of breeding material that may lead to the identification of promising lines and new cultivars. To do so, fertile plants are selected from the basic composite populations and at each enhancement step by recurrent selection. They are the starting point for the selection of segregating progenies by conventional pedigree method and the identification of promising fixed lines.

The number of progenies developed from population breeding has steadily increased from 1997 on. This report presents the outputs of the breeding strategy of the composite population PCT-4 and the identification of promising lines adapted to the Colombian savannah rice ecosystem.

MATERIAL AND METHODS

Composite population breeding

Population breeding by recurrent selection is very efficient for trait improvement, showing low heritability. Through short selection-recombination cycles, linkage blocks are break down and favorable genes are accumulated. This is a smooth process of continuous improvement.

Rice composite populations are highly segregating for numerous traits and are made of fertile (Ms ms) and male-sterile plants (ms ms), allowing natural cross-pollination. Grains produced by male-sterile plants are Ms ms and ms ms (pollen produced by fertile plants is ms or Ms and female organs of male-sterile plants are ms). To allow complete recombination between early and late flowering material, two to three sowing dates are made in the same physical plot. To avoid pollen contamination from other rice plots, each population is fenced by maize rows.

Harvesting the male-sterile plants represents a new cycle of recombination as well as seed multiplication of the population.

Composite population breeding strategies

Recurrent selection is a cyclic process involving three main steps: plant selection (selection unit), evaluation and recombination (recombination units) of the best performing selection units. Two recurrent selection strategies were used: mass recurrent selection and S_2 progenies evaluation.

The first strategy is based on phenotype selection or mass selection on both sexes, before flowering time. S_0 plants of each cycle of recurrent selection are, at the same time, the selection and recombination units. Each recurrent cycle is one year long. Selection pressure is needed at field condition; this was the case for acid soil and diseases.

The second strategy involves progeny evaluation. S_0 fertile plants are selected during the normal cropping season (March-September), in the Experimental Station of La Libertad (LSE). The generation S_1 is advanced at the Experimental Station of Palmira (PES), during the period October-February. S_2 seeds are harvested at PES and planted at LES, during the normal cropping season. S_2 lines are evaluated and selected to compare with commercial checks, in a statistical design (Federer 1956). The best progenies are selected and then

Table 1. Segregating lines from different composite populations evaluated in the Experimental Station La Libertad – LES (Villavicencio, Colombia, 2002).

Population	Generation and number of line						
	S_1	S_2	S_3	S_4	S_5	S_7	S_9
PCT-A\PHB\1\0, PHB\1, PHB\1, PHB\1 PCT-4\PHB\1\0, PHB\1, PHB\1, PHB\1 PCT-5\PHB\1\0, PHB\1, PHB\1, PHB\1 PCT-4\SA\1\1\, SA\2\1 PCT-4\SA\5\1 PCT-4 Bolivia PCT-11 Bolivia CNA-7 Bolivia	394						
PCT-4\SA\4\1		15					
PCT-4\SA\1\1, SA\1\1 PCT-11\0\0\3 PCT-4\SA\4\1			23				
PCT-4\0\0\2 PCT-4\SA\2\1				23			
PCT-4\0\0\0					7		
PCT-11\0\0\1						2	
PCT-4\SA\1\1 PCT-4\PHB\1\1, PHB\1 PCT-A\0\0\0 PCT-4\0\0\1							178

recombined from the remnant seeds from S_0 plants. A recurrent cycle is completed in two years time.

Selection of fertile plants for line development

The selection of S_0 fertile plants (Ms ms) is the starting point for segregating line development. Through out the selection process, selecting and harvesting only fertile plants allow eliminating the male-sterile gene. Advanced progenies are 100% fertile (Ms Ms). Line development follows traditional evaluation and pedigree selection.

The major characteristics bred for savannah conditions are early vigor, tolerance to soil acidity, resistance to rice blast (*Pyricularia grisea* Sacc.), good grain quality (translucent, long-slender grain) and early maturity (total cycle about 115 days).

A total of 179 advanced S_9 lines were selected using the pedigree method. This material comes from different phases of PCT-4 population enhancement (Table 1) and passes through the overall process of selection and agronomic evaluations.

Yield trials

Promising lines from different breeding populations were selected during the last years. Some of them were evaluated in preliminary experimental yield trials in Colombia, at LES and on-farm, in collaboration with Corporación Colombiana de Investigación Agropecuaria – Corpoica, Regional 8. The experimental design was randomized blocks with three replications.

The yield trials were cultivated on acid soils (Table 2). The fertilization consisted of 300 $kg.ha^{-1}$ of dolomitice lime, applied 30 days before sowing (as Ca and Mg nutrients, not for soil acidity correction), 177 $kg.ha^{-1}$ of Nitrogen (59 $kg.ha^{-1}$, at 20, 35 and 45 days after sowing), 155 $kg.ha^{-1}$ of Phosphorus, at sowing, and 116 $kg.ha^{-1}$ of Potassium (58 $kg.ha^{-1}$, at sowing, and 29 $kg.ha^{-1}$, at 20 and 35 days after sowing). No insecticide or other pesticide was applied.

The 24 advanced lines selected from the first recurrent selection cycle of the population PCT-4 and three commercial checks (Oryzica Sabana 6, Oryzica Sabana 10, and "Línea 30") were evaluated. During the cropping seasons 2000 and 2001, the trials were carried out at LES, and, in the 2002 growing season, in collaboration with Corpoica Regional 8, the trials were conducted in five places, two at LES and three on-farm, under savannah condition.

RESULTS AND DISCUSSION

The combined analysis of the three years, at LES (Table 3), shows that grain yields vary between 1550 $kg.ha^{-1}$ and 3300 $kg.ha^{-1}$. The checks Oryzica Sabana 10, Oryzica Sabana 6 and Línea 30 yielded 1550 $kg.ha^{-1}$, 2614 $kg.ha^{-1}$ and 2038 $kg.ha^{-1}$, respectively. It is to notice the bad behavior of the Línea 30, that showed erratic yielding throughout the years, with its lowest yield in 2002. This is mainly because of spicklets sterility, due to low temperatures (Figure 1), as a consequence of cold fronts coming from Brazil. The cold susceptibility of the Línea 30 was formerly detected when it was cultivated in the coffee region, at 1450 masl, where it presented more than 60% spicklet sterility.

Table 2. Soil analysis of trial areas in the Experimental Station La Libertad – LES (Villavicencio, Colombia, 2002)[1]

Sample	Depth (cm)	M.O (%)	P Bray II (ppm)	pH	Al	Ca	Mg	K	C.I.E	B	Zn	Mn	Cu	Al Saturation (%)
					(meq / 100 g)									
1	0-20	4.1	17.4	3.9	2.39	0.90	0.37	0.25	3.91	0.52	0.48	14.6	0.52	61.1
	20-40	3.5	4.7	3.8	2.96	0.45	0.17	0.11	3.69	0.66	0.40	9.0	0.56	80.2
2	0-20	5.9	22.5	4.1	2.70	0.69	0.34	0.22	3.73	0.23	0.41	11.1	0.49	72.4
	20-40	4.3	2.0	3.8	2.90	0.30	0.12	0.17	3.32	0.12	0.29	6.53	0.42	87.4

[1]- Clay = 43.4%, Sand = 39.1%, Loam = 17.5%.

Table 3. Selected lines from the yield trial in the Experimental Station La Libertad - LES (Villavicencio, Colombia, 2000-2002).

Line from the population PCT-4\SA\1\1[1]	Grain yield (kgha^{-1}) Year 2000	2001	2002	Average	% O.Sabana 6	% CIRAD 409	% O. Sabana 10
>975-M-2-M-3	3644	3333	2924	3300	1.35	1.50	2.13
>975-M-2-M-2	3275	3480	2669	3141	1.28	1.42	2.03
>975-M-3-M-2	3215	3439	2580	3078	1.26	1.40	1.98
>975-M-3-M-3	3367	3081	2529	2992	1.22	1.36	1.93
>982-M-3-M-5	3277	3240	2388	2968	1.21	1.35	1.91
>975-M-3-M-4	3321	3179	2375	2958	1.21	1.34	1.91
>1479-M-1-M-3	3028	3477	2271	2925	1.19	1.33	1.89
>1479-M-1-M-5	3016	3444	2306	2922	1.19	1.32	1.88
>1036-M-6-M-2	2868	3647	2206	2907	1.19	1.32	1.87
>1479-M-1-M-6	3265	3300	2142	2902	1.18	1.32	1.87
>1479-M-1-M-1	3240	3074	2356	2890	1.18	1.31	1.86
>975-M-2-M-1	2947	2972	2640	2853	1.16	1.29	1.84
>1044-M-3-M-4	3379	2890	2001	2757	1.13	1.25	1.78
Check							
O. Sabana 6	2139	3226	1978	2448	-	0.90	0.63
Línea 30 (CIRAD 409)	2332	3531	749	2204	1.11	-	0.70
O. Sabana 10	1240	2770	641	1550	1.58	1.42	-

[1]- PCT-4\SA\1\1: Nomenclature of the population PCT-4. One cycle of recurrent selection cycle for acid soil conditions.

The year 2002 was also atypical, with heavy rain precipitations and low solar radiation (Figure 2), that, in association with cold temperature, contributed to a high level of physiologic sterility. At contrary, all the lines from the population PCT-4, which are as early as the Línea 30, showed stable yields and, in 2002, did not present high levels of sterility, that is, an indirect measurement of their tolerance to cold. The analysis of three years trials shows that the average yield of the line PCT-4\SA\1\1>975-M-2-M-3 is 35%, 50% and 113% more than Línea 30, Oryzica Sabana 6 and Oryzica Sabana 10, respectively; and this line is as early as the earliest commercial check, Línea 30. This is a confirmation of the last year results, when we stated that it was possible to breakdown the negative correlation generally observed between earliness and grain yield. The best performing line

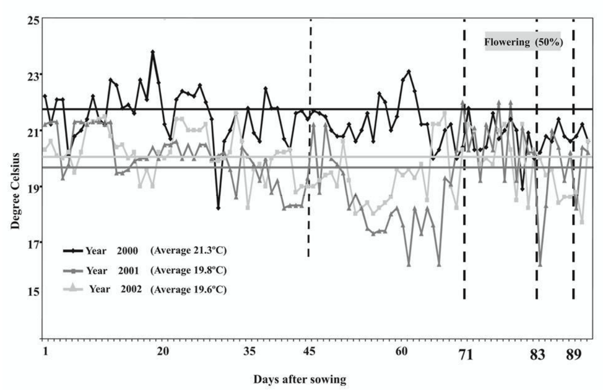

Figure 1. Minimum temperature during three growing seasons, in the Experimental Station La Libertad - LES (Villavicencio, Colombia, 2000-2002).

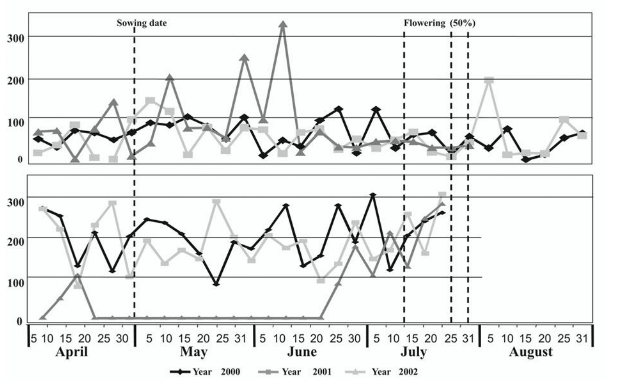

Figure 2. Rain precipitation and total relative solar radiation in the Experimental Station La Libertad - LES (Villavicencio, Colombia, 2000-2002).

PCT-4\SA\1\1>975-M-2-M-3 at LES was also selected in the trials conducted by Corpoica Regional 8 (Table 1).

Twelve other lines show similar yielding potential as the best check Línea 30. From these twelve lines, five were selected by Corpoica Regional 8 (Table 3 and Table 1). These lines represent a diversified option for upland rice in the Colombian savannah and can contribute to diversify the genetic material for producers. Grain quality of three lines is presented in the Table 4. In 2002, the 24 lines of the Colombian trial were shipped to Bolivia (CIAT Santa Cruz), Nicaragua (Gilles Trouche, CIRAD/CIAT) and Venezuela (Fundación DANAC y INIA Guárico), for local evaluation and selection.

Seed multiplication and genetic seed production

During 2003, the thirteen best promising lines were cultivated, at PES, for seed increase and further evaluation of milling and grain quality. Fifty individual panicles of each line were evaluated for the production of genetic seed. Depending on the results, the best top materials would be grown next year, in demonstration plots at LES.

Table 4. Grain quality of best promising lines and cultivar checks in three growing seasons (2000, 2001 and 2002).

Line	Year 2000	2001	2002	% Amylase
	White Belly			
PCT-4\SA\1\1>975-M-2-M-3	0.6	0.3	0.7	25.4
PCT-4\SA\1\1>975-M-3-M-3	0.5	0.3	0.6	26.4
PCT-4\SA\1\1>975-M-2-M-1	0.9	0.4	0.7	25.0
Check				
Línea 30 (CIRAD/CIAT 409)	0.4	1.0	0.8	25.5
Oryzica Sabana 6	0.6	0.7	0.4	25.2
Oryzica Sabana 10	0.8	0.5	0.8	24.0

CONCLUSION

The development of upland rice composite populations to broadening the genetic base of cultivated rice, using recurrent selection strategies, has been successful due to the collaborative project between CIRAD and CIAT. From these populations, promising lines, with a good adaptation to acid soils of Colombian savannahs, were identified and can contribute to diversify genetic material for producers. The line PCT-4\SA\1\1>975-M-2-M-3, extracted from the first cycle of recurrent selection of PCT-4 population, yields 35% more than the best commercial check (Línea 30), and shows the same earliness of that check cultivar, developed by conventional crossbreeding.

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