Annual Report

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Enhancing Rice Gene Pools
CIRAD/CIAT Collaborative Project

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Project proposals. Publications. Reports. Proceedings. Master Thesis. Oral presentations. Training. Conference organization, meetings and workshops. New collaboration between CIAT y CIRAD. Trips. Visits received.

List of Cooperators

- **Latin America and the Caribbean**
- **Argentina**
- Marta Nicosia, University of Tucumán
- Alberto Villegas, University of Tucumán
- Maria Antonia Marassi, University of Corrientes
- Juan Eduardo Marassi, University of La Plata
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- **Bolivia**
- Roger Taboada, CIAT Santa Cruz de la Sierra
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- Juana Viruez, CIAT Santa Cruz de la Sierra
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- Péricles de Carvalho Neves, Embrapa, Rice and Beans Center
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- **Uruguay**
- Fernando Pérez de Vida, INIA Treinta y Tres (currently in the U.S)
- **Nicaragua**
- Gilles Trouche, CIAT/CIRAD Collaborative Project
- **Venezuela**
- Gelis Torrealba, Instituto Nacional de Investigación Agrícola (INIA) Estado Guárico
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- **FLAR**
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- **Africa and Madagascar**
- Through CIRAD-France

- **Asia**

- Through Dr. Peter Kerridge, CIAT Regional Office
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- **Europe**
- Through Dr. Guy Clément, CIRAD-France

Highlights

I. Impact in Latin America of CIRAD's rice genetic resources

- Thirty-one (31) commercial varieties, having at least one CIRAD parent, were released in LAC during the last two decades (1982-2002). They were bred by the collaborative projects between CIRAD and Embrapa in Brazil and CIRAD and CIAT in Colombia.
- Six of them are CIRAD varieties directly released commercially, in Bolivia, Brazil and Nicaragua.
- Three (3) new promising lines were identified for their good adaptation to the Colombian hillside ecosystem.

II. Conventional and inter-specific crossbreeding of upland rice for the savannas ecosystem

- Three (3) upland rice lines, from conventional crossbreeding, released in Bolivia (CIRAD), Brazil (CIAT/CIRAD) and Colombia (CIAT/CIRAD)
- One (1) promissing CIAT/CIRAD line for next year release in Brazil
- Evaluation of a total of 751 lines:
  - 30 from conventional crossbreeding
  - 383 lines from inter-specific crosses: 45 from *Oryza sativa* by *O. glaberrima*, 24 from *Oryza sativa* by *Oryza. barthii* and 314 from *Oryza sativa* by *Oryza glaberrima*
  - 338 NERICA lines introduced from WARDA and selected at CIAT

III. Rice composite population breeding

- **Aerobic upland rice for the savannas ecosystem**
- Three (3) upland rice composite populations enhanced in Colombia
- Shuttle-recurrent selection breeding between Bolivia and Colombia of 3 upland composite populations
- Evaluation of 642 progenies from upland rice composite populations
- Identification, in Colombia, of a high yielding promising line selected from the recurrent population PCT-4
- Networking: II International Upland Rice Workshop in Bolivia
- Project proposal: Three (3) proposal presented. Two (2) in Cuba by IIA and CIRAD, and one (1) by INIA Venezuela
- **Irrigated lowland rice**
- Release of the line "Tio Taka" in Santa Catarina State, Brazil. This is the very first line coming-out from recurrent selection of the gene pool CNA-IRAT 4 developed by EMBRAPA and CIRAD.
- Site-specific population management with LAC NARS
- New site-specific populations developed at CIAT
- Evaluation and selection of progenies selected by LAC NARS from site-specific populations. Promising lines coming-out from the most advances NARS projects
- Networking: I International workshop on lowland rice recurrent selection in Venezuela. Preparation of the III International Conference on rice population breeding to be held in Venezuela in 2003.

IV. Producing upland rice with young coffee plantations in the Colombian hillsides

- The upland savanna line CT-10069-27-3-1-4 (CIRAD 445) confirms its adaptation to the mid-altitude hillside conditions (up to 1425 m.)
- In the mid-altitude Colombian hillsides, upland rice production in association with coffee in feasible and can benefit the small coffee producers of the region.

I. Impact in Latin America of CIRAD’s rice genetic resources

Châtel, M.; Guimarães, E.P.

Abstract

Increased production permitted to lower the price of rice to consumers. Rice is a staple food and principal source of calorie for the 20% lower-income people of Latin America and the Caribbean (LAC). The adaptation of the Asian green revolution to LAC and the release and adoption of high yielding varieties (HYV) was responsible for the increase of rice production in the region. During the last 40 years, about 300 varieties were released (262 and 37 for irrigated and upland respectively). They were developed by (i) the International Rice Research Institute (IRRI), (ii) the Centro Internacional de Agricultura Tropical (CIAT), (iii) the national rice research programs and (iv) the collaborative research projects between the Centre de coopération internationale en recherche agronomique pour le développement (CIRAD -France) and Empresa Braseleira de Pesquisa Agropecuaria (EMBRAPA - Brazil) and CIAT- Colombia, (Upland rice). The regional networks like INGER-LAC and FLAR, as well as bilateral collaborations fueled the diffusion of the new HYV.

This report analyses the contribution of the genetic resources of CIRAD in the background of the varieties released. For aerobic upland rice, 90% of the varieties have one or more CIRAD parent.

In LAC, the genetic resources of CIRAD represent a great contribution, but only few CIRAD lines were repeatedly used as parent (CIRAD 2, CIRAD 120 series and CIRAD 216). This lead to a possible narrowing of the genetic base. Furthermore, the new released varieties were used as parent for new crosses leading to a higher degree of consanguinity.

Facing this problem, the rice project of CIAT shifted to pre-breeding activities aiming at broadening the genetic base of rice in LAC.

Keywords: Rice, genetic resources, high yielding varieties, and Latin America and the Caribbean

Introduction

In LAC, starting in the 60’s, CIAT has been the leading research institution that have developed and permitted the released new HYV in the region.

CIAT started introducing rice germplasm from IRRI (Asian green revolution) to identify adaptation to the rice ecosystem of LAC and parents for crossbreeding. Later on, the introduction of germplasm was directed attending the different rice ecosystems (Irrigated tropical, sub-tropical and temperate climate, and aerobic upland rice for the savannas).

With the set-up of the regional rice project mandate and the increase in breeding activities, many breeding lines were developed and shipped to the national breeding programs through the INGER-LAC network, for local evaluation and possible release.

The main issue was to identify parents with biotic and abiotic traits of resistance, for the development of crossbreeding activities.

During the last 30 years, about 300 varieties were released as cultivars in LAC. They come in their great majority from progenies of crosses developed and selected by CIAT.

CIRAD’s rice genetic resources in LAC

Until the mid 80’s, CIAT concentrates on breeding to attend the irrigated rice sector of LAC

For its part, starting in the 60's, CIRAD developed rice breeding attending the upland rice ecosystem present in the West African countries but also the irrigated ecosystem in Madagascar.
From the 80's on, CIRAD started rice breeding activities in Latin America, mainly in Brazil and also in French Guyana.
The genetic resources developed by CIRAD were shared with CGIAR Research Centers working in rice and among them with CIAT. Thank to the CIAT's rice data bank, and the different publications of the institution, it has been possible to collect and analyses the information about the use of CIRAD's genetic resources in LAC. The present report analyses the contribution of the CIRAD's rice genetic resources in different breeding programs, as well as for their genetic contribution in the varieties released by LAC-NARS.

- **Use of the CIRAD rice genetic resources by LAC NARS**

The CIRAD varieties introduced by CIAT through the global IRTP and INGER Networks or directly through bilateral collaborations between CIRAD and LAC-NARS, were characterized and used as potential parents by the rice breeding programs in different countries.
Brazil: In Brazil, three public research centers are working in rice breeding: EMBRAPA Rice and Beans Center, State of Goiàs, IAC Campinas-Research Center of the State São Paulo and EMBRAPA Lowland Center-State of Rio Grande do Sul.
A total of 53 CIRAD rice varieties was used as parents in crosses by the three institutions mentioned above. EMBRAPA Rice and Beans Center used fifty (50) in 511 crosses, 284 times as female and 227 times as male parent. These numbers represent very well the intensity of the direct collaboration established during the period 1981-1991, in the framework of the upland rice-breeding project between EMBRAPA and CIRAD.
Eight (8) of the fifty (50) varieties worked-out by EMBRAPA Rice and Beans Center were used by IAC in seventy seven (77) crosses, 10 times as female and 67 times as male parent.
The lowland Center of EMBRAPA used only three (3) CIRAD varieties, from witch 2 different from the ones used by the other Brazilian centers. This resulted in fifteen crosses always using the CIRAD variety as the male parent. In this last case, the law intensity in the use of the CIRAD varieties is because the lowland EMBRAPA Center is focusing its breeding program on sub-tropical and temperate climate irrigated lowland rice ecosystem and that the CIRAD varieties are adapted to both upland and lowland tropical rice ecosystem.
The most successful CIRAD varieties used as parents in Brazil were CIRAD 2, CIRAD 13, CIRAD 101, CIRAD 112, CIRAD 177, CIRAD 195, CIRAD 216 and CIRAD 257. They are upland material and present good yielding potential, good plant type, earliness, one of them (CIRAD 216) have good grain quality (long slender grain).
Colombia: In Colombia, two research institutions were at charge of rice breeding. They are the former public Instituto Colombiano Agropecuario (ICA), and the international institution CIAT. During the period 1967-1983, crosses were designed and made in a common way between the two institutions, then CIAT took-over the responsibility.
A total of sixteen (16) CIRAD varieties was used in 1092 crosses, 703 times as female and 389 times as male parents.
The most successful CIRAD varieties used as parents in Colombia were CIRAD 8, CIRAD 13, CIRAD 120, CIRAD 121, CIRAD 122, CIRAD 124 y CIRAD 216. The varieties of the series CIRAD 120 bred in Madagascar were used intensively. These varieties were identified as source of resistance to the Rice Hoja Blanca Virus (RHBV). As mentioned earlier they were bred in Madagascar, were the RHBV does not exit. Looking at their genetic constitution its appears that they have the traditional line Makalioka 34, cultivated in the Alaotra lake region, as one of their

parents. Makalioka 34 was identified by CIAT as a source of resistance to the RHBV. It as transmitted its trait to its progenies

Mexico: In Mexico, the Instituto Nacional de Investigaciones Forestales y Agropecuarias (INIFAP) used 17 CIRAD varieties in 277 crosses.

Peru: In Peru, the Instituto Nacional de Investigaciones Agropecuarias y Agroindustriales (INIAA) used 8 CIRAD varieties in 74 crosses.

Ecuador: In Ecuador, 3 CIRAD varieties were used in 15 crosses.

- **Release of varieties selected from crosses with CIRAD germplasm (Table 1.)**

The CIRAD germplasm used by the national rice breeding programs, have permitted the development of promising progenies from witch some were released as commercial varieties.

The most relevant impact, during the period 1981-1991, was in Brazil in the framework of the collaborative project between EMBRAPA Rice and Beans Center and CIRAD. Sustainable impact in this country does go-on from 1991 up to now, through the collaborative rice breeding project between CIAT and CIRAD to witch Brazil continues to be the privileged client for upland rice breeding germplasm in LAC.

Brazil

During the period 1986 – 2002, fourteen (14) upland savanna lines, bred by the EMRAPA/CIRAD and CIAT/CIRAD collaborative rice breeding projects, were released.

EMBRAPA/CIRAD lines: One of the outputs of rice breeding project between EMBRAPA Rice and Beans Center and CIRAD (1981 –1991) was the release and adoption by farmers of eight (8) modern upland lines for the savannas ecosystem of the Brazilian Cerrado.

RIO PARANAIBA, CENTRO AMERICA, GUARANI, GUAPORÉ, TANGARA, DOURADÃO, XINGU and PRIMAVERA

CIAT/CIRAD lines: During the period 1992-2002, 67% of the upland rice lines released in Brazil come from CIAT. They were selected in Colombia, by the CIAT/CIRAD collaborative rice-breeding project, and then adapted by EMBRAPA Rice and Beans Center. They have at least one CIRAD parent.

PROGRESO, CANASTRA, MARAVILHA, BONANÇA, CARISMA and TALENTO

Colombia

CIAT and CIAT/CIRAD lines: During the period 1989 – 2002, five (5) lines having at least one CIRAD parent, were released as cultivars. Two (2) are from CIAT for the irrigated lowland ecosystem, three (3) are from CIAT/CIRAD for upland savannas ecosystem.

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ORYZICA SABANA 6, ORYZICA SABANA 10, ORYZICA LLANOS 4, PROGRESO 4-25 and CIRAD/CIAT 409

Bolivia

CIAT lines: Three (3) lines were released for the favorable upland rice ecosystem. They are from CIAT and have at least one CIRAD parent.

SACIA-1 (TACU), SACIA-3 (TUTUMA) and SACIA-4 (JISUMU)

Guatemala

CIAT lines: Three (3) lines were released. They are from CIAT and have at least one CIRAD parent.

ICTA IZABAL, MASAGUA and OASIS

Table 1. Released varieties coming from crosses with CIRAD germplasm

BRAZIL - EMBRAPA/CIRAD Crosses-		
Variety (Upland savannas)	**Year**	**CIRAD Parent**
RIO PARANAIBA	1986	IRAT 2
CENTRO AMERICA	1987	IRAT 2
GUARANI	1987	IRAT 2
GUAPORÉ	1988	IRAT 13
TANGARA	1989	IRAT 13
DOURADÃO	1989	IRAT 2
XINGU	1989	IRAT 13
PRIMAVERA	1997	IRAT 10
BRAZIL - CIAT/CIRAD Crosses		
PROGRESO	1993	IRAT 124 and IRAT 216
CANASTRA	1995	IRAT 122
MARAVILHA	1995	IRAT 121 and IRAT 216
BONANÇA	1999	IRAT 124 and IRAT 216
CARISMA	1999	IRAT 124 and IRAT 216
TALENTO	2002	IRAT 124 and IRAT 216
COLOMBIA - CIAT/CIRAD Crosses		
Variety (Upland savannas)	**Year**	**CIRAD Parent**
ORYZICA SABANA 6	1992	IRAT 216.
ORYZICA SABANA 10	1996	IRAT 124 and IRAT 216.
LÍNEA 30 (CIRAD 409)	2002	IRAT 124, IRAT 146 and IRAT 216.
Variety (Lowland irrigated)	**Year**	**CIRAD Parent**
ORYZICA LLANOS 4	1989	IRAT 122.
PROGRESO 4-25	2000	IRAT 120
BOLIVIA - CIAT/CIRAD Crosses		
Variety (Favorable upland)	**Year**	**CIRAD Parent**
SACIA-1 (TACU)	1993	IRAT 216
SACIA-3 (TUTUMA)	1994	IRAT 124 and IRAT 216
SACIA-4 (JISUMU)	1994	IRAT 124 and IRAT 216
GUATEMALA - CIAT/CIRAD Crosses		
Variety	**Year**	**CIRAD Parent**
ICTA IZABAL	1996	IRAT 122 and IRAT 216
MASAGUA	2000	IRAT 122
OASIS	2000	IRAT 121

- **Direct release of CIRAD varieties (Table 2.)**

Five (5) varieties from CIRAD showing good direct adaptation were released as commercial varieties in Brazil and Bolivia.

Brazil

IRAT 190, IRAT 177 and IRAT 216

Bolivia

IRAT 170 and IRAT 357

Table 2. Direct release of CIRAD germplasm

BRAZIL		
CIRAD Variety (Upland)	**Local name**	**Year**
IRAT 190	IREM 16 B	1982
IRAT 177	CABAÇU	1988
IRAT 216	RIO VERDE	1991
BOLIVIA		
CIRAD Variety (Upland small-holders)	**Local name**	**Year**
IRAT 170	JASAYE	1999
IRAT 357	JACUÚ	2002

- **CIRAD/CIAT promising lines (Table 3.)**

Colombia

Six lines have been identified as very promising. Three in Colombian, one in Peru, one in Brazil and one in Nicaragua.

Table 3. Promising CIRAD/CIAT lines

COLOMBIA		
Hillsides	**Cross**	**CIRAD Parent**
CIRAD 445	CIAT/CIRAD	IRAT 104 and IRAT 216
CIRAD 446	CIRAD, selected at CIAT	IRAT 265
CIRAD 447	CIRAD, selected at CIAT	IRAT 265
PERU		
Slash and Burn	**Cross**	**CIRAD Parent**
CIRAD 409	CIAT/CIRAD	IRAT 124, IRAT 146 and IRAT 216
BRAZIL		
Upland savannas	**Cross**	**CIRAD Parent**
CNA 8812 or CT13226-11-1-M-BR1	CIAT/CIRAD and Embrapa	IRAT 13, IRAT 124 and IRAT 216
NICARAGUA		
Low altitude Hillsides	**Cross**	**Year**
CIRAD 301	CIRAD	IRAT 104

Conclusion

In Latin America, the impact of the rice genetic resources of CIRAD is high. Thirty-one (31) new lines were released, mainly attending the upland savannas, but also the irrigated and hillside rice ecosystems. Three (3) new lines (CIRAD/CIAT 4445, CIRAD/CIAT 446 y CIRAD/CIAT 447) were identified as very promising for the Colombian hillsides ecosystem.

The impact was very important in Brazil, Bolivia and Colombia, and is related to two principal factors. The first one is the rice strategy that CIRAD implemented in the 60's, when the institution started working in upland savannas breeding for West Africa. A great number of enhanced lines were developed to attend the main rice ecosystem present in the region

The second factor was the development of bilateral and international rice breeding projects in Latin America with EMBRAPA-Brazil and CIAT-Colombia respectively. Doing research together was fruitful.

Nevertheless, it is to point out that only few CIRAD varieties were repeatedly used as parent, what is of concern for the genetic base of the released varieties. Furthermore, the new commercial varieties were use as parents in new crosses leading to a certain degree of inbreeding. That is why, at the beginning of the 90's the CIAT rice project shifted its breeding strategy, phasing-out traditional crossbreeding, towards pre-breeding activities to enhance and broaden the genetic base of rice.

Future activities

- Follow-up of the use of CIRAD germplasm by LAC NARs
- Monitoring the release of new varieties

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II. Conventional and inter-specific crossbreeding of upland rice for the savannas ecosystem

Châtel, M.; Ospina, Y.; Rodriguez, F.; Lozano, V.H.; Guzmán, D.; Martinez, C.P.; Borrero, J.

Abstract

Conventional crossbreeding has permitted the development and release of modern upland lines in Bolivia, Brazil and Colombia. Since 1996, no new conventional *"Japonica" Oryza sativa* crosses were made. Though, as we have advanced segregating lines in the pipeline, we continue their evaluation and multiplication in Colombia for future shipping to LAC NARS.

The CIAT rice project now concentrate on broadening the genetic base of upland rice. Inter-specific crosses between *Oryza sativa* and the African cultivated *Oryza Glaberrima* as well as with wild relative species is one of the new breeding strategies used to achieve the objective.

Key words: Conventional crossbreeding, *Japonica Oryza sativa,* wild species, genetic base, Latin America and line release.

Introduction

Since 1996, no new conventional intra-specific *"Japonica" Oryza sativa* crosses were made for the development of segregating and fixed lines. Though, as we have advanced segregating lines in the pipeline, we continue their evaluation and multiplication in Colombia for release to Latin American and Caribbean (LAC) NARS partners.

The CIAT rice project now concentrates its activities on broadening the genetic base of upland rice. Inter-specific crosses of *Oryza sativa* by *O. glaberrima,* and *Oryza sativa* by wild relative species are a new breeding strategy to achieve this objective. We are evaluating and selecting progenies of inter-specific crosses developed by CIAT between *Oryza sativa*, *Oryza glaberrima* and *Oryza barthii*.

We also evaluate and select NERICA lines (NEw RICe for Africa) introduced from WARDA.

Material and Method

- **Source of germplasm:** A total of 751 lines was evaluated at La Libertad Experimental Station (LES) in Villavicencio- Meta, Colombia.
  - 30 lines from conventional crossbreeding *(Oryza sativa)*
  - 383 lines from inter-specific crosses: 45 from *Oryza sativa* by *O. glaberrima*, 24 from *Oryza sativa* by *O. barthii* and 314 from Caiapo/ *Oryza glaberrima*
  - 338 NERICA lines introduced from WARDA and selected by CIAT
- **Experimental design and traits:** The experimental design and the traits evaluated are the same that was reported last year.

Results and Discussion

- **Conventional crosses *(Oryza sativa)*:** 30 lines from conventional crossbreeding were evaluated and 27 selected and harvested in bulk. The seed was stored in cold chamber. This material will be shipped to LAC NARS upon request for local evaluation and selection, through the new germplasm nursery networks, (VioCIAT).

- Variety release

Bolivia. The Centro de Investigaciones Agricola Tropical of Santa Cruz de la Sierra (CIAT Santa Cruz) and the Japanese cooperation (JICA) are investing in the promotion and use by small farmers of new upland rice varieties. Through the project named "Distribución de Semilla de Arroz de alta Calidad para Pequeños Agricultores" (DISAPA) they organize on-field demonstration, participatory seed multiplication and diffusion of seeds of high quality.

In 2002, CIAT Santa Cruz released the line CIRAD357 as JACUÚ, for smallholders.

Brazil. During the period 1986 – 2002, sixteen (16) upland lines were released. Seven (7) of them come from the former EMBRAPA/CIRAD project, and six (6) from the CIAT/CIRAD project, two (2) are from CIRAD, and one (1) is from Embrapa Rice and Beans.

In 2002, the line CIAT, CT 11251-7-2-M-M-BR1 was released as TALENTO.

A new CIAT/CIRAD promising line, CT13226-11-1-M-BR1, is to be released next year

Colombia. During 2002, CIAT and CORPOICA worked together to release "Línea 30" or CIRAD 409. Trials of efficiency were set-up at the LES and on-farm in the Colombian savannas.

Out of Colombia, “Línea 30” shows good adaptation in Pucallpa Peru and is in the process of impact assessment for the slash and burn ecosystem (Efrain Leguia and Douglas White; CIAT Pucallpa-Peru, personal communication)

- Line registration

CIRAD has a mechanism by witch breeders of the institution can register promising genetic material. In 2001 we apply for the registration of the upland line CT 10069-27-3-1-4 developed by CIAT/CIRAD. The line is well adapted to the mid-altitude hillsides (up to 1450 masl) in inter-cropping with young coffee plantations. In 2002 it was registered as CIRAD 445 and genetic basic seed produced (30 individual panicle rows).

- **Inter-specific crosses**

From the 338 NERICA lines introduced from WARDA, 74 were selected (selection index: 22%)
From the 79 inter-specific progenies from CIAT (45 from *Oryza sativa* by *O. glaberrima*, 24 from *Oryza sativa* by *O. barthii)*, 10 were selected (selection intensity: 13%).
Results of the evaluation trial of the 314 lines from Caiapo/ *Oryza glaberrima* are not yet disponible.

Conclusion

The former conventional crossbreeding projects of CIAT and CIAT/CIRAD continue being a source for the release of new varieties. But the released lines present narrow genetic base witch needs to be broadened. Inter-specific crosses as well as population breeding through recurrent selection are new breeding methods in use by CIAT and CIAT/CIRAD to reach this objective.

Future activities

- Renewing the upland genetic resources stored at CIAT.
- Seed multiplication of the selected lines for evaluation and selection by LAC NARS.
- Implementation of the upland VioCIAT nurseries.

III. Rice(*Oryza sativa* L.) composite population breeding

Aerobic upland rice (*Oryza sativa* L., *Japonica* type) for the savannas ecosystem

Châtel, M.; Ospina, Y.; Rodriguez, F.; Lozano, V.H.; Guzmán, D.

Abstract

Since 1996, following CIAT’s recommendations, the CIAT/CIRAD projects have phased out Oryza *sativa* conventional crossbreeding activities and concentrate on broadening the genetic base of rice. The development and enhancement by recurrent selection of upland rice populations are the new breeding strategies to achieve the objective.
Using a recessive male-sterile gene (ms), the development of rice population was eased.
In Colombia, upland basic composite populations were enhanced using recurrent selection-breeding methods. At each enhancement cycle, fertile plants are selected and are the starting-point of progeny selection. In 2002, a total of 619 lines was evaluated. Advanced lines are evaluated in yield trials with CORPOICA.

Key words: Upland rice, composite populations, genetic base, male-sterile gene, enhancement, recurrent selection, and promising lines.

Introduction

The former conventional crossbreeding projects of CIAT and CIAT/CIRAD continue being a source for the release of new varieties. In Latin America, conventional upland crossbreeding projects have permitted the release of 33 varieties in different countries.

But the released lines present some narrow genetic base witch need to be broadened. Population breeding through recurrent selection is a new breeding method used by CIAT and CIAT/CIRAD to reach the objective of broadening the genetic base of upland rice.

Since 1996, the CIAT/CIRAD project concentrates in the development and enhancement of upland rice gene pools (*Oryza sativa* L., Japonica type).

By using a recessive male-sterile gene (ms) from a mutant of IR36, rice population development and enhancement was eased. Basic populations were enhanced using two recurrent selection-breeding methods.

Form the basic germplasm and at each enhancement cycle, fertile plants are selected and are the starting point for the generation of segregating progenies, then evaluated and selected by conventional pedigree method. The number of progenies developed from population breeding has steadily increased from 1997 on. In 2002, 642 lines were evaluated and selected.

We shipped basic and enhanced populations, as well as segregating lines to regional Latin American NARS (Bolivia, Brazil and Nicaragua) for local evaluation and selection. The most advanced lines were evaluated in yield trials in collaboration with CORPOICA in Colombia.

Material and Method

- **Material**

- **Source of germplasm**

The populations PCT-4 and PCT-11 developed in Colombia and CNA 7 from Brazil are the basic germplasm for recurrent selection breeding.

- **Development of segregating and fixed lines**

During the cycles of genetic enhancement as well as during the recombination phases, fertile plants are selected. They are the starting-point for segregating and future fixed progenies. In 2002, we evaluated and selected 642 progenies in different segregating generations (S_1 – S_9).

- **Yield Trials**

During the cropping season 2002, twenty-four (24) advanced lines and three (3) commercial check (Oryzica Sabana 6, Oryzica Sabana 10, y "Línea 30" -CIRAD 409-), were evaluated in preliminary yield trials with CORPOICA.

- **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.

Sowing composite populations: Rice populations are highly segregating for numerous traits and are made of fertile (Msms) and male-sterile plants (msms) allowing natural cross-pollination. Planting is made in individual hill plots facilitating the identification of male-sterile plants where recombination occurs. 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.

Recombining and multiplying composite populations: Grains produced by male-sterile plants are Msms and msms (pollen produced by fertile plants is ms or Ms and female organs of male-sterile plants are ms). Harvesting the male-sterile plants represents a new cycle of recombination as well as seed multiplication of the population.

Enhancing composite populations by recurrent selection: 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 methods where used: mass recurrent selection and S2 progenies evaluation.

- **Selecting fertile plants for line development**

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

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

- **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 La Libertad experimental station (LES) and on-farm, in collaboration with CORPOICA Regional 8. The experimental design was of randomized blocks with 3 replications.

Results and Discussion

- **Population breeding at La Libertad Experimental Station (LES)**

Population enhancement was made through recurrent selection. Two different methods were used. Mass recurrent selection on both sexes (before flowering) for resistance to total rice leaf blast and Hoja Blanca Virus and selection based on S_2 lines for main agronomic traits.

- **Shuttle Breeding between Colombia and Bolivia**

In Bolivia, 90% of rice production is practiced under favorable upland conditions, both by mechanized and manual cropping by large and smallholders respectively.

Through the years of joint germplasm evaluation, we noticed the excellent behavior and direct possible adaptation of the upland germplasm developed by CIAT/CIRAD. Everything tells us that the environmental conditions of Santa Cruz de la Sierra are very similar to those present in Colombia, unless the very acid soils. In that scope, and to attend the upland rice sector both in Bolivia and Colombia, we decided to start shuttle-breeding activities. These activities are eased because the cropping seasons are different in Bolivia (October-March) and in Colombia (April-September)

In 1999, after completing the first cycle of recurrent selection in Colombia, the composite populations PCT-4 and PCT 11 from CIAT/CIRAD and the population CNA-7 from EMBRAPA-Brazil where shipped to the "Centro de Investigación Agricola Tropical de Santa Cruz", (CIAT SZ) Bolivia for evaluation and selection.

- **Shuttle Breeding steps**

Bolivia CIAT SZ

- 1999. Introduction of composite populations
- Cropping season 1999-2000: Evaluation and characterization of the composite populations. Selection of fertile S_0 plants in each germplasm.
- Cropping season 2000-2001: Evaluation and selection of the S_1 progenies and shipping to Colombia of the seeds of the selected progenies.

Colombia CIAT Palmira

- 2001: Recombination of the selected progenies, obtaining the enhanced populations with a second cycle of recurrent selection. Seeds of the enhanced populations were shipped back to Bolivia. During the recombination cycle fertile plants were selected for evaluation and selection in Colombia.

Bolivia CIAT SZ

Cropping season 2001-2002: Sowing the enhanced populations and starting a new cycle of recurrent selection in Bolivia.

Colombia CIAT (LES)

Cropping season 2002: Sowing the enhanced populations and starting a new cycle of recurrent selection in Colombia.

- **Line development**

During the cropping season 2002, at LES, 642 lines were evaluated and 112 selected (selection index: 19%). In the early segregating progenies (S_1 – S_4) 145 individual plants were selected in 56 progenies. Sixty-five (65) selected advanced progenies (S_5 – S_9) were harvested in bulk

- Part of the most advanced selected lines will be shipped to the countries were the CIAT/CIRAD project have cooperators (Argentina, Bolivia, Brazil, Colombia, Cuba, Nicaragua – Honduras y Venezuela) for local evaluation and selection. This will be done through the new germplasm nursery networks, (VioCIAT).

- **Yield trials**

During the cropping season 2002, in collaboration with CORPOICA, yield trials of 24 advanced lines and 3 commercial checks (Oryzica Sabana 6, Oryzica Sabana 10, and "Línea 30"-CIRAD 409-) were set-up. The trial was conducted in 5 places, 2 at LES, and 3 on-farm under savanna condition. Results are not yet available but we are reporting the results of the two previous years.
The combined analysis of the years 2000 and 2001 at LES (Table 1.) shows that grain yields are between 2000 and 3488 kg/ha. The checks "Línea 30"-CIRAD 409-, Oryzica Sabana 6 y Oryzica Sabana 10 yielded 2931, 2633 and 2000 kg/ha respectively.
The line PCT-4\SA\1\1>975-M-2-M-3 showed excellent behavior, yielding 19, 32 and 74% more than "Linea 30" -CIRAD 409-, Oryzica Sabana 6 and Oryzica Sabana 10 respectively. Furthermore, it is as early as the earliest check "Linea 30"-CIRAD 409-. This is a confirmation that it is possible to breakdown the negative correlation generally observed between earliness and grain yield. From an other point of view, the line does not present annual yielding fluctuations, as it is the case for the checks, suggesting better yielding.
Twelve (12) lines show similar yielding potential as the best check "Linea30"-CIRAD 409-. These lines represent a diversified option for upland rice in the Colombian savannas and can contribute to diversify the genetic material for the producers.

Table 1. Promising line selected from the upland rice composite population PCT-4. LES, Villavicencio-Meta, Colombia 2000 and 2001

Promising line and Checks	Year and Yield (Kg/ha)	Flowering (days)

	2000	2001	Average	
PCT-4\SA\1\1* >975-M-2-M-3	3644	3333	3488	71
Línea 30 (CIRAD 409)	2332	3531	2931	71
Oryzica Sabana 6	2140	3126	2633	83
Oryzica Sabana 10	1240	2770	2000	89

* PCT-4\SA\1\1: Nomenclature for the population PCT-4. One cycle of recurrent selection (selection cycle for acid soil –SA--, followed bay a recombination cycle.

Regional networking activity

One of the activities of the CIAT/CIRAD project relates to the training of rice breeders in the use of recurrent selection and monitoring the progress made by regional LAC NARS.

- **Shuttle Breeding between Colombia and Bolivia**

This activity was already presented in this report.

- **National workshop in Cuba**

The "Instituto de Investigaciones de Arroz de Cuba" (IIA) and the CIAT/CIRAD project jointly organized a national workshop in June 2001 in Sancti-Spiritus-Cuba.

The main objective was to inform Cuban scientists about the rice recurrent selection activities in progress in Cuba, and to present the regional activities of the CIAT/CIRAD project.

- **International workshop in Bolivia**

CIAT SZ, DISAPA, CIAT/CIRAD and EMBRAPA Rice and Beans Center jointly organized the second international upland workshop in Santa Cruz de la Sierra-Bolivia (March 4-9, 2002).

The main objectives of the workshop were to:

- Promote the integration of the upland rice breeders of the region.
- Share experiences in the management of breeding populations and the development of fixed lines.
- Select at field condition segregating and fixed lines to be introduced in each respective country (much better than only shipping-out lines).
- Have the concept from the group about the outputs and results of the Bolivian upland rice project
- Know in a near future (next year) the behavior and adaptation of the selected lines in Bolivia.

Upland rice nurseries were set-up in the CIAT SZ experimental station of Saavedra and in smallholders farms in San Juan de Yapacani, to identify and discuss selection criteria, booth for the mechanized and manual upland rice ecosystem of Bolivia.

Fourteen (14) breeders representing Bolivia, Brazil, Colombia y Cuba attended the workshop; invited breeders from Argentina and Venezuela could not attend. Fourteen (14) technical presentations were made.

Going-on with these activities, the group decided to have the next workshop in 2004 in Cuba.

Conclusion

Three (3) upland rice composite populations are in the enhancement process by recurrent selection and represent a reservoir for line development.

Promising lines have been selected attending both, the mechanized upland rice ecosystem in Colombia and Bolivia and the manual ecosystem practiced by small-framers in Bolivia.

In Colombia after two years of evaluation, the line PCT-4\SA\1\1>975-M-2-M-3 show very promising results with higher grain yield than the best commercial check and the same earliness. Furthermore it presents a more stable yield potential than the checks.
The on-going networking activities aim at maintaining a unites group of upland rice breeders in Latin America and the Caribbean.

Future activities

- To continue the enhancement of upland rice composite populations.
- To confirm in Colombia the behavior of the best selected lines through collaboration with CORPOICA regional 8.
- To release in a near future new upland rice lines in the region.
- To follow-up regional network activities.
- To continue the shipping of segregating and fixed lines as well as enhanced composite populations to the cooperators of the CIAT/CIRAD project and also to Dr. Gilles Trouche responsible for the new collaborative CIAT/CIRAD project on participatory rice breeding in Central America.
- Implementation of the upland VioCIAT nurseries network.

❑ Irrigated lowland rice(*Oryza sativa* L., *Indica* and *Japonica* type)

Châtel, M.; Ospina, Y.; Martinez, C.P.; Guzmán, D.

Abstract

As for upland rice, the project concentrates on broadening the genetic base of lowland rice trough the development of lowland rice populations with broad genetic base and their enhancement through recurrent selection.
Basic populations were developed at CIAT and distributed to LAC NARS for evaluation. Site-specific *indica* and *japonica* populations for the tropics and temperate areas, respectively, were developed with NARS. They are the starting-point of rice recurrent selection projects.

Keywords: Lowland rice, rice populations, genetic base, male-sterile gene, enhancement, site-specific populations, and recurrent selection.

Introduction

Population Breeding for Lowland irrigated rice is made in close collaboration with LAC NARS and CIRAD in France.
The breeding population project started by introducing to Colombia, different gene pools and populations previously developed in Brazil by CIRAD/EMBRAPA –Rice and Beans Center, and CIRAD. New populations were created by CIAT/CIRAD to attend the different rice ecosystems presents in LAC (Tropics, sub-tropics and temperate climate).
From 1996, this basic germplasm was dispatched to our regional cooperators for local evaluation and characterization. The best adapted composite populations were the starting point of population breeding activities in different countries as well as the development of site-specific ones.
Following networking activities, the CIAT/CIRAD project and Fundación DANAC-Venezuela organized, in October 2001, the First International Workshop on rice recurrent selection for

irrigated rice. This year we started the organization of the III International Conference in rice population breeding to be held in May 2003 in Venezuela.
Activities presented here after were conducted at CIAT Palmira experimental station (PES). Population breeding activities directly conducted by NARS and monitored by the CIAT/CIRAD project are to be presented in a book to be published by CIAT/CIRAD (Colombia), EMBRAPA (Brazil), Fundación DANAC (Venezuela) and FAO, at the beginning of 2003 for the III International Conference

Materials and Method

- **Materials**

- **Basic populations:** In late 1996, the CIAT/CIRAD composite populations PCT-6, PCT-7, PCT-8 (*Indica* type) and GPIRAT-10 (*Japonica* type) were shipped to LAC NARS for local evaluation and characterization.
- **Site-specific populations:** Following the evaluation and characterization of the introduced germplasm, LAC breeders, in coordination with CIAT/CIRAD, started the creation of site-specific populations.
- **Development of segregating and fixed lines:** From the introduced and site-specific populations, LAC breeders started selecting S_0 fertile plants witches are the starting point for line development

- **Methods**

- **Site-specific populations:** Site-specific populations are created by the introduction of locally selected germplasm identified by NARS breeders into an introduced CIAT/CIRAD population considered as good genetic background and segregating for a male-sterile recessive gene.
- **Development of segregating and fixed lines:** Starting from selected S_0 fertile plants, the progenies are evaluated and selected by conventional pedigree method. Segregating progenies are evaluated and only fertile plants are selected to eliminate the male-sterile gene. The best-advanced fertile lines are tested in nurseries and then best promising lines in regional trials.

Results and Discussion

The results presented here after correspond to the activities conducted at CIAT-PES in collaboration with NARS breeders.

- **New site-specific populations**

- **Argentina (Sub-tropical rice ecosystem):** During 2000 and 2001, the site-specific population PARG-3 was synthesized by introducing in the CIAT/CIRAD population PCT-8 of six (6) parents identified and selected by the Argentinean breeders. The population was shipped to Argentina for evaluation and selection during the cropping season 2001/2002.
- **Chile (Temperate climate rice ecosystem):** The site-specific population PQUI-2 is being developed in Chile for cold temperature tolerance, yielding potential and grain quality. The source of adapted genetic and male-sterility background comes from the population PQUI-1 previously developed and selected in the country. Twelve (12) parents showing good adaptation to cold tolerance and being genetically divergent from the genetic constitution of PQUI-1 represent the new variability incorporated to PQUI-1. They come from the CIRAD cold tolerance project in Madagascar (5 parents), the Chilean breeding project (6 parents) and

IRRI (1 parent).The crosses between each one of the new parents and male-sterile plants of the population PQUI-1 were made in Chile, as well as the evaluation of the F_1 generation. Because of only one cropping season in Chile and for speeding-up the development process of the PQUI-2 population, in 2001, seeds of the F_2 generation were harvested in bulk and part of it was shipped to CIAT for recombination. The PQUI-2 recombined population will be shipped back to Chile for sowing during the cropping season 2002/2003.

- **Uruguay (Sub-tropical/temperate climate rice ecosystem):** Three (3) site-specific populations were developed at CIAT-PES: PURG-1 with round/medium grain type for rice exportations to the Asian market, PURG-2 with long-slender and high grain quality for the rice exportation to the Middle- East market and PURG-3 for long term population enhancement.
  (During the development of the populations PURG-1 y PURG-2, forty (40) fertile plants were selected for their evaluation to cold tolerance by the Fondo Latino Americano de Arroz de Riego-FLAR)
- **France and Chile (Temperate climate rice ecosystems):** In countries were rice productions and consumption are relatively low, market niches exist. It is important to diversify of different rice types for attracting potential new consumers. Market niches are also very attractive to the producers and the rice industry who both benefits of high aggregate value of the rice production and transformation. This is the case of aromatic rice in France, and anticipating would be the case in Chile, were the industry and some consumers are already looking for new rice types. Rice aroma is a very complex trait to deal with by conventional breeding because it involves a great number of major and minor genes. Population breeding using recurrent selection would be better adapted. It was decided to develop a new site-specific population to be enhanced both in France and Chile. As rice cropping season are inverted between France and Chile it would be possible to develop shuttle-breeding activities. Twenty-six (26) aromatic and non-aromatic parents were selected by CIRAD-France, and the population PQUI-1 from Chile was selected as good genetic and male-sterile background, well adapted to the rice temperate climate ecosystem. Individual crosses between each new source of variability and male-sterile plants of the population PQUI-1 were made in 2001 at CIAT-PES. The F_1 generation of each one of the twenty-six (26) crosses was sown and the F_2 seeds harvested separately. Part of the F_2 seeds of each individual cross was shipped to CIRAD-France for evaluation during the cropping season 2002 (April to September). At CIAT-PES, the other part of each individual F2 seed was bulked in equal proportion obtaining the basic population named PACQ-1. The basic population was sown to obtain the first cycle of recombination. From the basic recombined population the seed will split in three part. One part to be stored in the CIAT cold chamber, an other part to be shipped to Chile for its evaluation during the cropping season 2002/2003 (October to March), and finally a third part to be shipped to CIRAD-France for evaluation during the cropping season 2003.
- **Colombia:** Taking in account that the main objective of the CIAT rice project is to broaden the genetic base of rice, through different advanced breeding methods. It was decided to integrate two of them witch are the inter-specific crosses and recurrent population breeding. Two new populations were set-up by introducing seven (7) advanced inter-specific advanced lines (six from the cross *Oryza rufipogon*/BG90-2, and one from the cross *Oryza barthii*/Lemont) into the Venezuelan tropical site-specific population PFD-1 and the Argentinean sub-tropical site-specific population PARG-3. The new populations were named

PCTFD-20 and PCTARG-19, respectively. In relation to the already existing populations managed by CIAT/CIRAD and LAC NARS, the new germplasm integrates in its constitution a new type of genetic variability. The two new populations will be enhanced first in Colombia before being shipped to LAC NARS.

- **Development of segregating and fixed lines**

Each one of the LAC rice breeders involved in composite population breeding is very conscious that the finality of their work is the production of promising lines to be released as commercial varieties. The most advanced rice population breeding projects are in Brazil, Argentina, Chile, Cuba and Venezuela. Each one is evaluated and selected line gardens and regional trials set-up with promising lines extracted from the populations they are working with.

- **Brasil:** The collaborative project between Embrapa Arroz e Feijão (former CNPAF) and CIRAD-CA (former IRAT), developed in 1989 the lowland rice genetic pool CNA-IRAT 4. Breeding this genetic pool by two cycles of recurrent selection leads to the selection and evaluation of lines extracted from the enhanced germplasm by different rice research institutions in Brazil (National Network organized by Embrapa Rice and Beans).This work resulted in 2002 in the release of the line “Tio-Taka” by the “Empresa de Pesquisa Agropecuária e Extensão Rural” (EPAGRI), of the State of Santa Catarina.
  This is the first ever rice line released in Latin America coming from the enhancement of a gene pool by recurrent selection.
- Other important results are coming-out in different Latin American countries. This is the case of **Chile.** During the cropping season 2001/2002, there were 10 line gardens representing a total of 886 segregating and advanced lines from the population PQUI-1 in different cycles of enhancement. Seventeen (17) promising lines were evaluated with 3 commercial checks in a yield trial. The preliminary result of the trial show that 5 lines yielded more that the checks Oro and Diamante, and 3 are slightly yielding more than the best commercial variety Brillante.

Regional networking activity

One of the activities of the CIAT/CIRAD project relates to the training of rice breeders in the use of recurrent selection and monitoring the progress made by regional LAC NARS.

- **I International workshop on irrigated rice recurrent selection breeding**

The first international workshop was held in Venezuela during October 25-31, 2001 and was organized jointly by Fundación DANAC – Venezuela, CIAT/CIRAD and EMBRAPA. Rice breeders from Argentina, Brazil, Chile, Colombia, Cuba and Venezuela attended the event and 17 technical presentations were made and published in CD ROM format. The workshop was the forum where the progress in recurrent selection breeding in the different LAC countries was presented and discussed. It was also the place that permitted to develop new mechanisms of collaboration and information sharing between breeders.

- **III International conference on rice population breeding**

We are organizing jointly with Fundación DANAC–Venezuela, EMBRAPA and FAO, the third international conference to be held in Venezuela in May 2003. The first and second international conferences were held in Brazil in 1995 and 1999.
During 2002 we concentrate in the diffusion of the event to the scientific rice LAC community and in the elaboration and revision of the technical presentations, to be published in a book.

Conclusion

In different LAC countries, and for different rice ecosystems, rice composite population breeding is a reality and NARS breeders have a great compromise in their collaborative work with the CIAT/CIRAD project.
Two of the breeding strategies of the CIAT rice project were merged by the creation of new broad genetic base populations using inter-specific advanced lines.
Segregating and advanced lines are being evaluated and selected by each LAC rice program, and promising lines are coming-out

Future activities

- To finalize the creation of the new site-specific populations
- To follow-up supporting rice LAC breeders
- To ensure the development and selection of promising breeding lines and their release as commercial varieties by LAC rice breeders

IV. Producing upland rice with young coffee plantations in the Colombian hillsides

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Abstract
Production of upland rice in the hillsides of the Colombian coffee zone, is an option for both food security and land use management of young coffee plantation. To evaluate the effect of two cycles of rice cultivation on young coffee plantations, an experiment was conducted at the experimental stations La Catalina, Pereira – Risaralda, and Naranjal, Chinchiná - Caldas.
The treatments were conformed according to a factorial design with different rice densities and spatial arrangement of coffee. Coffee variety Colombia and upland rice line CT-10069-27-3-1-4 (CIRAD 445) were uses as crop species.
The results of inter-cropping upland rice with coffee indicate that coffee does not affect rice production. Average rice-paddy production varied between 3760 and 4736 Kg/ha, depending of the year and site of evaluation.
At Naranjal, rice does not affect the subsequent coffee productions, but it varies at La Catalina, according to coffee spatial arrangement.
The highest coffee production (Naranjal: 8253 and La Catalina: 7566 kg/ha of dry grain) was reached by using a rice-sowing density of 60 Kg/ha, distributed in 3 rows with spatial arrangement of coffee of 1,00x1,00 m.

Keywords: Upland rice, coffee, inter-cropping, hillsides

Introduction
In the Colombian coffee region, the production of staple food, except plantain, is not enough to reach self-sufficiency. Agronomic solutions were proposed, trying reverting the situation and to upgrade the livelihood of the coffee producers. Inter-cropping food crops with young coffee plantations can reduce food insecurity and coffee cost production, waiting for the first coffee harvest. It is also a way to better manage land use in the hillsides. The “Centro Nacional de Investigación de Café” CENICAFE set-up different experimental trials, inter-cropping food-crops like tomato, beans and maize with young coffee trees. Upland rice was for the first time

introduced in the Colombian hillsides in 1993. Experimental results of the adaptation of upland rice lead to the identification and selection of one upland savanna rice line adapted to the mid-altitude hillsides (up to 1425 m). Counting with adapted rice germplasm, it was decided to study the inter-cropping of upland rice and coffee to ensure the production of confident data to be shared with the scientific and development communities.

Material and Method

- **Material**

- **Localization:** The experiment was set-up in two experimental stations of CENICAFE: La Catalina, Pereira – Risaralda, at an altitude of 1310 m, and located at 4° 45´ North and 75° 44´ West, and Naranjal, Chinchiná, Caldas, at an altitude of 1425 m and located 4° 58¨ North and 75° 39¨ West.
- **Germplasm:** In 1993, upland rice was introduced for the very first time in the Colombian hillsides. Upland lines developed by the CIAT/CIRAD rice project for the Colombian savanna ecosystem were selected for earliness, because of vegetative and reproductive cycle elongation with cold temperature in altitude. They were evaluated in collaboration with CENICAFE during 1993 and 1994 (Moreno et al, 1996). The upland savanna rice line CT10069-27-3-1-4 (CIRAD 445) was selected for presenting good yielding ability and low spicklet sterility witch is an indirect information about cold tolerance. The coffee variety used was Colombia, for its high yielding potential and resistance to the coffee rust (*Hemileia vastatrix* Berk. y Br.).

- **Methods**

- **Experimental design:** The experiment was an augmented factorial design 3x3+1, with 10 treatments and three (3) sowing distances between coffee plants (1,00x1,00 m; 1,42x1,42 m and 2,00x1,00 m), three (3) rice sowing densities (60, 80 and 100 kg of seed /ha). For maintaining the same population (10.000 plants/ha) of coffee plants, only one plant was grown when spacing was 1x1m, and two plants for the spacing 1.42x1.42 and 2.00x1.00 m. The design was of complete blocks with five replications. Coffee spacing represented the principal plot and rice densities were the sub-plots.
- **Evaluation:** The evaluation was on rice paddy-grain production/ha and coffee fruit production later on transformed to dry coffee grain.
- **Sowing upland rice:** Rice was direct seeded by drilling seeds, in 3, 4 and 6 rows depending of the spatial arrangement of the coffee plants, 1,00x1,00 m, 1,42x1,42 m and 2,00x1,00 m respectively.
- **Crop management:** The management of the two crops was made according to their respective necessities and agronomic practices. The fertilization both for coffee and rice was made according to soil analyze and crop requirements. The first rice sowing was with minimum tillage just after the sowing of the coffee plants. The fertilization was 25 kg/ha of P at sowing and 80 kg/ha of N (a third at sowing, a third at tillering and the last third at flowering). Rice harvesting was manual, cutting the panicles and leaving the straws on field. Six month old coffee plants were sowed and the fertilization was 150, 200, 250 and 300 kg/ha of urea at 30 days, 5, 9 and 13 months respectively. After 18 month and at each 6 months, 700 kg/ha of the formula 17-6-18-2 were applied.

Results and Discussion

- **Upland-hillside rice production (Table1.)**

The results show that the upland-savanna rice line CT-10069-27-3-1-4 (CIRAD 445) confirm its good adaptation to the mid-altitude hillsides of the Colombian Coffee region. It is feasible to grow selected upland-savanna rice germplasm up to an altitude of 1450m.

- **La Catalina (1310 m):** Data analysis of the two years of experiment does not show any effect of coffee plantation on rice production. Furthermore rice-sowing density have no effect on rice production. The good vigor of the rice plants permitted good competition with coffee plants and rice sowing density of 60 Kg/ha is enough to reach good yields. These results show that it is perfectly possible to inter-crop rice with young coffee plantations during two cropping seasons. The accumulated paddy-rice production reached about 8,000 Kg /ha. By manual harvesting the rice panicles, and leaving the vegetal material on the ground leads to prevent soil erosion and high level of weed infestation.
- **Naranjal (1425 m):** In each spatial coffee arrangement, the rice sowing densities do not affect rice-paddy production. Nevertheless, they affected rice-paddy production at each rice-cropping season. During the cropping seasons 1996 and 1997, the best rice production, 4250 Kg/ha and 5712 Kg/ha, were with coffee sowed at 1,42x1,42m and 1,00x1,00m respectively. Independent of coffee spatial arrangements and rice sowing densities and number of rows, rice production was 26% higher during the cropping season 1997 than in 1996. The residual fertilization of the year 1996 is perhaps responsible of this difference in rice yield. In conclusion, and as well as in La Catalina, rice density of 60 kg/ha is enough, but the number of rice rows have to be no more than 3 to reach the best production during the second cropping season, with coffee spacing of 1,00mx1,00m

Table 1. Upland-hillside rice production in inter-cropping with young coffee plantations. La Catalina and Naranjal, 1996 and 1997 cropping seasons.

Coffee (10.000 plants/ha)	Upland-Hillside rice		Paddy-rice production (kg/ha)					
			La Catalina			Naranjal		
	Seed density (kg/ha)	Number of row	1996	1997	Average	1996	1997	Average
1,00x1,00m (One plant by site)	60	3	4275	3866	4070	3338	5931	4634
	80	3	4541	4100	4320	3256	5469	4362
	100	3	4728	4293	4510	3342	5736	4539
1,42x1,42m (Two plants by site)	60	4	4184	3768	3976	4158	4140	4149
	80	4	4285	3855	4070	4201	4769	4485
	100	4	4216	3796	4006	4389	4626	4507
2,00x1,00m (Two plants by site)	60	6	4542	4102	4322	3659	4283	3971
	80	6	3764	3354	3559	3562	4386	3974
	100	6	3694	3269	3481	3934	4549	4241
Average			4248	3822	4035	3760	4876	4318

- **Coffee production (Table 2.)**

In Colombia, (Mestre and Salazar, 1995) showed that coffee production when in nonoculture, is not affected by spatial arrangements nor by the number of plants by sowing site, when a density of 10,000 plants/ha is used.

In the experiments conducted in both sites, when inter-cropping coffee and upland-hillside rice, the coffee production depends on the spatial arrangement.

- **La Catalina:** The highest coffee production (average of 3 harvests: 7566 Kg/ha of dry grain) was with 1,00x1,00 m and one plant by site. Reduction of 30 and 25% of the production is observed when the spatial arrangements 1,42x1,42 m and 2,00x2,00 m and two plants by site, respectively. This can be explained because of the presence of more rice rows and subsequent competition with coffee. In some cases rice completely covered and shadowed the coffee plants. But this is manageable by reducing the number or rice rows what is not a problem for rice production, which as we have seen does not depend of sowing density or number of rows. Coffee production was higher in 1998 than during 1997 and 1999. This is due to the intrinsic behavior of coffee production witch is biennial with an alternate high and low production.

- **Naranjal:** As well as in La Catalina, the best coffee yield (average of 2 harvests: 8253 Kg/ha of dry grain) were scored in each one of the harvest with a spatial arrangement of 1,00x1,00 m and one plant by site. Reduction in coffee production observed with the coffee arrangements1,42x1,42 m and 2,00x2,00 m and two plants by site is explained by the same considerations than in La Catalina, and the solution is the same one. Coffee production was higher in 1999 and is because of the biannual production cycle of coffee.

Table 2. Coffee production in inter-cropping with upland-hillside rice. La Catalina, 1997, 1998 and 1999 and Naranjal, 1999 and 2000.

Coffee (10.000 plants/ha)	Upland-Hillside rice		Coffee dry grain production (kg/ha)						
			La Catalina				Naranjal		
	Seed density (kg/ha)	Number of row	1997	1998	1999	Average	1999	2000	Average
1,00x1,00m (One plant by site)	60	3	4940	11231	5668	7280	10031	7823	8927
	80	3	5953	10217	6650	7606	9994	5790	7892
	100	3	5981	10686	6770	7812	9271	6608	7940
1,42x1,42m (Two plants by site)	60	4	1681	3497	1210	2129	5762	4099	4930
	80	4	1506	4198	1333	2346	5396	3483	4439
	100	4	1932	4154	1177	2421	5220	3287	4253
2,00x1,00m (Two plants by site)	60	6	1461	3277	1249	1996	4752	2960	3856
	80	6	1303	3076	1153	1844	6770	3274	5022
	100	6	1401	3228	1082	1904	5863	3239	4551
Average			2906	5952	2921	3926	7266	4879	6072

Conclusion

Upland rice was first introduced to the Colombian coffee hillsides region in 1993. Never before rice was grown in these conditions. Different upland savannas rice lines from the CIAT/CIRAD project were evaluated and the line CT-10069-27-3-1-4 (CIRAD 445) was selected for its good adaptation (yield potential and tolerance to cold temperature) to mid-altitude conditions.

The results of the experiments of rice inter-cropping with coffee indicate that the average rice production is between 3760 and 4736 Kg/ha of paddy-rice, depending of the year and site of evaluation.

The highest production can be reached by using a sowing density of 60 Kg/ha of rice seed, distributed in 3 rows.

The highest coffee production, with an average of 8253 and 7566 kg/ha of dry coffee grain, was when coffee is planted at a spatial arrangement of 1,00x1,00 m and one plant per site, in Naranjal and La Catalina respectively

These results are confirming that when in association, the adaptation of spacial arrangements of the crops is important, to maximize the production of each one by minimizing competition effects.

Upland-hillside rice inter-cropped with young coffee trees permits an excellent production of this staple food and does not affect the subsequent coffee production. In that sense it is a reasonable option for increasing food security in the Colombian hillsides, and a sustainable way of producing coffee. Furthermore, selling surplus of production can improve the livelihood of the coffee producers.

Future activities

- To share the results with the Coffee producers community. Contact was already made with Dr. José María Astaiza, Executive Director of the Cauca Coffee Committee, who is to socialize the results with the staff Comity in August 2002.
- To officially release the upland rice line CT-10069-27-3-1-4 (CIRAD 445)

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