Annual Report 1994

Rice Program

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CIAT
Centro Internacional de Agricultura Tropical
International Center for Tropical Agriculture

CONTENTS

RICE PROGRAM ANNUAL REPORT 1994

Introduction and Overview

The rice program has been the smallest of CIAT's programs and in recent years experienced a significant reduction, when it went from 8 Senior Staff (SS) positions in 1990 to 6 SS in 1992 and to 3.7 SS by mid-1994: one irrigated rice geneticist, one upland rice geneticist, one plant pathologist and 0.7 of a plant physiologist. The program leader was under a fixed term, seven months contract. However, the program has strong technical support from CIAT's BRU and VRU while agronomic and systems research is maintained by collaboration mainly with the Tropical Lowlands Program. The program has made a substantial effort to maintain research activities at the high level of commitment to excellence that has characterized it from its origin when CIAT was created in 1967. The situation has been exhacerbated by termination of CRIN in 1992. Due to a funding crisis of the International Network for Genetic Evaluation of Rice for Latin America (INGER-LAC) since 1992, the rice program has also been in charge of maintaining, although at a restricted level, the network activities for the region, while stable funding is found in collaboration with IRRI.

The project approach, initiated in 1993, continues to be the format for the monitoring and evaluation of work progress which is jointly assessed on a continuos basis by project coordinators and the program leader.

The RP program focuses its work on trying to solve those technical aspects that can contribute to a sustainable rice production and where the regional program can have a comparative advantage versus other partners like IRRI and NARS of LAC. Most of the work is directed to shifting the yield frontier and increasing yield stability, while increasing the efficiency of input use and contributing to enhance the production base.

Tropical irrigated rice faces a yield barrier of about 9 metric tons/hectare (t/ha), although farm yields are still only half that level. Promising efforts are underway at IRRI to break this barrier through a more efficient plant type and raise yields by 20%. (It is likely that a similar proportionate gain would be realized on-farm even though the farm yield level *per se* is lower than the yield potential level). If successful, CIAT will quickly add the necessary pest resistance traits appropriate for Latin America and the Caribbean (LAC) to the IRRI germplasm base, so that LAC obtains the benefits as soon as Asia does. CIAT is also adopting a second approach to overcome the yield barrier, called "recurrent selection". This method has proven its worth in maize, delivering steady yield increases over the long term, so CIAT is adapting it to rice.

For upland rice, which accounts for about 30% of LAC production, CIAT has recently achieved an exciting breakthrough in the 4-ton yield barrier, raising it to 6 tons (50%). Average farm yields are expected to double, from 1.3 to 2.5 t/ha. Simultaneously, grain quality was improved in these varieties, to increase crop value by an estimated 20%.

Enormous impact is expected as these varieties reach the farm over the next 5 years. The list of achievements and impact over the past three decades explains why the annual rate of return of rice research investments by CIAT is around 70%:

- 98 varieties released in LAC since 1967 were based on CIAT germplasm and 36 were based on IRRI crosses of a total of 246 released varieties which are now grown over approximately 2.5 million ha., or 90% of LAC's irrigated rice area. There has been a progressive increased dependency of national programs of LAC on CIAT-made crosses as the source for new varieties (Table 1). The situation is more evident in Central America where, out of 10 varieties released in 1991-94, all of them were CIAT-made crosses. The Caribbean, on the other hand, shows a preoccupying situation: only 2 varieties were released in 1991-94, both of them in Guyana.
- The $2 million/year CIAT rice research effort has had a rate of return of about 70% per year. Benefits to society associated with the new rice technologies are about US$600 per year, with a third of them going to producres and the rest to consumers.
- Increased profits stimulated a 57% increase in the area sown to irrigated rice since 1967.
- Rice prices in real (inflation-adjusted) terms have declined by 40% since 1967.
- In reaction to lower prices, rice consumption in LAC increased by 50% since 1967, from 20 to 30 kg white (milled) rice per person per year.
- There is a higher yield potential (44% increase in on-farm yields for irrigated rice since 1967, and a near doubling of yield potential for upland rice).
- Resistance to blast and hoja blanca has improved.
- Training of regional scientists by CIAT, and the establishment of two networks (INGER-LAC, for germplasm and CRIN, for the Caribbean) has been crucial to the impact achieved, through strengthened national research capacity.

HIGHLIGHTS OF PIPELINE WORK

- ***Yield potential.*** For both irrigated and upland rice, recurrent selection populations are now being established to create basis for steady yield gains over the long term. CIAT's scientists visited IRRI to learn more about its new plant type and acquiring seed for testing and breeding for adaptation to specific LAC constraints (direct seasing and specific pests). An apomixis gene from the pasture grass *Brachiaria* will be cloned and attempts will be made to transfer it to rice.
- ***Nutrient efficiency (including water).*** Studies of root mechanisms are underway, to identify traits that can be selected to increase efficiency. The bases of acid tolerance, aluminum toxicity, phosphorous and silicon efficiency are being studied. Competition for water and other nutrient uses are being studied in collaboration with EMBRAPA, Brazil.

- ***Weeds.*** Three mechanisms through which rice varieties might enhance other interventions to achieve better weed control while reducing herbicide dependence are being explored: enhancing rice capacity to compete with weeds by identifying traits for competitiveness, and studying the trade-offs between competitiviness and productivity; anaerobic seeding tolerance (building on IRRI work), which is the ability of rice to germinate and establish through a weed-smothering water layer; early vigor, which can shade out weeds; and allelopathy (building on IRRI and USDA work), or the production of weed-inhibiting chemicals by rice roots.
- ***Blast.*** A better understanding of the relationship between genetic families of the fungus identified by using DNA fingerprintings and virulence/avirulence factors specific to each family is allowing rice breeders and pathologists to identify resistance gene combinations to which corresponding virulence gene combinations are absent in the pathogen, therefore, excluding possible compatible interactions between the pathogen and the rice plant. This should increase the effectiveness in more stable resistance overtime in farmer's fields. Efforts are being made to extend these studies to the LAC rice growing countries.
- ***Hoja blanca (RHBV) and its vector, Tagosodes Oryzicolus.*** The available resistance to each is based on a single gene. Genetic transformation for resistance to RHBV is being attempted, to create additional novel sources of resistance to safeguard against possible future breakdowns of the present resistance.

On the institutional side, a breakthrough was accomplished by the program during 1994, when efforts to consolidate the Latin American Fund for Irrigated Rice Research (FLAR), based on private, semiprivate and public contributions from participating countries of LAC, led to the official creation of FLAR early in 1995 by four countries (Brazil, Colombia, Uruguay and Venezuela) and two international institutions (IICA and CIAT). The Fund constitutes a unique effort by the countries of LAC to undertake the responsibility and the control of an irrigated rice research agenda for the region, in collaboration with CIAT and other international institutions like IICA and IRRI.

Rice research has been very dynamic in LAC, with both the problems and the methodologies having evolved rapidly. The continuous delivery of new varieties and technologies has been made possible by a solid partnership with upstream research centers (like IRRI) and national programs in the region. The impressive impact achieved by them can be found in better economic opportunities for rice farmers throughout LAC, an increased importance of rice as a food staple in the region, stronger and better articulated institutions both of private and public nature and an enhanced political position of the cereal in most countries. But the challenge continues. The rice program believes that it is possible to continue to achieve scientific breakthroughs in the search for higher productivity and efficiency while increasing its sustainability. Our answer partially lies in a new interinstitutional arrangement where those that share our goals and have been the direct benefitiaries of research will take on a fully participatory approach to generate rice science and disseminate knowledge in LAC. The results presented in this Annual Report provide a detailed account of how our activities have been targeted to meet the challenge.

Luis Roberto Sanint
Rice Program Leader

Table 1. Rice varieties released in Latin America and the Caribbean by origin.

Sub-region and Country	1970-1980						1981-1990						1991-1994						TOTAL					
	Total						Total						Total											
	Released	Local	IRRI	CT/P*	Others	% CT	Released	Local	IRRI	CT/P	Others	% CT	Released	Local	IRRI	CT/P	Others	% CT	Released	Local	IRRI	CT/P	Others	% CT
Caribbean																								
Belize							1			1		100%							1			1		100%
Dom.Rep	5	4	1			0%	4	2	1	1		25%							9	6	2	1		11%
Guyana	2	1	1			0%							2		1	1		50%	4	1	2	1		25%
Suriname	11	11				0%	1	1				0%							12	12				0%
Subtotal	*18*	*16*	*2*			*0%*	*6*	*3*	*1*	*2*		*33%*	*2*		*1*	*1*		*50%*	*26*	19	4	*3*		*12%*
Mexico	22	14	8			0%	11	5	2	2	2	18%	3	2		1		33%	36	21	10	3	2	8%
Central America																								
Costa Rica	3		1	2		67%	2			2		100%	4			4		100%	9		1	8		89%
El Salvador							4			4		100%							4			4		100%
Guatemala	2			2		100%	5			4	1	80%							7			6	1	86%
Honduras							4			4		100%	1			1		100%	5			5		100%
Nicaragua	1		1			0%	1			1		100%	3			3		100%	5		1	4		80%
Panama	2	2				0%	4	1		3		75%	2			2		100%	8	3		5		63%
Subtotal	*8*	*2*	*2*	*4*		*50%*	*20*	*1*		*18*	*1*	*90%*	*10*			*10*		*100%*	*38*	3	2	*32*	*1*	*84%*
Tropical Brazil	4	4				0%	30	13	2	11	4	37%	18	10		6	2	33%	52	27	2	17	6	33%
Temperate Brazil	11	3	4	4		36%	12	5	1	4	2	33%	1	1				0%	24	9	5	8	2	33%
Andean Countries																								
Bolivia							2		1	1		50%	4			3	1	75%	6		1	4	1	67%
Colombia	8		1	6	1	75%	6			6		100%	5			4	1	80%	19		1	16	2	84%
Ecuador	4		2	2		50%	2		1	1		50%	1			1		100%	7		3	4		57%
Perù	4	1	3			0%	9	5	1	3		33%	2	2				0%	15	8	4	3		20%
Venezuela	1			1		100%	4			2	2	50%	2			2		100%	7			5	2	71%
Subtotal	*17*	*1*	*6*	*9*	*1*	*53%*	*23*	*5*	*3*	*13*	*2*	*57%*	*14*	*2*		*10*	*2*	*71%*	*54*	8	9	*32*	5	*59%*
Temperate South America																								
Argentina							2	2				0%							2	2				0%
Chile	3	3				0%							1			1		100%	4	3		1		25%
Paraguay	1			1		100%	3			1	2	33%							4			2	2	50%
Uruguay							4	4				0%	2	2				0%	6	6				0%
Subtotal	*4*	*3*		*1*		*25%*	*9*	*6*		*1*	*2*	*11%*	*3*	*2*		*1*		*33%*	*16*	11		*3*	2	*19%*
TOTAL	**84**	**43**	**22**	**18**	**1**	**21%**	**111**	**38**	**9**	**51**	**13**	**46%**	**51**	**17**	**1**	**29**	**4**	**57%**	**246**	**98**	**32**	**98**	**18**	**40%**

* Varieties resulting from crosses made at CIAT.

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07 JUL. 1995

I. PROJECT 1
IMPROVED LOWLAND RICE GENE POOLS

A. ACTIVITY RL01: LATIN AMERICAN IRRIGATED RICE PARTNERSHIP INITIATIVE, FLAR

Abstract. A watershed event during 1994 was the effort to create an association of private and public-sector rice institutions, farmer cooperatives and industries to fund international irrigated rice research. Subsequently (in early 1995), the Fondo Latinoamericano de Arroz de Riego became a reality, the first such organization in the world, as far as we are aware. It should place Latin American rice improvement on a more sustainable long-term path, since the benefits derived from research will now feed the research itself, as direct benefiaciaries take its control and responsibility. CIAT is one of six members (along with Brazil, Colombia, Uruguay, Venezuela and IICA) that pledged a total of US$315,000 for 1995. The initial funding commitment is for three years. CIAT was instrumental in coordinating the process that gave life to FLAR and gives the Fund the reliability and credibility needed for such an international effort.

Rationale/Justification

Past accomplishments. Significant advances in rice production have been made over the past three decades in Latin America and the Caribbean (LAC). About 220 new rice varieties were released for flooded environments, with 40% coming from crosses made at CIAT, 13% at IRRI while almost all of the rest has parentage from IARC's progenitors. Modern semidwarf varieties now account for more than 90 percent of all flooded rice production, itself representing 70 percent of total rice production in the Region. Average yields in flooded areas have risen from 3.0 tons per hectare in the mid-1960s to 4.5 t/ha in 1990; and total rice production doubled between 1967 and 1990, making the Region largely self-sufficient in rice. With rice prices falling by 40 percent in real terms over the period, consumers have benefitted greatly, rice is well established as a "wage good", and the crop has become the most important source of calories and proteins for that 20 percent of the Region's population with lowest incomes.

Central to these accomplishments have been:

- a linkage by the Region through CIAT to the world's premier source of rice germplasm (IRRI);
- the development of a strong, regionally relevant rice improvement program through a productive partnership of CIAT, Fedearroz, and ICA in Colombia; and
- excellent linkages between CIAT's regional rice program and national programs and producers in major rice producing countries of LAC.

While the upstream linkage to IRRI was a valuable component of this three-part improvement model, high quality downstream activities at the country level, frequently involving cooperation between public programs of research and extension with private producer organizations, as in the case of Colombia, Brazil, Venezuela and Uruguay were key to locally relevant adaptive efforts which accelerated and expanded the spread of improved germplams, complementary cultural practices, and related institutional and policy developments. Even though the investment commitments made by the private and public sectors all along the way over the past two decades were of major proportions, handsome (even unprecedented) returns have been gaines- between 60 and 80 percent annually on each U>S. dollar invested.

The Challenge

The past two decades have resulted in strong national rice improvement programs, high-yielding rice varieties on farmers' fields, and networks of germplasm improvement and related information linked, via CIAT, to the premier upstream research resource, IRRI.

Building on this model and stock of capital for sustained progress while assuring its continued dedication to the tasks ahead is the challenge for FLAR. For this purpose, the Fund appears to be a viable alternative both by reason of several emerging constraints and opportunities.

First, the maturity and high level of development of national capacities for rice improvement in LAC impose a more important role and responsibility than in the past on national organizations in determining the direction and conduct of future rice improvement efforts.

Second, with large returns currently being enjoyed from rice improvement efforts, those organizations that paid for programs of the past are logically expecting that mechanisms can be devised in the future to capture and turn some of those returns to the long-run maintenance of needed programs.

Third, given the "opening of the economies" —a process whose momentum is likely to continue to build in the future— it is well known that the patterns of demand for new technologies of all kinds will change, the quantities demanded of them will increase and the need to participate in economic blocks will also become more pressing. Rice producers and improvement programs will be especially challenged by these changes.

Fourth, the rapid technological advances in the rest of the world imply that countries of LAC must find ways to keep in touch with other regions by maintaining strong linkages to foreign sources of technology. The mechanism of the past has proved to be efficient in avoiding duplication of efforts, using the specialization of tasks, achieving economies of improved germplasm, complementary cultural practices, and related institutional and policy developments. Even though the investment commitments made by the private scale and providing a fully participatory research apparatus. In this sense, the new effort must be based in the principle of cooperation and efficiency in research while providing stability to the regional research system.

In short, while building on accomplishments of the past, future rice improvement efforts will need to be organized to address the following four challenges:

- fully participatory, cross-country management;
- mechanisms for stable self-financing;
- rapid response and flexibility to adapt to market-led developments; and
- new upstream demand and consumer preference requirements.

The Mechanism

The Fund constitutes a mechanism that permits stakeholders to participate in and shape the future of the new activities for rice improvement in the Americas, with voting power that is equal for all partners but where short and long term benefits are proportionate to their stakes. A steering committee and a technical commission offer best prospects for ensuring a match between a rapidly changing external environment with the internal constraints and opportunities of the organization, through a shared vision of all partners that is translated into mutually agreed strategies and action plans.

It is a self-financing, not-for-profit fund. The nature of public good is maintained, since most resources being pledged have semi-public origins.

The vision, or overarching goal, of the Fund is widely shared, simple, and easily understood: to assume the control and responsibility of irrigated rice research in the region, provide a stable framework and make it available to LAC countries as a public good. Support for development of a highly competitive rice economy in LAC describes the participants' goal: one which secures sufficient rice to meet domestic consumers' needs at minimum cost, while maintaining a rice sector that is profitable, competitive, efficient and that does not harm the environment. Progress against that goal would be measured by higher yields, new varieties, lower unit costs, more rational pesticide use and decreasing relative prices to consumers, among other indicators.

As stated in the heads of agreement, the mission, objectives and strategies are:

Mission of FLAR

To carry out activities in countries of Latin America and the Caribbean (LAC), towards a sustainable development of the irrigated rice sector, so as to make it competitive, profitable and efficient, while protecting the environment, to achieve lower unit costs of production and, consequently, more attractive relative rice prices to the consumer.

Objectives of FLAR

To fulfill its mission, the Fund aims to:

a. Create a permanent forum for LAC, where information on the commercial needs and opportunities of member countries is permanently updated.

b. Increase sustainable rice production (keeping in mind efficiency, equity, and environment) in terms of:
   - greater stability, with enhanced genetic diversity,
   - increased profitability, with reduced unit costs,
   - greater technical and economic efficiency,
   - more attractive prices for the consumer,
   - more competitive in the context of an open economy, and
   - no environmental risks.

c. Assume a commodity approach by program in areas of common interest to all Fund participants:
  - work not only with germplasm but with the entire system, including crop management, postharvest issues, alternative uses, quality, etc.
  - bring into the picture markets, consumption issues, etc.

d. Focus research on irrigated rice:
  - defined as rice for which water use in flooded conditions (anaerobic) is controlled,
  - where the greatest efficiency of production is feasible, and
  - where producers are commercial, whether large- or small-scale.

Strategies to Achieve Objectives

To achieve its objectives, FLAR will follow these strategies:

a. Identify and develop practical projects and activities applicable to its mission. A well rounded research agenda will have to include:
  - Germplasm: continued, wide access by the Americas to the world's best materials and active exchange with all regions of the world;
  - Breeding: productivity-increasing, regionally relevant varietal improvement to secure a continuing stream of new varieties;
  - Crop management: integrated approach for a more rational use of inputs, to achieve more efficiency, lower unit costs and less risk to the environment;
  - Post harvest: high payoff market intelligence and business development which identify and exploit trends in (and the requirements of) traditional and new markets and uses; and
  - Institutions: viable, self-governed national organizations for cost-effective rice improvement, promotion, and technology transfer.

b. Obtain sufficient and stable financing on behalf of participating countries and institutions. Each country will be responsible for the internal mechanisms of capturing funds and of establishing legal commitments.

c. Obtain financial resources from donors interested in promoting activities congruent with the Fund's mission.

d. Attract the participation of all LAC countries. Each member country, in turn, will search for mechanisms to strengthen the participation of private and public institutions.

e Identify sources of rice technology and information, both in LAC and in other countries, and search for exchange mechanisms.

f. Identify and assume common positions regarding intellectual property rights on products and materials resulting from research carried out by the Fund, in consonance with the laws of each country member.

g. Facilitate training and communications with nonmember institutions.

The Role of CIAT

CIAT has been instrumental in coordinating the process that gave life to FLAR. It was clear that the Center has a great deal of credibility among regional rice institutions and, together with IRRI, is seen as a fundamental piece in the irrigated rice research structure. For the stability of FLAR, CIAT's participation is basic.

First, and more importantly, CIAT's participation gives FLAR the reliability and credibility needed for such international effort.

Second, it can also provide the institutional mechanisms to gather the resources. The Fund has been created through bilateral agreements between each institution representing a participating country and CIAT. But the Fund does not have legal status. Once the Fund is created, CIAT makes it legally viable at the international level by contracting, buying, selling, etc. of goods and services in the name of FLAR.

Third, CIAT will house some of FLAR's scientists at headquarters and will also facilitate, at a charge, the use of infrastructure and know-how for germplasm exchange, breeding activities and secretariat tasks (monitoring flow of funds, accounting, etc.).

The Participants

Early in 1994, CIAT coordinated the process to create a mechanism to support irrigated rice research activities funded by the private sector of LAC. Four countries showed their firm commitment from the beginning tp bring FLAR into existance: Brazil, Colombia, Uruguay and Venezuela. In these countries, unions between public programs of research and extension with private producer organizations have been successful and are well consolidated. Another institution, IICA, also decided to join the effort. These were the founding participants of the Fund.

There is consensus among founding participants that the financial contribution to the Fund should be related to the amount of rice produced by each country member but also that short and long term benefits should be proportionate to their stakes.

Contributions were set as follows:

- A fixed amount of US$20,000 per year of participation
- A variable contribution correlated to paddy rice production: for each 400,000 Metric Tons, the representative institution from the country will pay US$5,000 per year of participation.

Resources pledged for 1995 are as follow:

Brazil	US$70,000	
Colombia	US$40,000	
Uruguay	US$30,000	
Venezuela	US$30,000	
CIAT	US$40,000	plus half time of the RP leader (some US$55,000)
IICA	US$50,000	
Total yearly pledges	US$315,000	

Other countries were directly visited during the process, where the rice sector is relatively well organized and there is an important public effort being supported by rice producers: Argentina, Ecuador and Dominican Republic. These countries are almost ready to join, but could not make the definite commitment this past January 16, when the Agreement of Acceptance for membership in FLAR was signed. The Dominican Republic was even represented in the signature. The steering committee decided to allow until the end of February for additional participants to pledge resources as founding members with full representation in the committees during 1995. Along with them, Costa Rica and Guyana received relevant material.

Benefitiaries from FLAR's Activities

FLAR is based on the principle that all founding partners participate in the decision making process with equal voting power. The activities promoted and executed by the Fund will be of common interest and, therefore, decisions should be reached by consensus. If consensus is not reached, there are clear clauses about quorum and conditions to decide by the vote of a majority.

However, the contributions of each country is correlated with its ability to pay: higher rice production implies higher royalties and benefits and therefore, higher contributions. It was also agreed that those that pay more can also participate more in FLAR's activities. In each project, the amount to be distributed to in-country activities will be proportional to the contribution of each country.

With respect to intellectual property rights, a clause was included in the Heads of Agreement, by which participants will treat FLAR's products as public goods. A given country can, subject to its own internal laws, protect products within its legal boundaries (including custom unions) and make them the subject of royalties, but that product must remain freely available to FLAR and/or to other countries of the world.

Next Steps

Non-member countries. High priority has been placed in continuing informal consultations with representatives of the rice industry in the non-participating countries including representatives of national programs of agricultural research, seed producers, associations of rice producers and with IRRI to check the provisions of the Heads of Agreement already approved by founding participants and secure their membership in FLAR. To this end, CIAT's scientists will participate in a Caribbean Rice Workshop, where the mechanism will be discussed with representatives from the region to seek their participation. Later in the year, Central American countries will also be visited with the same purpose.

Other international institutions. Its participation is also seen as very important. Instituions like IRRI, CIRAD, IIMI, etc. can bring their own expertise into the group and contribute to maintain a balance of activities towards all countries of the region.

"Technical workplan". This will be developed with input from researchers that are members of the technical commission. That meeting was set for March 11-14, 1995, at Porto Alegre, Brazil. The project will be finalized and approved by the Steering Committee, when will be ready for submittal to the donor community. The project will be targeted to the Interamerican Development Bank.

The main aspects of the technical agenda include research, extension and/or training in topics such as:

- Securing access to the world's elite germplasm, through INGER-LAC and other complementary mechanisms.
- Maintaining a well focussed breeding effort to characterize progenitors and develop new lines with higher and more stable yields.
- Improving crop management through sound research and extension in Integrated Pest Management projects.
- Optimizing the flow of knowledge and technologies generated by CIAT in its biotechnology unit in disease control (mainly blast).
- Conduct market intelligence and business development activities in traditional and new market opportunities for member countries.

Hiring a breeder. FLAR has advertized the position to hire a breeder that will be based at CIAT's headquarters in Palmira.

Breeders' workshop at CIAT. Early in the second semester of 1995, FLAR, together with INGER-LAC and with CIAT's Rice program, will organize a rice breeders' workshop in Palmira, where elite germplasm, mainly of interest to FLAR members, will be evaluated. Lines from IRRI's new plant type will also be displayed. Breeders from the region will assist together with some experienced consultants that will be hired to express their views

Contact potential donors. They will be identified to promote a project where the current Fund's resources will be used as seed capital, or collateral, for additional funds in the ratio of 1:2 from Fund pledges to donor resources. The project's duration may be longer than three years, in which case, a unanimous support from all participants must be reached to extend the Fund's life.

Information dissemination. The role of FLAR as a hub for information gathering and dissemination is also crucial. FLAR constitutes a rice forum for the region. In that sense, it has to contribute to organize meetings, workshops, etc. and will have its own newsletter, where business information, market developments and rice related news will be spread to participating members.

FLAR and Nonmember Countries of LAC

Membership has its benefits. While the products of FLAR will be public, the decision making process will certainly be biased by the needs and objectives of participating countries. Some projects, such as INGER-LAC, will have a regionwide coverage and participation, but most of them will be executed, to a large extent, by participating countries. Information sharing is mainly designed to for the network of participants.

A critical issue is how to achieve balance in the region, to ensure that strategic projects that are not attractive to the participants but are important to society at large, can be addressed. Another critical issue is how to maintain a balance of activities that alleviates the bias against nonmember countries that are the smaller and/or poorer in the region. These questions are typical of any new initiative of this kind. The international institutions that particiapte in FLAR can play an important role in this regard by monitoring these issues and helping to make FLAR more participatory and meaningful for the region at large.

Chronology of the Process

In its extraordinary meeting the first week of December, 1993 CIAT's Board decided to discontinue funding for irrigated rice breeding after 31 December 1994, and advised the Institute to seek a mechanism for the support of international irrigated rice research through contributions from regional, mainly private sector rice entities. In a CIAT Management Committee meeting on December 6 and in a CIAT-wide Staff meeting on December 7, Dr. Nores announced that this would be one of his highest priorities for 1994, and it would be the highest priority for Dr. Scowcroft.

The news of the Board's decision was delivered to Colombian collaborators by Dr. Nores to a joint meeting with FEDEARROZ and ICA on 14 December 1993. They had deep concerns along the following lines:

a. Why was irrigated rice cut, when it was a higher priority than savanna rice for some Colombian institutions?

b. Why was prior consultation not made with these partners of 25 years?

c. Instead of cutting irrigated rice, why not reduce budgets to other CIAT crops of less importance to the commercial sector in Colombia and LAC?

d. Why should CIAT support continue for Africa when IRRI has cut support for LAC?

Clearly, a new initiative would have to deal with a number of concerns like these from the potential partners across LAC, who in fact had a long history of reliance on CIAT and now felt somewhat abandoned.

The primary outcome of that meeting included a decision to hold a 1-2 day meeting at CIAT including CIAT, ICA and FEDEARROZ, to define a 5-year project to carry on the irrigated rice work. A consultant could be hired to write the project, hopefully to be submitted by late June. It would request bridging support for the first 18 months (from IDB, UNDP, RF or others) to give time for the process of bringing in contributions from the region-wide rice sector. It was hoped that Colombian backing could be parlayed into Andean support, which in turn could rally wider LAC support at the upcoming LAC Rice Conference in March. Dr. Nores instructed Dr. Habich to coordinate this inter-institutional initiative.

Following up on this, on 16 December Dr. Habich convened an internal CIAT meeting (GH, MW, JC) to formulate a strategy for the 2-day meeting, and decided to contract Dr. Luis Sanint to help organize the meeting and write the project document.

The 2-day meeting was held on 12-13 January at CIAT. It included representatives from FEDEARROZ (NG, DM), ICA (RA, DL, EG) and CIAT (GH, WS, MW, LS, CM, AF). First, they aired many of the same concerns as expressed in the meeting with Dr. Nores in December, plus a new one - the fear that a campaign for funding of international rice research would compete with funding of national research systems. This concern was later echoed in other countries. Nevertheless, the consensus was that the group had no alternative but to try and make it work.

The main discussions concerned a) a mechanism for gathering funds, and b) the research priorities that would to be addressed. On the mechanism issue, the idea of a formal Partnership was presented by Dr. Scowcroft, based on his experience in forming such a type of association for malting barley improvement in Australia. The Partnership is a legal entity existing separately from any of the existing collaborating instututions, with its own Board of Directors, budget and facilities (contributed by the partners). The Directors jointly decide the priorities, policies and procedures, and monitor progress. They also decide on the distribution of benefits, eg. the disposal of intellectual property rights. This in particular was a sensitive issue for CIAT (in fact, brought up with special concern during the External Program & Management Review team later in the year). However it had to be faced. In the Australian case, the Partnership had reserved varietal protection rights for just two years, then released them into the public domain. After discussion, both ICA and FEDEARROZ representatives expressed support for this type of mechanism, and agreed to help bring in support from other Andean country institutions, in Ecuador and Venezuela, before the March Rice Conference.

On the subject of research priorities, a major concern raised in the meeting was that the international mechanism not duplicate national efforts. Towards this end, a group discussion identified the following general areas where an international mechanism could make a unique contribution:

Internationality (ability to cross borders, to deliver region-wide benefits)

Economies of scale for costly, strategic research

Synergy (share and build upon different countries' experiences)

Strategic perspective (less bound by short-term objectives)

Convenor/catalyst (would have high visibility and influence)

With these in mind, proposed goals of the Partnership were delineated: To develop technologies and policies for more sustainable, stable, technically-efficient, profitable and environmentally-friendly rice production, delivering lower rice prices to consumers, and increasing LAC's competitiveness against other global sources of rice.

It was also confirmed that the Partnership would work on irrigated rice only. It would take a commodity approach, i.e. it would look at the whole crop system, not just germplasm. The other aspects could include agronomic, postharvest, economic, marketing and consumer issues. Four general categories of work were identified: germplasm, production systems, information/technology transfer, and public relations. Following discussions, top priorities were assigned to the following tasks:

- Establishment of the partnership, especially fundraising
- Regional rice breeding
- INGER-LAC network
- Soil-water management
- Prioritization and impact assessment
- Publications and training

On Jan. 26, Dr. Nores sent a long letter (drafted by MW) to Dr. Lampe, IRRI DG to explain the Board decision and the Partnership initiative. Responding on 21 February, Dr. Lampe expressed sorrow but understood the rationale behind these events. He indicated support in principle for CIAT's effort to seek support from the private sector and expressed a wish to remain informed.

The consultant, Dr. Sanint proceeded to Cúcuta on Feb. 8 with NG of FEDEARROZ to discuss the initiative with Venezuelan institutions, meeting with representatives from the Consejo Consultivo Nacional del Arroz del Venezuela, Asoportuguesa, and Aproscello. The Venezuelans placed a high priority on a breeding position and the INGER network, and suggested that the inter-institutional mechanism could be relatively simple, basically a funds-collecting entity. Membership could consist of an entrance fee, plus an annual contribution.

Another visit was made by Dr. Sanint to southern Brazil, Uruguay and the Dominican Republic during the first week of March. The Partnership idea was presented and well received in all three countries. Southern Brazil and Uruguay saw the existing proposal as too "tropicalized", and urged more consideration of temperate-zone needs. The intention to follow it up during the Rice Conference was agreed upon.

During the IX Rice Conference for Latin America and the Caribbean, a meeting was organized by Dr. Sanint and held on March 25 with representation of Argentina (A. Livore), Brazil (E. Flores and M. Rocha), Colombia (N. Gutiérrez), Uruguay (C. Mas), Venezuela (M. Saldivia), IICA (E. Moscardi), IRRI (G. Khush) and CIAT (GH, MW, LS). A general discussion raised a number of key issues. As this was the first time both tropical and temperate countries had gathered to discuss the subject at the same time and place, the differences in their priorities became apparent. The importance of INGER to the tropical countries (mentioned above for Venezuela) was not equally so to the temperate ones, because the tropical germplasm emphasized by the network was not well-enough adapted to the Southern Cone. The temperate countries, having in general stronger national breeding programs, could handle their own finished-variety breeding, and placed a higher priority for the international mechanism on more strategic research on novel traits (such as cold tolerance and sheath blight).

So that they could effectively convince their own constituencies of the importance of the international mechanism, the participants felt that a careful assessment of priorities would be necessary (needs assessment). It was agreed to hire a consultant (F. Cuevas) for this purpose, with $5,000 support from IICA. The needs assessment would then be used to develop a proposal to the region.

The meeting participants also expressed a preference for a simpler mechanism than the formal, legal Partnership. Following on the earlier indication of Venezuela, the concept of a simple Fund began to emerge as the preferred mechanism of the initiative, at least in its start-up phase. This could follow in general the example of the sugarcane industry. Sugarcane growers and processors associations from around the world (both developed and developing countries) pool funds for biotechnology research, as explained by Dr. James Cock in a meeting with MW.

Also at the IX Rice Conference, in a special plenary session discussing institutional change in rice research, the initiative was explained by Dr. M. Winslow, in substitution for Dr. Scowcroft. A paper on the subject is being published in the Proceedings. Dr. Habich also addressed the plenary session on the Board's decision and changes at CIAT.

As the initiative was now taking more concrete shape, and to avoid giving any impression of exclusivity, Dr. Habich prepared a circular to be sent across the region to all CIAT's rice collaborators describing the initiative to date. It was sent on 4 April to a mailing list of over 400 supplied by the Rice Program. On 3-8 May Dr. Habich met with the Board of Directors of Procisur and further explained the initiative to southern cone NARI leaders.

Dr. Winslow also presented the concept to the US rice research community at the Technical Meeting in New Orleans in March, and to global rice country and institution representatives at the FAO Rice Technical Commission meeting in September, in Rome.

Dr. Cuevas' needs assessment consultancy was carried out in two meetings, one for the tropical countries in Caracas on 22 April, and and another for the temperate countries in Concepción del Uruguay, Argentina on 11 May. Given the prior awareness of differing needs of tropical and temperate countries, the emphasis was on identifying a few key topics which cut across and interest both sub-sectors. Blast and sheath blight were revealed as the top cross-cutting subjects. However, Dr. Cuevas noted that the on-farm impacts of these research activities might be a long time in coming, and recommended that the initiative help towards the identification of improved varieties for quick release, as particularly suggested by the tropical countries. This would generate the visible impact that would probably be critical for the future survival of the initiative.

Based on this, Dr. Sanint drafted a proposal focusing on blast, sheath blight and grain discoloration, for $500,000. On 28 June, Dr. Winslow modified and developed this further into standard CIAT format to include blast, sheath blight, and improved gene pools, which required a budget of $871,000 per year, including $335,000 for in-country research and training expenditures. These formed the basis for subsequent, iterative discussions with the countries involved. A meeting was tentatively planned for 11 August, but could not be realized due to summer travels of various participants.

August, 1994. Changes in IRGA's representatives and prohibition of brazilian public servants to travel on official business for the rest of the year.

November, 1994. Rice program leader (L.R. Sanint) travels to Brazil, Argentina and Uruguay, where he gets written commitment from all three countries to participate. Argentina has problems meeting the deadline of January, 1995. He also travels to Venezuela to secure its participation.

January 16, 1995. The Act of Agreement to constitute the Latin American Irrigated Rice Fund, FLAR, is signed at CIAT by representatives from Brazil, Colombia, Uruguay, Venezuela, IICA and CIAT. Also present at the act there were Colombian officials Juan José Perfetti, Viceminister of Agriculture, Alvaro Balcázar, Jefe Unidad de Desarrollo Agrario-DNP, Juan Manuel Ramírez, Director-ICA, Germán Aya, Director Regional 9-Corpoica, Edmundo García, breeder-ICA, Michel Desmidts, project officer-IDB. Two observers came from the Dominican Republic: José Bisonó, rice farmer, and José Sánchez, President Mingoló Rodríguez farmers' association.

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B. ACTIVITY RL01: GERMPLASM DEVELOPMENT

Abstract. Characterization of traits closely associated with high yields, including early vigor, and moderate tillering will enhance the opportunities to increase the yield potential in our regional germplasm adapted to the diverse direct-seeded conditions found throughout LAC. A recurrent selection project to increase the yield potential of lowland rice initiated in 1993 provided the elements to build four new base populations which will be distributed to key NARs in 1995. There are differences among these base populations, mainly in terms of their genetic background and the cytoplasm source. Breeding activities in collaboration with ICA/CORPOICA /FEDEARROZ in Colombia led to the release of Oryzica Yacu 9 as a variety for irrigated conditions for some areas in Colombia while collaborative activities with ICTA in Guatemala led to the identification of two promising lines that will be released as varieties in early 1995. Advanced breeding lines combining resistance to rice blast, *Tagosodes oryzicolus*, RHBV, high yield potential, and good grain quality were identified and will be distributed to NARs in 1995. The inheritance of the resistance to *Tagosodes* in Makalioka and Mudgo was studied; results suggested that resistance may be under the control of a single dominant gene modified by a minor gene which affects the expression of the resistance depending on the plant genotype and length of exposure to the insect. Anther culture continued to be used as a breeding tool to bridge wide crosses, develop germplasm tolerant to low temperatures, and produce doubled-haploids suitable for RFLP and PCR-based gene tagging. The rice anther culture lab. processed 321 entries for the various projects of the breeding program and generated about 19.000 green plants. A course-workshop on anther culture was held at CIAT to share CIAT's knowledge and expertise on using AC in breeding, and to stimulate closer collaboration between tissue culturists and breeders. The analysis on the genetics of AC response was completed. Results corroborate the simple inheritance of AC response reported in other works; it is proposed that the AC response could be inherited as an incomplete dominant trait. Co-segregating analysis indicated that it is possible to recover plants combining high response to AC (up to 70% callus induction and 90% green plant regeneration) and grain type characteristic of true-indica. Results also suggested that gene(s) encoding for callus induction, plant regeneration, and grain length segregate independently. An study conducted to assess the contribution of the cytoplasm source in relation to AC response showed that the indica/indica combination responded significantly lower than the indica/japonica or the japonica/indica combinations for callus induction, total number of plants/anther, and number of green plants/anther. Results from different experiments confirmed that AC is under genetic control, and that the cytoplasm of the female parent in a cross combination is very important; besides, high response to AC can be transferred to non-responsive types. Therefore, through a recurrent selection scheme it is possible to develop indica gene pools responsive to AC.

Research Activities

Rice is the most important food grain crop in tropical Latin America (LAC), where most of the region's poor are concentrated. Lowland rice accounts for about 70% of the region's total rice production. Improved lowland varieties have reduced the cost of rice by 40% over the past 25 years, mainly due to CIAT activity done in close collaboration with national agricultural research and development institutions. The benefits of this research go mainly to consumers (67%) and particularly to the poor, who spent about 10% of their total income on rice. The percentage of CIAT- generated germplasm achieving varietal release has increased steadily over time, from 9% during 1967-71 to 50% over the last five years. During the last two years, the rate reached 65%. The basic dynamics of the irrigated rice sector, and breeding lines already in the pipeline, suggest that this proven record of impact will continue in the near future.

A number of exciting new traits are being generated within the rice program in other interdisciplinary projects, and as well as globally which promise to continue the remarkable record of past and present impact. Those important new traits, however are usually in genetic backgrounds that are not-well enough adapted to LAC direct seeding conditions. Therefore, this project will combine the total set of traits into gene pools adapted to LAC lowlands. Traits to be added include greater yield potential, a new plant type for direct seeding, traits to enhance weed control, more durable resistance to blast, diversified resistance to *Tagosodes* and RHBV, better grain quality in sub-tropical zone, and possibly novel sheath blight resistance.

A decision made by CIAT's Board of Trustees to discontinue core funding for this project after 1994 led to unavoidable cuts in support staff and in operating budget, which impeded our work. Despite these setbacks this project was able to continue to show major impact through research done in key areas. Results for 1994 are presented and discussed following four broad categories, mainly: improved germplasm for the tropical lowlands, population improvement, biotechnology, and diversified resistance to *Tagosodes* and hoja blanca virus.

Improved Germplasm for the Tropical Lowlands

This conventional pedigree breeding work is done in collaboration with ICA/CORPOICA and FEDEARROZ in Colombia and with ICTA's rice program in Guatemala. The objective is to develop high-yielding germplasm adapted to irrigated and rainfed lowland conditions, tolerant to major diseases and insect pests, with good grain quality, and early to intermediate growth duration. To ensure good disease pressure "hot spot" sites are used three in Colombia and two in Guatemala. Promising lines are made available to other NARDs through INGER, and serve as potential varieties or as parents in crossing programs. The continuity of this breeding work will depend on finding new funding sources.

After three years of intensive testing and evaluations in farmer's fields, CIAT/ICA/CORPOICA/FEDEARROZ decided to release the breeding line CT 8837-1-17-9-2-1 as Oryzica Yacu 9 for commercial plantings in the Tolima-Huila and Cauca Valley areas. Oryzica Yacu 9 outyielded several commercial checks (Table 1) and showed a high level of resistance to rice blast (*P. oryzae*) and excellent milling and eating qualities; it is also resistant to lodging. This new variety is susceptible to rice hoja blanca virus and moderately susceptible to *Tagosodes oryzicolus* under controlled lab. conditions; however, under field conditions it has shown a good level of tolerance.

A total of 200 crosses were made to recombine resistances to several biotic and abiotic stresses; however, 22 of them were interspecific crosses between cultivated rice and some wild rice species (*O. rufipogon, O. glaberrima, O. barthii and O. minuta*) with the aim of introgressing into cultivated rice some important plant traits found in the wild populations such as resistance to rice blast, bacterial blight resistance, plant hopper resistance, early vegetative vigor, and drought avoidance. A backcrossing program to cultivated rice with the aid of molecular markers will be used to identify and select best recombinants.

Following a shuttle breeding approach F2, F3, F4 and F5 populations comprising around 500 crosses were planted and evaluated at CIAT-Palmira, Santa Rosa- Villavicencio and Saldaña-Tolima. Over 4,700 plant selections in F5-F6 generations and 150 bulk-populations were selected for further testing next year.

A three-year evaluation of 156 potential new donors for the irrigated crossing program was completed. Data are being analyzed specially in terms of disease resistance and yield potential to select best donors to be incorporated into the germplasm bank. A complete screening of this bank will be done early in 1995 to up-date data, specially on disease reaction.

On the other hand, given the increase demand for rice germplasm suitable to different agroindustrial uses, a group of 93 entries with diverse grain traits was put together for evaluation in CIAT-Palmira and Santa Rosa. Entries were evaluated for grain shape and length, gelatinization temperature, amylose content, disease and insect reaction, yield potential, flowering, and plant height. This nursery and the characterization will be made available to interested parties through INGER during 1995.

In collaboration with ICTA, breeding activities in Guatemala were conducted at Cristina and Cuyuta. Blast incidence and drought stress at the seedling stage were severe in Cristina where blast susceptible checks had a 8-9 reaction, while Oryzica Llanos 5 showed a resistant reaction; besides, leaf scald and false smut were also important at flowering time. Disease pressure was low in Cuyuta, although lodging was high. Around 850 lines in the F3, F4 and advanced generations were evaluated in Cristina resulting in a selection index ranging from 22 to 36%. Nine promising lines were evaluated in 18 sites in demonstration plots; lines CT 9807-3-5-1-2-M, CT 9145-4-21-5P-1MI, CT 9841-6-1-1P-4I-MI and CT 8240-1-3-9P-2I-4I-1I-MC did very well; on the other hand, another set of 16 lines was evaluated for the first time in regional trials in 18 sites; best lines in this group were: CT 9506-38M-6-1-M-2-1P, CT 8837-8-5C-1C-3C-1C-MC, CT 8837-8-4C-2C-3C-4C-MC and CT 9852-3-21-1-1P-MI. Purification and production of breeder seed from these lines will be done in 1995. A total of 62 advanced lines were evaluated in observational yield plots in Cristina and Cuyuta. Early in 1995 ICTA will release lines CT 8008-16-3-1P-5I-5I-MI and CT 6543-4-7I-4I-7I-MI to replace current varieties such as Precoz-ICTA, ICTA-Polochic, and ICTA-Motagua which have become very susceptible to rice blast.

Population Improvement for Irrigated Rice

CIAT's rice breeding program for irrigated rice has mainly used the pedigree method and occasionally the backcross method. It is widely believed that this strategy restricts the achievement of favorable new gene combinations. By using a "population improvement approach", novel combinations can be achieved and gradually pyramided into an ever - improving yet genetically broad-based population. This approach requires that a larger number of crosses be made to gradually recombine desired genes and handcrossing may be a limiting factor. However, this can be overcome by using genetic male sterility. Several populations for irrigated conditions have been developed by CIRAD-CA/ EMBRAPA using genetic male sterility. The objective of this activity is to use these populations and another one developed at CIAT to form different new populations to suit diverse needs found in the irrigated ecosystems in LAC. Anther culture will be used to rapidly fix superior genotypes extracted from these populations. Breeders in national program may evaluate and use these populations to suit their own needs. The continuity of this activity after 1995 will depend on the availability of new funding sources.

Fourteen parental sources for high yield potential were identified in 1993 (Rice Program Ann. Report 1993) and crossed in different combinations to CIRAD-CA's gene pools and WC 232^{*5} - Early (CIAT's irrigated line) to form new base populations (Table 2). Some of these parental sources (B4353C-KN-7-0-0-2, BG 989, PNA 1004F4-33-1, OR 83-23, Perla (Cuba), RP 2087-115-10-5-1, and Morelos A88) had not been used before in our irrigated breeding program and therefore, represent new gene sources to broaden the genetic base of irrigated rice in LAC.

There are differences among these new base populations, mainly in terms of their genetic background and the cytoplasm source. Populations PCT-6, PCT-7, and PCT-8 are similar in the sense that they share the same source of male sterility (IR 36), while RL 01 derived its male sterility from a mutant line of Tox 1011-4-1 obtained through mutagenesis. This induced male sterility was transferred through backcrossing to an improved CIAT's line (CT 6047-13-5-3-4M) for irrigated conditions; this particular breeding line was used as the recurrent parent because of its resistance to several diseases and insect pests, good plant type, high yield potential, and good grain quality. Population PCT-6 was derived from IRAT Mana (a tropical indica population developed by the introduction of 15 genotypes well adapted to the French Guyana's conditions), while populations PCT-7 and 8) have essentially the same genetic background and were initially developed from 9 indica genotypes. Seed of the new base populations (PCT-6, PCT7, PCT 8 and RL01) will be increased for distribution to some key partners in the region in 1995. Furthermore, the gene pools IRAT MANA, IRAT 1/420, CNA-IRAT 4/2/1, IRAT Med A, and CNA-IRAT P/1/0 were evaluated for yield potential and response to anther culture. Individual fertile plants were harvested in these populations and planted in two-row plots. Yield data is being analyzed while the response to anther culture will be discussed together with some other activities related to anther culture.

Two hundred grams of seed from IRAT MANA, CNA IRAT 4/2/1, and CNA-IRAT P/1/0F were sent to national programs in Guatemala (ICTA) and Panama (IDIAP) for evaluation under favored upland conditions. Data from Guatemala (based on disease reaction, plant and grain type, and yield potential) indicated that CNA-IRAT 4/2/1 was better adapted to local conditions found there and was selected for further evaluation in 1995; 30 fertile plants were selected for line development and seed from sterile plants was bulk-harvested.

Biotechnology

Rice anther culture. This technique has proved to be useful to accelerate the introgression of desirable traits into breeding populations resulting in substantial savings in breeding time. Previous work done at CIAT indicates that anther culture (AC) has proved to be useful in accelerating the development of germplasm tolerant to low temperatures with excellent grain quality; increasing the recovery of useful recombinants from wide crosses including resistance to rice blast (*P. oryzae*) and rice hoja blanca virus, and drought tolerance; and facilitating the production of doubled haploid lines suitable for RFLP -and PCR- based gene tagging. The methodology optimized (Sanint et al, 1993; Lentini et al, 1994) shows a significant progress in several lines of research . Following are reported the main activities conducted during 1994:

Bridging wide crosses and development of cold tolerant germplasm. We are using anther culture to help broaden the genetic base of irrigated rice in LAC by facilitating interspecific crossing and gene recombination. In this activity we are trying AC to enhance introgression of novel blast resistant genes from substitution/addition lines developed by IRRI through its wide hybridization project. Lines selected in 1993 were re-tested in Santa Rosa in 1994 but only one line (WHD 15-75-1-127) continued to show high level of resistance to blast.

This year the Rice Anther Culture Laboratory (RACL) processed 321 entries for the various projects of the breeding program. This includes 47.5% for the recurrent selection (durable blast resistance), and indica X japonica crosses for the irrigated new plant type projects); 21% for the sabana; 7.4% for single seed descent blast resistant project; while 14.4% are F1 and F2 populations from crosses made at IRRI to be used in gene - mapping of traits related to submergence and drought tolerance. This is a collaborative research project with several advanced labs. with funding from Rockefeller Foundation. The remaining 10.1% are IRGA breeding lines. The RACL generated about 19,000 green plants with 4 technicians from January to October 1994. Data from the last two months is being analyzed. In contrast, about 4,000 plants were produced last year during the same period of time even though we had 5 technicians. This year the medium containing maltose and silver nitrate was implemented routinely at large scale. Data will be analyzed to determine if the increase in efficiency for production of green plants is due to the new medium or/and the genotypes processed.

About 1,000 doubled-haploids lines produced by RACL were evaluated by the rice breeding programs of Argentina (INTA), IRGA (Brazil), INIA (Chile) and INIA (Uruguay) under different environmental conditions in the field. Their data for 1993/94 indicate that from 9% to 17% of the DH lines were selected and some of these line are being advanced to yield trials for further selection in 1994/95. Additionally, over 2,000 new DHs were sent to this region last year for initial evaluation in 1994/95 crop season. Breeders indicated that the DH population showed a suitable genetic diversity to accelerate the selection process and stated their interest in including AC derived plants in their programs. Thus, the AC-derived lines generated by the RACL could be effectively used to quickly generate parents combining a range of characteristics for CIAT's breeding program and advanced lines to be distributed to National Programs to help them to develop varieties. This way AC would aid filling the gap originated when the Program moves away from producing finished lines through pedigree towards germplasm development.

Genetic factors affecting response to anther culture. Studies on the genetics of AC response were conducted through dialell and backcrosses (BC) inheritance analyses using 14 single crosses between true-indica (non-responsive) and japonica (highly responsive) genotypes. F1 (and their corresponding reciprocal cross) and F2 generations, and populations with one, two or three BC's to each parent were examined. The co-segregation of AC response and grain type was also evaluated. Results corroborate the simple inheritance of AC response reported in other works. Most F1 generations showed an intermediate response between the high-responsive and the non-responsive parents (Tables 3 and 4). Thus, the AC response could be inherited as an incomplete dominant trait. A more rigorous analysis of the data will be conducted using a generation mean analysis to determine the number of genes and the inheritance of this trait. Maternal effects (crosses with CT 8707, Table 3) and combinatory ability effects (crosses with CICA 8 respect to those with Oryzica 1, Table 4) were noted in some crosses. The AC response increased in the BC to the responsive parent (japonica), whereas it decreased in the BC to the non-responsive parent (indica), as expected due to the simple genetic control. But the level of decrease in AC response respect to the F1 depends on the indica genotype used as the backcross parent (Table 4). Co-segregation analyses indicate that it is possible to recover plants combining high response to AC (up to 70% callus induction and 90% green plant regeneration) and grain type characteristic of true-indica rice (up to 8.7 mm length) as early as in the F2 generation and subsequently, in the BC-indica generations (Table 5). Plants with high callus induction and/or green plant regeneration, and long grains were recovered from the segregating generations indicating that the gene(s) encoding for callus induction, plant regeneration and grain length segregate independently. Some plants combining high AC response and indica-grain type were selected and will be used as parents for crossing with least responsive genotypes. Results indicate that the high response to AC can be transferred into non-responsive genotypes. Therefore, the development of an indica gene pool with increased AC response could be feasible through recurrent selection.

An study was conducted to assess the contribution of the cytoplasm source in relation to the response to anther culture using various crosses from the breeding program. Three genotype combinations were used including 23 indica/indica crosses, 31 indica/japonica, and 31 japonica/indica. The indica/indica crosses responded significantly lower than the indica/japonica or the japonica/indica for callus induction, total number of plants/anther, and number of green plants/anther (Table 6). Although not statistically significant, a higher response for all the parameters evaluated was noted when using a japonica as the female parent, suggesting possible maternal effects depending on the genotype used (Table 6). Therefore in rice breeding with AC, the inclusion of a japonica parent may improve the application of this technique to a wider range of crosses.

The response to AC of five gene pools developed by CNA/CIRAD-CA (indica pools #1, #2, and #3; japonica/indica pool #4; and japonica pool #5, Table 8) including a total of 258 crosses was evaluated using the two induction media (N6m and NL) previously optimized with a more reduced number of genotypes. The NL medium induced a significantly higher callus formation than the N6m (Table 7 and 8). However except for the pool #5 (japonica), the differentiation of green plants per callus was higher with N6m respect to NL (Table 7 and 8). Nonetheless, the efficiency of recovering green plants/ anther was not statistically different although it tends to be higher with NL as result of a higher callus induction from this medium. At present, different medium compositions are being evaluated to attempt to increase the green plant differentiation from calli induced on NL.

Transfer to NARs of the anther culture methodology optimized at CIAT. A first course-workshop on Anther Culture for Rice Breeding was held at CIAT on February '94. This is part of the two-year transfer project sponsored by the Rockefeller Foundation. Twenty participants from 10 institutions of 8 countries assisted. Each Institution was represented by a breeder and a specialist on plant tissue culture. The workshop was designed to share CIAT's knowledge and technical expertise on using AC in breeding, and to stimulate closer collaboration between tissue culturists and breeders. Cross-country collaboration was also encouraged. The second workshop will be held in Argentina and Brazil, with a short field visit in Uruguay. For this event, twenty one participants from 11 institutions will attend. The emphasis will be on the participant's experience using the technique and field evaluations and selection of doubled-haploids for breeding. Three invited speakers will participate to share their experience in the use of AC at large scale in breeding (CIRAD, Guadalupe), the development of the first cereal (wheat) variety in Brazil through AC (CNPT, Río Grande do Sul), and the improvement of response of indica AC (Universidad de Corrientes, Argentina). A Manual was prepared, and a revised version (English and Spanish) will be ready for International distribution by March 1995. The preparation of an audio-tutorial video on this subject was initiated on early December. The video should be ready by mid-1995, and it is prepared in a didactic way to complement the information contain in the Manual.

Diversified *Tagosodes*/Hoja Blanca Resistance

Rice hoja blanca virus (RHBV) causes severe recurrent epidemics in the Andean, Central American and Caribbean countries of tropical LAC. It is transmitted by *Tagosodes oryzicolus*, which can also cause serious feeding damage even when not viruliferous. Usually rice farmers use pesticides to control the insect vector, even when the problem is not apparent, as "insurance".

Resistance to Tagosodes and RHBV in breeding populations.This activity was carried out in connection with Project 5, and its main objective was to test segregating populations and advanced breeding lines for resistance to both feeding damage per se and RHBV. A field technique was used to mass -screened advanced breeding lines for resistance to RHBV. Susceptible and resistant checks were planted every 40 testing lines. A total of 10 cages, each with 100 pots were used to multiply the vector colony; pots were then carried to the field and shaked over the testing material to spread the vectors as uniform as possible; the percentage of insect vectors in the colonies used for the screening in 1994A and 1994B was around 85% and the disease pressure was high and quite uniform as shown by the reaction of both susceptible and resistant checks.

A total of 7240 breeding lines were screened for resistance to RHBV and 2572 (35%) showed a resistant reaction (1-3); many of resistant advanced lines originated from crosses that combined different sources of resistance to RHBV like Colombia 1, IRAT 122 and Colombia 1/M312A.

Besides, three experiments were conducted under greenhouse conditions to evaluate the effect of plant age on the level of resistance shown by several sources of resistance and breeding lines. Data is being analyzed and will be reported next year.

The test for resistance to feeding damage caused by *Tagosodes* was done under greenhouse conditions using the standard seedbox screening test with a virus -free colony. Tests entries were sown in wooden flats filled with soil; susceptible and resistant checks were also sown randomly in each seed box. Test insects, in number sufficient to kill the susceptible checks were uniformly distributed onto 15 days old seedlings. The insect damage was graded upon the death of the susceptible cultivar. A total of 4484 breeding lines were evaluated and 46% (2052) were rated as resistant (1-3). A group of 360 advanced breeding lines was identified as resistant to both *Tagosodes* damage and RHBV. A nursery will be up for distribution to NARS in 1995, specially to those countries where RHBV has come back.

Genetics of resistance to *Tagosodes oryzicolus*. The inheritance of the resistance to *Tagosodes* in Makalioka and Mudgo was studied; these cultivars were crossed with IR 8, a susceptible variety. Based on the F1 and F3 data (Table 9) and the reaction of the resistant cultivars it was proposed that resistance in both cultivars is controlled by a single dominant gene (AA) accompanied by a modifier gene (BB). This modifier gene affects the expression of the resistance depending on the plant genotype and length of the exposure to the insect. In the case of Mudgo it was suggested that the modifier gene is present in a recessive form (bb) but in a dominant form (BB) in Makalioka. In its recessive form, the modifier gene speeds up the expression of the susceptibility to *Tagosodes*.

Furthermore, several crosses were made to study the inheritance of the resistance in IRAT 120, IRAT 124, and Amistad 82; F2 and F3 seed is being produced.

References

Sanint, L. R.; C. P. Martínez and Z. Lentini. 1993. Economic analysis of rice anther culture versus conventional breeding. Trands in CIAT commodities 1993. Working document No. 128:74-96.

Lentini, Z.; P. Reyes; C. P. Martínez; V. M. Nuñez and W. Roca. 1994. Mejoramiento del Arroz con Cultivo de Anteras. Aplicaciones en el desarrollo de germoplasma adaptado a ecosistemas Latinoamericanos y el Caribe. CIAT, Cali, Colombia. p.79.

Table 1. Mean yield [1] (kg/ha) of several breeding lines in the Tolima-Huila area in Colombia in regional trials under irrigated conditions from 1992 to 1994.[2]

	Sites			
Breeding lines/checks	Meseta Ibagué	Tolima Sur	Huila	Mean yield
CT5748-38-2-1-2	6.597	5.356	6.183	6.045 f
CT8008-16-10-10P	7.640	6.173	6.326	6.642 bc
CT8008-16-3-3P	7.747	6.302	6.952	6.916 abc
CT8837-1-17-9-2-1**	7.800	6.484	6.814	6.983 ab
CT9162-12-6-2-2-1	8.503	6.077	6.869	7.055 a
IR 22	6.526	5.210	5.411	5.605 g
CICA 8	7.084	6.109	6.779	6.615 cd
ORYZICA 1	7.061	5.381	6.196	6.101 f
ORYZICA 3	7.731	5.322	6.404	6.505 de
ORYZICA LLANOS 5	6.966	5.427	6.727	6.270 ef
Regional Trials (No.)	5	8	7	20

1. Differences at the 5% level according to Duncan's test.
2. Source: ICA/CORPOICA/FEDEARROZ.

** Oryzica Yacu 9.

Table 2. New base populations formed for tropical lowland ecosystems in LAC.

Original into population	Population source	New population name	Cultivars introduced new population
IRAT MANA	CIRAD-CA	PCT-6	B4353C-KN-7-0-0-2, BG 989, El Paso 144, PNA 1004F4-33-1 Oryzica Llanos 4, OR 83-23, Perla (Cuba), Oryzica 3, Morelos A88, RP 2087-115-10-5-1
IRAT 1/420P	CIRAD-CA	PCT-7	Oryzica 3, B4353C-KN-7-0-0-2, BG 989, PNA 1004F4-33-1, OR 83-23, RP 2087-115-10-5-1
CNA-IRAT 4/2/1	EMBRAPA/ CIRAD-CA	PCT-8	Oryzica 3, Oryzica Llanos 4, BG 989, Perla (Cuba), El Paso 144, and B4353C-KN-7-0-0-2
WC 232^{*5}-Early (CT 6047-13-5-3-4-M^{*5})	CIAT	RL01	B4353C-KN-7-0-0-2, CT 6241-17-1-5-1, BG 989, Oryzica Turipana 7, PNA 1004F4-33-1, 5685, OR 83-23, Perla (Cuba), RP 2087-115-10-5-1, BR IRGA 410, BG 90-2, El Paso 144, Oryzica 3 and Morelos A88

Table 3. Anther culture response of crosses between CT 6241-17-1-5-1, Todoroki Wase and IR 43.

Parent or cross	Calli (%) per anther	Green plants (%) per callus
IR 43	0.0 d	0.0 d
CT8707	0.0 d	0.0 d
CT6241	19.8 b	43.9 a
Todoroki Wase	42.2 a	28.8 b
IR 43/CT8707	0.0 d	0.0 d
CT8707/IR 43	0.0 d	0.0 d
CT6241/Todoroki	58.3 a	28.3 ab
Todoroki/ CT 6241	65.2 a	23.2 ab
CT8707/Todoroki	2.2 bcd	0.0 d
Todoroki/CT 8707	15.9 bc	3.3 cd
CT8707/CT 6241	6.6 bcd	3.3 cd
CT6241/CT 8707	11.8 bcd	0.0 d
IR 43/Todoroki	15.4 b	12.3 bc
Todoroki/IR 43	17.9 b	12.8 b
Todoroki/IR 43 F2	12.7 bc	11.7 b
Todoroki/IR 43//IR 43	5.2 c	7.2 c
Todoroki/IR 43//Todoroki	24.9 b	17.6 b
IR 43/CT 6241	13.9 bc	11.9 bc
CT6241/IR 43	13.4 bc	22.1 b
CT6241/IR 43 F2	4.5 cd	7.5 b
CT6241/IR 43//IR 43	5.4 c	7.9 b
CT6241/IR 43//CT 6241	12.3 bc	15.9 b

Means with the same letter are not significantly different according to Waller-Duncan K-ratio test, $p \leq 0.01$.

Table 4. Anther culture response of crosses between CT 6241-17-1-5-1, Oryzica 1, and CICA 8.

	Green plant (%)	
Genotype or cross	Induction (%)	Regeneration
Oryzica 1	0.0 h	0.0 d
CICA 8	1.2 fgh	1.0 d
CT 6241	33.9 a	11.8 abc
CT 6241/CICA 8 F1	19.4 bc	23.4 a
1 BC CICA 8	13.5 bc	4.6 bcd
2 BC CICA 8	5.9 def	2.8 cd
3 BC CICA 8	5.2 def	9.5 abc
1 BC CT 6241	17.4 bc	9.5 abc
2 BC CT 6241	12.2 bc	9.3 abc
3 BC CT 6241	22.5 ab	16.5 ab
CT 6241/Oryzica 1 F1	31.6 a	15.3 ab
1 BC Oryzica 1	2.4 fgh	4.6 bcd
2 BC Oryzica 1	0.6 gh	0.3 d
3 BC Oryzica 1	0.3 h	0.3 d
1 BC CT 6241	10.4 bcd	9.8 abc
2 BC CT 6241	29.3 ab	13.9 abc
3 BC CT 6241	12.1 bcd	16.0 abc

Means with the same latter are not significantly different according to Waller-Duncan K-ratio test, $p \leq 0.01$.

Table 5. Offspring plants selected from the crosses Todoroki/IR 43 F2, Todoroki/IR 43//IR 43, and Todoroki/IR 43//Todoroki showing cosegregation of high response to anther culture (from the japonica parent) and long rice grains (from the indica parent).

Genotype	Calli/anther (%) Mean (Range)	Green Plants/callus (%) Mean (range)	Grain length (mm) Mean (range)
IR 43	0.0(0.0)	0.0(0.0)	8.5 (8.0-9.0)
Todoroki Wase	42.2(16.7-96.7)	28.8(7.0-60.0)	6.7(6.2-7.1)
Todoroki/IR 43			
F2	12.7(0-69.4)	11.7(0-82.5)	7.4(6.0-8.3)
BC IR 43	5.2(0-50.0)	7.2(0-50.0)	8.1(7.1-8.8)
BC Todoroki	24.9(0-71.7)	17.6(0-90.0)	7.0(6.5-7.9)
Todoroki/IR 43 F2 Plant No			
3-13	69.4	9.7	8.2
3-20	10.5	61.1	7.8
3-24	13.6	14.0	8.3
3-26	50.0	0.0	7.8
4-6	2.8	65.0	7.7
4-8	2.8	40.0	7.6
4-12	10.2	0.0	7.7
4-17	34.7	12.5	7.9
4-25	11.3	4.0	7.8
BC IR 43 Plant No.			
3-13	12.5	0.0	8.7
3-17	8.6	38.0	8.2
3-21	44.4	1.8	7.7
3-26	6.1	90.0	8.7
4-13	1.8	12.5	7.8
4-19	1.3	55.6	8.3
BC Todoroki Plant No.			
3-23	25.4	18.0	7.9

Table 6. Influence of the cytoplasm source on the response to anther culture. CIAT's anther culture lab.

Response variable	Mean value (cross type)[1]			Overall mean	Prob>Chisq[2] H_o: ì$_i$ = ì$_j$
	i x i	i x j	j x j		
Callus induction	2.88b	23.72 a	34.03 a	21.84	0.0001
Total No. Plants/calli	17.94	12.34	20.38	16.96	0.3289
Total No. Plants/ anther	0.48b	4.59 a	10.46 a	6.44	0.0056
Green plants/total No. plants	45.56	49.32	51.93	50.10	0.8245
Green plants/calli	13.25	6.93	12.33	10.50	0.3730
Green plants/anther	0.23b	2.95 a	7.61 a	4.53	0.0211

1. Values with the same letter are not significantly different.
2. Level of significance according to Kruskal-Wallis's test.

i = indica;
j = japonica.

Table 7. Influence of two induction medium on the response to anther culture. CIAT's anther culture lab. 1994.

Response variables	Induction Medium				N6-NL	Difference Prob>Z/1
	N6		NL			
	Mean	N	Mean	N		
Callus induction	4.37	252	16.79	258	-12.42**	0.0001
Total No.Plants/calli	38.31	70	19.84	120	18.47**	0.0001
Total No. Plants/anthers	4.78	70	6.76	120	-1.98^{NS}	0.2568
Green plants/total No. plants	63.84	65	56.59	109	7.25^{NS}	0.3286
Green plants/calli	26.92	70	14.51	120	12.41**	0.0005
Green plants/anthers	3.43	70	4.98	120	-1.55^{NS}	0.1481

1. Level of significance according to Mann Whitney's Range Test.

** Highly significant difference; NS= non-significant.

Table 8. Genetic differences in the response to anther culture of five gene pools developed through recurrent selection.

Response variable	Gene pools (average) 1	2	3	4	5	Prob > X_2 [1] $H_0: \tau_i = \tau_j$
N6m Medium						
Callus induction	1.55	0.24	0.72	15.87	4.83	0.0001
Total No. Plants/calli	35.57	20.00	36.98	39.39	40.36	0.7418
Total No. Plants/anther	1.59	0.46	2.68	7.38	3.32	0.0001
Green plants /total No. plants	51.85	91.67	45.00	68.64	64.82	0.3133
Green plants/ calli	17.67	17.50	19.00	28.28	33.42	0.2664
Green plants/ anther	1.29	0.39	1.21	5.31	2.52	0.0005
NL Medium						
Callus induction	9.27	14.35	15.29	38.28	9.47	0.0001
Total No. Plants/calli	8.94	16.29	11.62	32.76	20.12	0.0001
Total No. Plants/anther	1.12	3.57	3.55	15.36	2.51	0.0001
Green plants /total No. plants	23.01	37.00	56.22	66.66	72.90	0.0002
Green plants/ calli	1.87	13.24	7.36	25.76	16.40	0.0001
Green plants/ anther	0.36	1.38	2.21	12.16	1.88	0.0001

1. Level of significance according to the Kruskal-Wallis test.

Table 9. Analysis of F3 families in crosses IR 8/Mudgo, IR 8/Makalioka, and Makalioka/Mudgo based on the reaction to the mechanical damage caused by *Tagosodes orizicolus*.

Phenotypic classification	IR 8/Mudgo Obs.	Exp.	X^2	IR 8/Makalioka Obs.	Exp.	X^2	Makalioka/Mudgo Obs.	Exp.	X^2
Herogeneous families **	80	75	0.33	79	75	0.21	99	100	0.02
Homogeneous susceptiblefamilies	20	25	1	21	25	0.64	1	0	
Total	100	100		100	100		100	100	
X^2 observed			1.33			0.85			0.02
X^2 tabular			3.84			3.84			3.84

Obs. = Observed value.
Exp. = Expected value.
** Families presenting susceptible and resistant plants in different proportions.

II. PROJECT 2
IMPROVED UPLAND RICE GENE POOLS - REPORT 1994 [1]

A. Activity RU01. Germplasm Development

Abstract. Since 1992 the section has been devoting more resources to population improvement. In 1994, the third cycle of recurrent selection for earliness, grain quality and blast resistance was completed for three populations and a new one was created. The line development component still has an important role and is allowing for varietal release. Bolivia released two varieties in 1994 (Sacia 3 - Tutuma, and Sacia 4 - Jisunu). Genetic studies for understanding the mechanisms and the genetic control of the most important traits for rice-pasture association was initiated together with the physiology section.

Introduction

The upland rice breeding activities are focussed on the acid upland soils savannas of Latin America. It is well known that these are oxisols and ultisols with high Aluminum Saturation, and deficient in P, K, Mg, Ca, and S. Table 1 presents a summary information on climatic data obtained in the main breeding sites used to carry on these activities.

CIAT began breeding upland rice for acid-soils savannas in 1984. The main objective has been to develop germplasm with the following traits: a) tolerance to soil acidity; b) resistance to diseases (mainly leaf and panicle blast) and insects (mainly *Tagosodes oryziculus*); c) good grain quality (translucent, long, and slender); and d) earliness (growth duration shorter than 115 days); and lately it was added, the understanding of the mechanisms and the genetic control of the most important traits for rice-pasture association.

Line Development

In the sequence the breeding methodology used is described. Each year germplasm from Africa, Asia, and Latin American NARS is introduced. These lines are planted under acid-soils savannas, the best ones are selected and organized in a nursery named "Potential Parents". During 1994, the introduced germplasm (693 lines) were planted in three locations, one of them was used by a student from "Universidad de los Llanos Orientales" as a BS Thesis. This set of material was evaluated for soil acidity in a special trial (acid and non acid strip trial). At this stage the lines are fully characterized. A total of 211 lines were selected to continue under evaluation in 1995, before been used as parents in the crossing program. Table 2 indicates where the selected lines are coming from and the percentage of selection obtained with each introduced set of materials.

Recently all Potential Parents are evaluated against the blast lineages identified in Colombia for genetic diversity through the PCR technic and screened for aluminum tolerance under controlled conditions. All of this information is combined to decide on

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[1] Detailed information about these activities is presented in the publications "Mejoramiento de Arroz para las Sabanas de Suelos Acidos, 1993B y 1994A" and Upland Rice Improvement in Recessive Male Sterile Gene Pools and Populations, 1993-1994 Report.

the parents to be used and the crosses to be made (normally three way combination). Most of these data are in the final stages of analysis and will not be presented in this report.

The segregating generations F_2 and F_4 are evaluated under acid-soils savannas. Selection is made considering the priority traits previously mentioned. The selection units are line and plant basis (pedigree method). The F_3 and F_5 generations are advanced at an off-season site by planting the lines under irrigated conditions and selecting only for highly inherited traits, the selected lines are bulked. This site is also used for seed multiplication. Table 3 shows the number of crosses evaluated beginning in 1983. Since 1987 the number of crosses made has been declining because more emphasis has been concentrated on population improvement.

The advanced lines are distributed to NARS through INGER-LAC. To assess the yield potential of the produced lines, the program collaborates with CORPOICA by running some of the preliminary yield trials within different cropping systems (rice monocrop, rice-pasture association, and in rotation with soybean). In 1994, there were 4 trials carried on by this section: rice monocrop at La Libertad and Altillanura (native savanna and after soybeans), and rice pasture association at Altillanura. The most relevant material was line #30 (CT11891-2-2-7, IRAT 146/CT6196-33-11-1-3-M//CT10035-9-3-M-6) which was ranked first in all tests, except after soybean, when it was second. Other than been a high yielding material it is 10 days earlier than Oryzica Sabana 6, has good grain quality, and resistance to blast and other diseases. This line, together with 5 others, will be passed to CORPOICA for further evaluation.

This strategy has allowed NARS to release varieties in Colombia (Oryzica Sabana 6, 1991 and Oryzica Turipana 7, 1992), Bolivia (Sacia-1, 1993, and Sacia 3 and 4, in 1994), and Brazil (Progresso, 1994).

With the objective to better understand the mechanisms and the genetic control of the most important traits for rice improvement a few studies were done. A MSc Thesis was used to repeat with improved material the inheritance study for soil acidity. The material analyzed were the F_1, F_2, BC1, BC2 generations of the single crosses Oryzica Llanos 5 (Susceptible)/Oryzica Sabana 6 (Tolerant) and Oryzica Llanos 5 (S) x Monolaya (T). The results indicated that: tolerance is dominant, the trait is highly inherited, and the tolerance present Oryzica Sabana 6 is controlled by 1 or 2 genes, and by Monolaya by 3 to 4 genes. Together with the physiology section similar studies are under way to understand the genetic control mechanisms of the traits that play an important role in the association rice-pasture.

Population Improvement

Lately, population improvement through recurrent selection, was incorporated into the breeding strategy. The objective is to improve populations for specific traits (blast resistance, tolerance to soil acidity, and earliness). The flow chart presented in Figure 1 shows how the two components are tied together.

Population improvement has been used as a source for potential parents with specific traits to suit the NARD's demands for their breeding programs. The alternative used to achieve this goal is the use of recurrent selection, which is a cyclic process where each cycle is made of 2 phases: a) selection of genotypes with favorable traits; b) intercrossing of the selected genotypes. This process promotes chromosomal reassortment, useful segmental interchanges and will gradually concentrate the frequency of desirable alleles.

A Rice Recurrent Selection Program using recessive male sterile gene of IR36 started in 1984, in Brazil, in the framework of a collaborative project between CNPAF/EMBRAPA and CIRAD-CA. As a result, several gene pools and populations have been obtained targeting different rice ecosystems, some of these have been the starting point for Recurrent Selection in different countries of Latin America (Brazil, Argentina and Colombia) and Africa (Cote d'Ivoire, Mali, and Madagascar).

In Colombia a set of selected gene pools and populations have been introduced in 1992 by CIAT from Brazil (CNPAF) and French Guyana (CIRAD-CA). These materials have been observed and characterized under colombian rice ecosystems conditions to know about its behavior and possible use in a recurrent selection program.

In 1992, the CIAT rice program introduced 3 sources of germplasm for tropical upland. The principal objectives of the study were: a) to know about the behavior of the introduced germplasm under colombian upland acid soil savanna, b) identification of adapted fertile genotypes to enter the traditional line breeding program, and c) to create new populations by introducing locally adapted lines into the introduced germplasm used as a source of good male sterile background.

One tropical japonica upland gene pool (CNA-IRAT 5/0/3), one tropical japonica upland population (CNA-IRAT A /0/1) and two tropical indica/japonica populations (CNA-IRAT P/ 1/0F and IRAT Lulu /0/1) have been observed under acid soil upland savanna conditions at La Libertad Experimental Station, Colombia.

Each population was represented by 2000 individual hill plot plant for easier identification of fertile and male sterile plants. Two 1000 seeds sowing dates spaced by 10 days have been used to allow good natural intercross between early and late genotypes and maintain the genetic variability of the original population. To avoid pollen contamination each gene pool or population was fenced with rows of corn.

Each material was characterized by sampling about 400 individual plants for tolerance to acid soil and initial vigor at 45 days after seeding (das), heading time (50%), plant height at harvesting time, number of fertile and male-sterile plants at flowering time, tillering at 45 das, tolerance to neck blast and male sterile plant seed set.

All germplasm had high number of plants tolerant to soil acidity (Table 4), but the IRAT Lulu population showed poor adaptation and the lowest number of symptom free plants. Contrary behavior was showed by the CNA-IRAT 5 and A. These can be explained looking at the genetic constitution of the different germplasm, the former is indica/ japonica and the other two are composed of 100% tropical upland japonica lines.

Population CNA-IRAT P presented the highest number of plants with scores between 1 and 3, indication of vigorous plants. This result confirms the observations made in traditional breeding where indica/japonica derived lines show, in most of the cases, significant higher initial vigor under upland conditions.

The early vigor difference observed between the two indica/japonica populations can be explained by the fact that IRAT Lulu has in its genetic background only 25% of the most vigorous population CNA-IRAT P and aromatic rice lines that are known not to have good early vigor.

Flowering date was scored on an individual plant basis in each population. The CNA-IRAT P and IRAT Lulu populations are the latest ones with 42.6% and 67.5% of plants with flowering time more than 95 days. The earliness of the CNA-IRAT A population is because it was derived from the CNA-IRAT 5 gene pool by introducing in it 50% of new variability coming from 7 upland japonica early lines.

The distribution of plant height is different mainly if considering japonica and indica/japonica germplasm. CNA-IRAT P and IRAT Lulu present higher number of smaller plants than the japonica germplasms CNA-IRAT 5 and A. This result can be attributed to the introduction of semi-dwarf indica irrigated material in the upland japonica gene pool CNA-IRAT 5.

The indica/japonica populations CNA-IRAT P and IRAT Lulu present a high tillering ability. About 80% of the variability is concentrate above 17 tillers per plant. The maximum variability for the japonica germplasm is between 9 and 16 tillers per plant. The differences observed between the two types of germplasm can be attributed to the introgression of modern high tillering indica lines into the japonica gene pool CNA-IRAT 5.

The upland gene pool and population CNA-IRAT 5 and A have presented 6.8% and 3.7% of susceptible plant to neck blast, respectively. The indica/japonica populations CNA-IRAT P and IRAT Lulu were more susceptible with a special mention to the last one with 52.1% of the plants with neck blast.

Using these germplasm a recurrent selection program was initiated in 1992. The selection criteria used were: earliness, disease resistance (mainly blast), and grain quality. Each cycle requires only one planting time, because evaluation, selection (plant base) and recombination (using male sterile gene) are done in the same season. Therefore, for CNA-IRAT 5, A, and P three recurrent cycles were completed and significant visual progress was made (it will be measured in 1995). Even though the results are apparently significant these populations do not have all traits at the level the region requires, thus there was the need to develop a new population.

Development of New Population

From all the introduced germplasm evaluated the most useful for upland acid soil savannas conditions was the CNA-IRAT A. This population was chosen as the male sterile background to create a better locally adapted population.

The process started by selecting 8 breeding lines identified by this section. Through manual crossing each line was combined to different male sterile plants of the CNA-IRAT A. Each resulting F_1 was grown separately and observed at CIAT-Palmira Experimental Station under lowland irrigated condition to ensure good F_2s seed production, one combination was discarded. Selection of genotype was made in each F_1 and the F_2

seeds of the selected F_1 plants were harvested and mixed in equal proportion. The new basic population is identified as PCT-4\0\0\0. Its genetic constitution is presented in the Table 5.

The first recombination cycle in under way. The behavior of the new population after one cycle of recombination will be characterized and compared to the original CNA-IRAT A population under savanna acid soil conditions in 1995 cropping season.

Table 1. Climatic information obtained in the two major breeding sites.

Breeding Sites	Rainfall[1] (mm)	Temperature (°C)		Relative Humidity (%)
		Max	Min	
La Libertad	2700-3000	30.6	21.0	80
Altillanura	2000-2200	32.8	21.3	80

[1] Well distributed between April and October

Table 2. Sources of introduced germplasm for 1994 acid soil evaluation.

Origin	Number of entries	Number of selection	Selection percentage
IURON	77	18	23.4
AURON	90	11	12.2
AURPSS	143	28	19.6
WARDA	204	129	63.2
Indonesia	147	15	10.2
India	20	6	30.0
French Guayana	11	4	36.4
TOTAL	692	211	30.5

Table 3. Number of crosses evaluated from 1983 to 1993.

Year	Cross (#)	Crosses Evaluated		
		# F_2	# F_4	# F_6
1983	43	-	-	-
1984	335	-	-	-
1985	697	183	-	-
1986	158	325	79	-
1987	213	129	30	48
1988	188	118	31	21
1989	123	75	35	15
1990	103	48	45	8
1991	89	111	25	37
1992	17	57	62	18
1993	32	0	32	32
tal	1998	1046	339	179

Table 4. Characterization of upland rice gene pool and populations planted under acid soils at La Libertad Experimental Station during 1994. The information is presented as percentage of plants within each class.

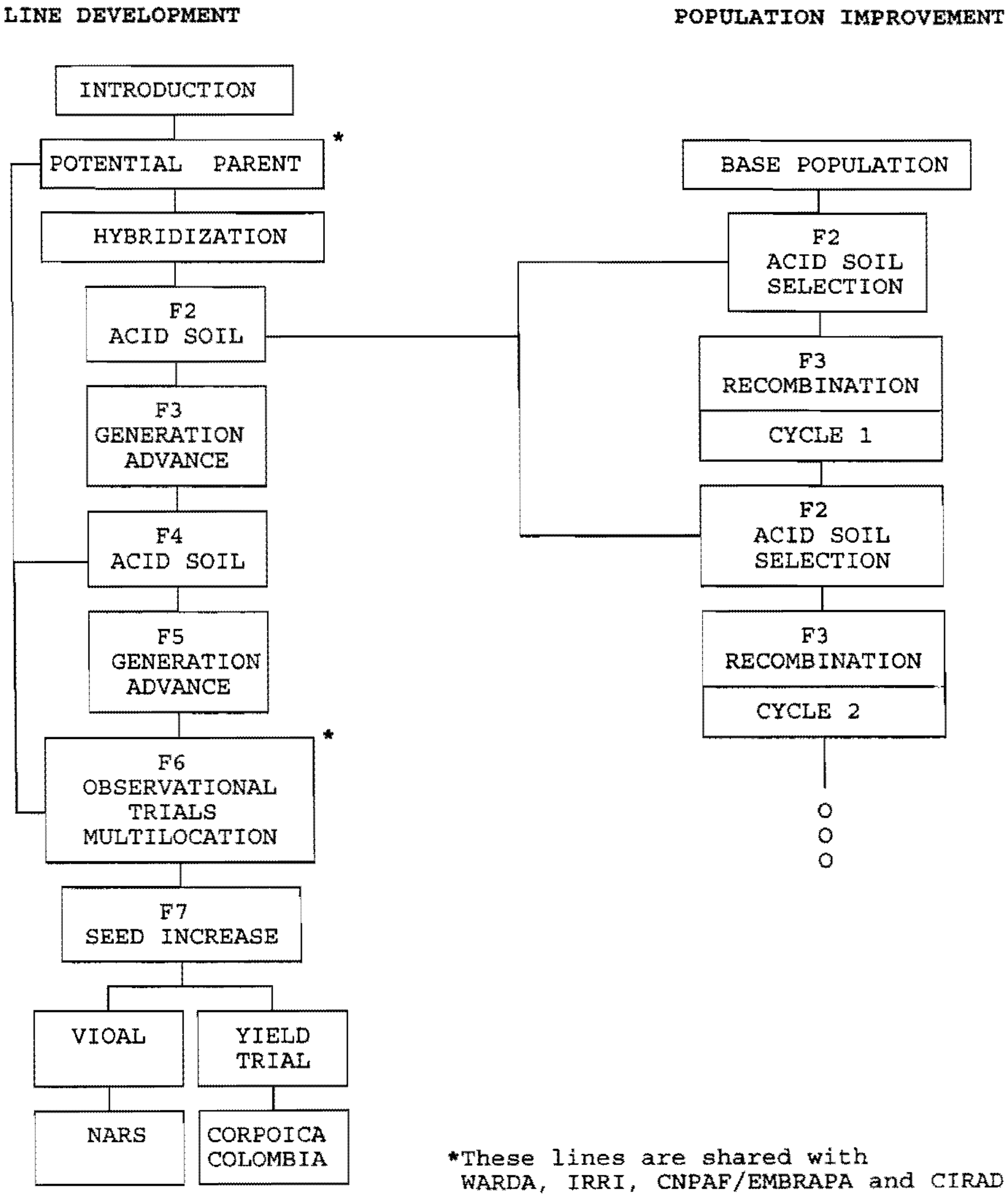
Characteristic	Gene Pool	Population		
	5	A	P	LULU
Reaction to Acid Soil				
1 - 3	85.1	85.6	82.3	66.3
5 - 7	14.9	14.4	17.7	33.7
Initial Vigor				
1 - 3	33.6	28.2	50.7	38.4
5	49.9	65.1	32.6	47.9
7 - 9	16.5	6.7	16.6	13.7
Days to Flowering				
< 74	30.7	38.6	8.7	1.8
75 - 84	14.2	41.5	13.8	5.7
85 - 94	38.6	8.6	34.9	42.6
> 94	16.3	11.3	42.6	67.5
Plant Height				
< 64	28.0	20.7	40.9	50.3
65 - 74	26.1	33.7	23.2	16.7
75 - 84	23.9	29.8	25.6	17.2
> 84	21.8	15.2	10.2	15.8
Number of Tillers				
< 8	25.9	24.9	6.0	5.3
9 - 16	52.7	49.5	11.7	0.9
17 - 28	20.0	24.9	51.9	42.7
> 29	1.3	0.8	30.3	52.6
Reaction to NBI				
1 - 5	6.8	3.7	10.8	52.1
6 - 9	93.2	96.3	89.2	47.9

Table 5. Genetic constitution of the PCT-4[1] population.

Germplasm Source	Origin	Percentage
CT6196-33-11-1-3-M	Colombia-CIAT	8.33
CT11231-2-2-1-4-M	Colombia-CIAT	4.17
CT11231-2-2-3-1-M	Colombia-CIAT	4.17
CT11231-2-2-2-1-2-M	Colombia-CIAT	8.33
CT11608-8-6-M-2-M	Colombia-CIAT	8.33
IR53167-3-M	Philippines-IRRI	8.33
A8-394-M	Brazil-IAPAR	8.33
CNA-IRAT A	Brazil-CNPAF/EMBRAPA-CIRAD-CA	50.0

[1] PCT-4 is a japonica population targeting the moist savanna ecosystem of Latin America.

Figure 1. Flow chart of the upland rice breeding activities for acid soils savannas.



*These lines are shared with WARDA, IRRI, CNPAF/EMBRAPA and CIRAD

B. ACTIVITY RU01: SILICON EFFICIENCY OF RICE GENOTYPES

Abstract. Silicon deficiency was identified as a major, previously-unrecognized yield and yield stability constraint for savanna rice over the past several years, and research reported in 1994 focused on the search for genetic variation in Si efficiency which might be useful in raising the level of this element under soil deficiency conditions. Significant variation, on the order of 100%, was found in percent tissue Si contents in several plant organs, among 60 genotypes examined. This appears to support the possibility of breeding for higher Si levels. Further confirmatory work is underway.

Research Activities

This activity is attempting to identify genotypic differences in the ability to take up soil silicon (Si) under upland conditions.

The results of 1993 field trials are described here because Si analyses could not be completed until 1994. Likewise, 1994 field trials will be reported in the 1995 annual report.

Background

Silicon (Si) is a major macronutrient for rice, increasing its yield, vigor, lodging resistance, and resistance to diseases, particularly blast and grain discoloration. Recent evidence indicates that typical upland rice soils may be strongly deficient in Si, implicating this deficiency as a major, previously-unrecognized nutrient constraint affecting both yield and yield stability (disease) over a large rice area in Latin America.

Results published in 1986 by M. Yamauchi and M. Winslow at IITA were the first to document Si deficiency as a yield loss and disease-inducing constraint for upland rice grown on acid soils, in West Africa. Irrigation was found to markedly ameliorate Si deficiency through Si supplied in groundwater. A followup study by Winslow (1992) found large genotypic differences within West African rice germplasm for Si content, and found them correlated with resistance to several diseases there.

Acid soils also predominate in the major upland rice growing areas of Latin America, and subsequent research is attempting to validate these findings here. During 1992-94, silicon deficiency has been identified as a cause of blast susceptibility and yield loss at CIAT's Santa Rosa station, in collaborative studies between CIAT (F. Correa) and the University of Florida (L. Datnoff and G. Snyder). Collaborative experiments between the Rice and Savannas Programs were sown in 1993 on more representative savanna soils at La Florida and Matazul in the Colombian Llanos, which also led to the implication that Si deficiency may indeed be a widespread phenomenon in the savannas (see Savannas/Tropical Lowlands annual reports for details). Yield reduction was 40%, with another 10% loss due to lower milling recovery of whole grains.

If these results are representative, silicon deficiency in the savannas may be costing LAC an estimated 5-7 million tons of paddy rice annually.

Description of Experiments

Sixty genotypes from CIAT's upland rice breeding project were chosen in 1993 for study of silicon content in different environments. They were selected on the advice of Dr. Guimaraes to represent the range of diversity used in the CIAT upland breeding project. Both indica and japonica ecotypes were included. They were sown in two-row plots with 3 replications at three locations, Palmira, Santa Rosa and Matazul, in 1993. Matazul was hoped to be the "stress" or low-Si site, and believed to be most representative of the larger neotropical savanna cultivated under well-drained upland conditions. Santa Rosa was included based on previous findings of Si response; it was suspected that it might function as an intermediate-Si site, since the soil water situation alternates between saturated and upland, and it is known that groundwater supplies Si. Palmira was chosen on the basis that it should be a rich source of Si, due to the well-drawn floodwater used for irrigated paddy cultivation and the young, 2:1 soil clay type which normally has high Si content.

Unfortunately, the Matazul trial had to be abandoned as it was eaten by cattle. Also, one of the of the three reps in Santa Rosa was also lost, due to very uneven stand establishment. Altogether, 58 varieties grew sufficiently well to be sampled at Palmira, and 56 at Santa Rosa.

Results

Results showed statistically-significant differences among genotypes and plant organs (Table 1). Twofold or more variation among genotypes was observed, depending on the plant organ. This genetic variation implies a potential to genetically elevate the Si content of low-Si but otherwise desireable germplasm.

Large differences were also apparent between sites (Table 1). Husks averaged 7.6% at Palmira, or 62% more than the Santa Rosa value of 4.7%. Even Santa Rosa, however is substantially higher than found at other sites in related trials (see Rice-Savannas collaboration, described earlier), namely, 3.1% in Matazul and 2.3% in La Florida. These several-fold differences in site Si supplying capability probably have important implications for plant performance and disease resistance in different locations. Many rice scientists often note large differences in disease among different growing environments, but often attribute them to climatic or epidemiological factors. The present results indicate that role of soil Si variation would warrant closer attention in such cases.

Furthermore, such large variation in tissue nutrient content across sites is not commonly reported for other macro-nutrients such as N and P, because they are so vital to plant growth that growth is restricted when they are limiting, in a sort of self-correcting mechanism that maintains internal nutrient contents at essential levels for carrying out basic biochemical functions. Si uptake could be unique in that it may be "facultative", i.e. rice growth is less affected by its variation than for N or P.

Some interesting differences are also apparent among tissues (Table 1). The husk and mature flag leaves had the highest Si contents, while the neck had just a third of that amount (necks tested at Palmira only). Could the low Si content of the neck be one reason this organ is the one most damaged by blast?

At both sites, the husk gave the lowest coefficient of variation (Table 1). This may be because it comes from seeds which become thoroughly mixed in the harvest bag (which cannot be easily done for leaves and necks), naturally resulting in highly representative samples. It is also one of the easiest organs to harvest and store, often being automatically collected and stored for grain yield trials. It is also non-bulky and simple to prepare for Si analysis, and has a high Si content. Furthermore, it correlates well across genotypes with Si contents of other organs (Table 2), particularly at Santa Rosa. Thus, measurements of Si in the husk appears to provide a reasonable, if approximate prediction of how a genotype will rank for Si content in another organ. Given all of the above, and the need to reduce sampling for maximum efficiency in a breeding program, the husk may be the most efficient organ for Si sampling across large numbers of genotypes, as an overall indicator of relative Si content.

While the Si content of different plant organs was correlated across genotypes, it was not well correlated across sites (Table 3). In other words, varieties ranked differently across the two sites, for all three organs observed. This g x e makes breeding more complicated, since performance at one site may not be a good indicator of performance at another. Since Palmira is a lowland irrigated site, however it may be that a number of the true upland rices tested fared poorly there because of lack of adaptation to inundated culture, which could have affected Si uptake. A comparison of Santa Rosa and Matazul would have been helpful in clarifying this, had the latter trial not been destroyed.

One important achievement of this activity in 1994 was the successful installation and testing of an Si analysis procedure at CIAT by Dr. K. Okada, based on the University of Florida method. Plant tissue, soil and water analyses can now be performed.

Winslow (1986) measured 50-100% higher Si content in japonica upland rices compared to indicas in the African breeding germplasm of IITA. Verification of this difference between ecotypes was sought in the present study. The phenol test of Oka was used to characterize indica vs. japonica type for each genotype. It proved to be a simple, effective and repeatable test, and the results matched well with previous known information on the sources and ecotypes of the 60 genotypes. This test could probably be very useful in a number of other applications in the CIAT rice improvement effort.

Ecotype, however turned out not to be closely associated with Si content in this study (Table 4). Japonicas had very slightly higher mean Si levels, but the correlation between ecotype and Si level was nonsignificant at both sites. This result suggests that genotypes can be found within each ecotype which could be valuable breeding sources of high Si content.

Based on their organ Si contents, a set of ten genotypes was selected for more in-depth study during the subsequent 1994-5 planting and postharvest analysis cycle (Table 4). A wide range of values for the husk and neck in particular were sought in making the selections, while attempting to include several of the most important varieties and parents used in the breeding program, and including both indica and japonica types.

Larger-plot trials of these 10 genotypes were sown in 1994 at Matazul and Palmira, both to try and confirm the 1993 findings, and to extend them to an analysis of Si uptake per unit land area (as opposed to just percent of dry weight). This should clarify whether genotypes with higher percent Si contents are truly more efficient in extracting soil Si, or rather are simply producing less biomass (sometimes referred to as the "dilution effect"), either of which could explain an elevated Si content on a percentage basis. Large numbers of Si analyses are needed for those 1994 trials, so the results will not be available until 1995.

Table 1. Means and variability of Si content of different plant organs, and the statistical significance of genotypic differences. Grown in 1993 at two sites, Palmira and Santa Rosa.

			AOV Statistics	
	Si Content			
Site and organs	mean	range	F value for genotypic differences	Coefficient of variation (%)
	% of dry weight			
Palmira (3 rep x 58 g'type)				
Hust, mature	7.6	5.2.9.2	16.8***	6.1
Leaf, mature	7.8	5.5-10.7	5.7***	11.6
Leaf, flowering	5.4	3.8-7.3	2.1***	16.1
Neck, mature	2.7	1.7-3.7	6.0***	12.1
Santa Rosa (2 rep x 56 g'type)				
Husk, mature	4.7	2.7-6.6	5.4***	16.4
Leaf, mature	4.1	1.8-6.6	5.4***	20.5
Leaf, mature	3.3	1.2-4.6	5.0***	18.6

*** Significant at $p < 0.001$

Table 2. Correlations of Si contents (% fo dry weight) among organs, across genotypes. Coefficients are within-site, for two sites.

	Organ (at the same site):			
Site, and organ	Hust, mature	Leaf, mature	Leaf, flowering	Neck mature
Palmira (58 g'types				
Hust, mature	-	0.29*	0.15	0.28*
Leaf, mature		-	0.52**	0.31*
Leaf, flowering			-	0.26*
Neck, mature				-
Santa Rosa (56 g'types				
Hust, mature	-	0.70***	0.61***	-
Leaf, mature		-	0.83***	-
Leaf, flowering			-	-
Neck, mature				

1. Neck data available for Palmira only.

Table 3. Correlations between sites of Si contents (% of dry weight) of 56 genotypes, for three plant organs. None are significantly greater than zero.

	Santa Rosa		
Site and organ	Husk	Leaf, mature	Leaf, flowering
Palmira			
Husk	0.13		
Leaf, mature		-0.04	
Leaf, flowering			0.09

Table 4. Correlation between the ecotypes (indica or japonica) of genotypes tested, and Si content in the mature hustk.

Site and ecotype	Number of genotypes	Husk Si content (mean) % of dry weight	Correlation coefficent ecotype x Si value*
Palmira			
japonicas	39	7.7	
indicas	19	7.4	0.250
Santa Rosa			
japonica	38	4.7	
indicas	18	4.6	0.063

Table 5. Si contents of selected genotypes out of 58 tested in 1993, chosen to span a range of values for more detailed testing in 1994. Averages over the two sites.*

Genotype	Rice ecotype[1]	Organ Husk, mature	 Leaf, mature	 Leaf, flowering	Neck[2], mature
		Si content, % of dry weight			
Tox 1785-19-18	J	7.0	6.1	3.7	3.4
Ngovie	J	7.0	5.7	4.0	3.1
Colombia 1	J	6.9	5.3	4.2	2.4
Tox 1859-102-6M-3	I	6.4	6.4	4.6	3.2
Oryzica Turipana 7	J	6.1	6.0	3.6	2.5
IAC 165	J	5.9	5.4	3.8	2.9
Oryzica Llanos 5	I	5.5	5.1	4.5	2.5
Nam Sagui	I	5.4	5.7	4.1	1.8
Makalioka	I	5.3	4.6	3.4	1.7
Oryzica Sabana	J	5.0	5.8	3.6	2.5
IRAT 13	J	4.9	5.9	3.9	2.4

1. I = indica; J = japonica
2. Neck data available for Palmira only.

C. ACTIVITY RU52: MECHANISM OF ACID SOIL TOLERANCE

The rice-pasture system has been developed and now is being adopted in both Llanos and Cerrados in Latin America to a large extent. The development of the upland rice varieties which adapted to acid soils in savanna is also progressing. However, the mechanisms of the acid-soil tolerance of upland rice have not been elucidated yet, which is hampering the development of effective screening methods. So far, it has been speculated that the adaptation of certain genotypes (mainly *japonica* type) to acid soils compared with the non-adapted group (mainly *indica* type) is due to their the tolerance to high levels of aluminum in the acidic soils. However, there is not enough detailed research reported on the acid-soil tolerance for upland rice. Therefore, first, various aspects of acid-soil stress in the field is reported. And then the growth and nutrient uptake of both tolerant and susceptible genotypes under acid and non-acid conditions were analyzed. Thirdly, the response of both acid-soil tolerant and susceptible genotypes to lime application was analyzed in pot experiments.

Acid-soil Stresses for Upland Rice in Savanna Soil

So far a lot of soil data on the acid soils in Llanos Orientales were reported. However, the dynamic aspects of the stresses of acid soils have been reported scarcely. And in addition to that, the soil data have not been analyzed as the stress for upland rice, which have been domesticated under some degree of soil acidity.

In this report, in order to clarify the different aspects of acid-soil stresses, the soil as well as the soil solution were analyzed through the cropping season of upland rice in savanna soil field under high and low soil acidity created by two levels of liming.

Materials and Methods

In an acid-soil savanna soil field at the CORPOICA station of La Libertad, two levels of lime application were created with the application of dolomitic lime (55% $CaCO_3$ and 35 % $MgCO_3$) at 0.3 and 3 t/ha. As acid-soil tolerant genotypes, Oryzica Sabana 6, IAC165, CT10037 and CT9997 were grown. As acid-soil sensitive genotypes, Oryzica Llanos 5 was grown. The experimental design was the split-plot design with 4 replications with the lime treatment as main treatment and genotypes as sub-treatment. Phosphorus was applied before sowing, and nitrogen and potassium as both basic and sequential fertilizers. The total amount of the fertilizers applied was 75, 26 and 50 kg/ha for N, P, and K, respectively.

The soil samples were collected with hydraulic sampler (Soil sampler, Model SS-4804, Concord) at 0-20, 20-40, 40-60, 60-80, 80-100 cm depth.

The soil solution was collected as follows: the soil samples were collected from the field without drying, adjusted roughly at field capacity with distilled water and incubated for 4 days at room temperature. Then soil solution was collected by centrifugation at 3500 rpm for 45 min. The Al and P was measured by modified xylenol orange method (Hesse 1971) and malachite green method (Ohno et al. 1991), respectively. Ca, Mg and K was measured by atomic absorption.

The experiment was conducted with split-plot design with 4 replication with lime treatments as main plots and the genotypes as sub-plot. In this section, the data from the plots of Oryzica Sabana 6, for which the most detailed analysis was conducted, will be reported.

Results and Discussions

In the previous report (Rice Program Annual Report 1993), it was confirmed that the soil acidity progressed during the growing season of upland rice in low lime plots where only the 0.3 t/ha of lime was applied. The soil pH decreased (Fig.1-a), the aluminum saturation slightly increased (Fig.1-b), and Al concentration in the soil solution increased drastically from the middle of the growing season (Fig.2-a).

The data of the aluminum concentration in soil solution revealed that the aluminum concentration of the low lime treatment was maintained at the low level at which even the acid-soil susceptible genotypes may not be affected at the early stages of growth (Rice Program Annual Report 1993). However, it started to increase at 60 DAE (days after the emergence) and reached to several hundreds uM Al at 80 DAE when the soil pH decreased to pH 4.3. At this aluminum concentration, the inhibition of the root elongation can be expected. The electric conductance of soil solution followed the same pattern (Fig. 2-b).

The Ca and Mg concentration increased in the same pattern as the Al did (Fig.2-c,d). As the amelioration effect of Ca and Mg was well known, the increase of Ca and Mg may have alleviated the effect of increased level of Al in soil solution to some extent.

The progressive acidification during crop growth occurred only at the surface soil of 0-20 cm depth. In the subsoil, although the aluminum saturation of soil was very high, soil pH was between 4.4 and 4.6, and the aluminum concentration was not as high as it was at the low lime treatment of 0-20 cm (Fig.3). Therefore, it was shown that the subsoil acidity, which is often the problem in acid soils in temperate regions was not the problem for the tropical savanna soils.

The results at the flowering stage for the all genotypes showed that there were no differences in the characteristics of the soil and soil solution among the genotypes (no data is shown).

The incubation experiment with small pots using the same type of fertilizers and the soil (top soil (0-10 cm) of native savanna at Matazul farm in the altillanura of the Eastern savanna) revealed that the sequential application of KCl decreased soil pH and the soil pH reached the minimum level of 4.3 within 40-50 days of incubation (Fig.4). On the other hand, the sequential application of urea first slightly increased the pH and then decreased it at 50 days after the incubation, and seemed to reached down to the pH of 4.0-4.2 within 50 days. The mechanism for the KCl to decrease the soil pH may be to increase the salt concentration in soil solution and drive out the exchangeable Al into the soil solution. The mechanisms of the urea application to decrease pH is supposed to be due to the nitrification of urea.

It has been considered that the application of 300 kg/ha of dolomitic lime which is the common practice of the farmers at Llanos Orientales has the role of only supplying the Ca and Mg which is necessary to the rice and pastures but does not have the role of correcting the acidity of the soil. These results, however, showed that the 300 kg/ha of dolomitic application suppressed the possible soil acidity (mainly the Al problem) even for the acid-soil susceptible genotypes of upland rice at least for the early growth stage (Fig.2). The possibility of aluminum toxicity exists only at the later stages when the soil acidity increased progressively. Therefore, the early screening for acid-soil tolerance under low lime condition could be misleading. The possible causes for such increase in soil acidity with time are: 1) increased salt concentration in the soil solution due to the sequential KCl and urea application, 2) nitrification, and 3) decrease of cations due to the leaching and/or absorption by plants.

The Response of Acid-Tolerant and Non-Tolerant Rice Genotypes to the Dolomitic Lime Applications

In the same experiment described above, the genotypic differences in growth, nutrient absorption, root development under low and high lime treatment on savanna acid soils were analyzed. The purpose was to find out the true limiting factor of growth for the acid-soil susceptible varieties.

Materials and Methods

The root sampling was conducted with a "Concord" core sampler mounted on a tractor with a 2-inches-diameter auger. The root samples were taken from both sides of the rows and between the rows, and both were combined. The roots were sampled at 0-20, 20-40, 40-60, 60-80, and 80-100 cm depth. The root samples were washed with tap water on 40 mesh sieves, and their length was measured with a root scanner (Comair, Hawker de Havilland Victoria). Leaf area was measured with a Li-Cor 2000.

Results and Discussions

The final yield is shown in Table 1. As the results of the analysis of variance, there was significant effect of genotypes on yield, but no significant effect of lime level nor the interaction of liming level x genotype. The yield of Oryzica Llanos 5 was lower than other improved upland rices (Oryzica Sabana 6, CT-9997, CT-10037), and then that of IAC47 was further lower than Oryzica Llanos 5. If we account the difference in the growth duration (Oryzica Llanos 5: 135 days; IAC47: 111 days), however, the efficiency to produce the yield was almost same for Oryzica Llanos 5 and IAC47. And although there was no significant effect of liming in general, IAC47, and to a lesser extent, Oryzica Llanos 5 and Oryzica Sabana 6 had lower yield under low lime treatment (by 20%, 7.5% and 6% (not significant), respectively. However, this fact does not coincide with the general idea that the Oryzica Llanos 5 is acid-soil susceptible and the other are tolerant. Therefore, these results indicate that the Oryzica Llanos 5 may not be the representatibe susceptible variety and/or the low pH or high Al may not be the primary limiting factor of this soil even for the susceptible genotypes.

The effect of element concentration of top parts at the time of flowering on the final yield is shown in Fig.6. There was a significant correlation between nitrogen concentration and final yield in general (Fig.6-a). The lower yield of Oryzica Llanos 5 seems to be due to its lower nitrogen concentration. The low yield of IAC47, however, cannnot be explained by the nitrogen as is seen from the figure. The phosphorus concentration of IAC47 was especially low irrespective of the liming treatment, which may partially account for the general low yield of IAC47 (Fig.6-b). The phosphorus concentration of Llanos 5 was rather higher than other genotypes. There was not a consistent effect of tissue potassium concentration on the final yield (Fig.6-c). In the case of calcium, the low lime treatment caused much lower Ca concentration only for the three genotypes whose yield was affected by the liming treatment (Oryzica Llanos 5, IAC47, and Oryzica Sabana 6). The magnesium concentration of all genotypes was significantly affected by the lime treatment

(Fig.6-e). The aluminum concentration did not affect the yield significantly (Fig.6-f). Rather, the high lime treatment increased the Al concentration of two low-yielding varieties (Oryzica Llanos 5 and IAC47), which also demonstrates that the aluminum uptake was not limiting the final yield even for the case of susceptible variety.

Fig. 5-b shows the development of leaf area during the growth. The leaf area of Oryzica Llanos 5 at low lime treatment was severely suppressed especially at the flowering stage. This may be due to the insufficient absorption of nitrogen at the stage.

The root length distribution along the depth at the flowering stage is shown at Fig.6. In the first place, the lime treatment only slightly affected the root length of Oryzica Llanos 5, although the restriction of the root length is considered as one of the most evident symptoms of the aluminum toxicity. And the root lentgh of Oryzica Sabana 6 (tolerant) also seems to be affected by the lime treatment at the deeper soil layer. Secondly, the Oryzica Llanos 5 had the shallower rooting pattern in general. Thirdly, the rooting pattern of IAC47 was deep, but it had less surface roots than other genotypes did.

From these results, the following conclusions were drawn.

1. The aluminum toxicity may not be the limiting factor for yield even for the genotypes which are considered as acid-soil susceptible.

2. The low yield of Oryzica Llanos 5 may be ascribed to its lower capacity to recover nitrogen in soil due to its shallower root system. The nitrogen in the aerobic soil usually exists as nitrate which is easily leached down with high rainfall. The experimental site had high rainfall during the rainy season. It was also reported that the shallower rooting crops can suffer from nitrogen deficiency in high rainfall conditions because they cannot recover sufficient nitrate from the soil. The deficiency of the nitrogen can severely reduce the leaf development. Thus, the poor nitrogen absorption with shallower root system is suggested to be the main reason for the low yield of Oryzica Llanos 5 under the conditions of high-rainfall savanna.

3. The lower yield of IAC47 can be partially ascribed to having less roots at the surface soil, although the root system was deep. Phosphorus usually stays at the surface soil especially for the type of soil used for this experiment with high P fixing capacity. The Ca and Mg was applied as dolomitic lime, which also stays in the plow layer and leach down to the subsoil only at very slow rate. Therefore, the IAC47, with the lower root length density especially at the surface soil seemed to be unable to absorb enough P and Ca from the soil. The deep roots under this high-rainfall condition did not contributed to the yield.

4. The improved upland genotypes (Oryzica Sabana 6, CT9997 and CT10037) had a balanced root system (having both enough surface roots and the deep roots).

5. It seems that there is room for the improvement in increasing the absorption capacity for calcium under the low-lime condition, for the varieties whose final yield was affected by the lime treatment (IAC47, Oryzica Llanos 5, and Oryzica Sabana 6).

Response of Acid-Soil Tolerant and Susceptible Genotypes of Upland Rice to the Dolomitic Lime Application

The application of dolomitic lime to the acid soil alleviates the acid-soil stresses. The amount of the lime needed depends on the kind of the stresses of the acid soil. Therefore, the detailed analysis of the response to lime application may reveal the major kind of stress which makes the difference between the genotypes. However, there were limited researches reported on the responses of upland rice to the lime application using soil as the growth medium, and the clear results have not yet been obtained. Therefore, we conducted the lime response experiment with the purpose of clarifying the major limiting factor for the upland rice growth under the acid-soil conditions.

Materials and Methods

The varieties of Oryzica Sabana 6 and Oryzica 1 were used as the representative varieties of acid-soil tolerant and susceptible varieties, respectively. Both the surface (0-10 cm) and sub (15-30 cm) soil of native savanna at Matazul farm in altillanura of Llanos Orientales in Colombia were used. For each, plastic pots of 10 inches diameter, 6 kg of soil were used. The dolomitic lime (55 % $CaCO_3$, 35 % Mg CO_3) was applied at 8 levels. For fertilizers, N, P, K, Zn were applied at the rate of 100, 80, 100, 16 ppm (w/w). The N or K were applied at 3 or 4 times during the growth, respectively. Both the plant and soil samples were harvested at flowering and physiological maturity. The analysis of soil and soil solution were conducted as in the previous experiments.

Results and Discussions

1. At higher rate of lime application, the lime increased the soil pH and maintained the aluminum concentration of the soil solution at low level. At low rate of lime application where the acid stress was expected, the tolerant varieties maintained the soil pH higher and the soil solution Al concentration lower than the susceptible variety did (Fig. 7). This results suggests that maintaining higher soil pH may be one of the mechanisms of the acid-soil tolerance.

2. At the low level of lime application (less than 50 ppm), the tolerant genotype maintained lower tissue concentration of aluminum and obtained higher total dry weight than the susceptible genotype did (Fig. 8). In the figure which shows the relationship between the aluminum concentration in the tissue and the total dry weight (Fig. 10-a), however, there was no genotypic difference. These results demonstrated that the acid-tolerance of the upland rice does not rely on the mechanisms of "internal tolerance" but on the mechanism of "exclusion."

3. At the treatment of no lime application (0 ppm), there was clear genotypic difference in the panicle dry weight (Fig.9). On the other hand, there was no difference in the panicle dry weight at the 200 ppm lime application which is close to the normal practice of upland rice farmers at savanna. This results correspond to the results of the previous two reports which showed that the conventional application of 300 kg/ha of dolomitic lime ameliorate the soil acidity even for the susceptible genotypes at least for the first phase of the growth.

4. The root length and the root-to-top ratio of susceptible variety was lower than those of the tolerant one at the low rate of lime application (0-50 ppm) (Table 4). This result suggests that the root growth of the susceptible variety was affected directly by the aluminum stress. However, the specific root length (root length/root weight) was higher for the susceptible variety than for the tolerant one. This is not the usual symptom of the aluminum toxicity.

5. From the figure of the relationship between tissue element concentration and the growth, it was shown that the Ca deficiency is not the major limiting factor for both varieties (Fig.10-b). The role of high Al as the toxic substance for the growth was confirmed (Fig.10-a), but the role of deficiency of Mg could not be excluded from this experiment (Fig.10-c).

6. The further experiment to clarify the major factor which differentiate the genotypes (whether high Al or low Mg) should be conducted.

References

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TABLE 1. Yield of upland rice at low and high lime application (at La Libertad, 1993)

Amount of lime applied (kg ha^{-1})	Genotype					
	Oryzica Llanos 5	IAC47	Oryzica Llanos 6	CT 9997	CT 10037	Average
			Yield (kg ha^{-1})			
0.3	2730(94)	2170(80)	3460(93)	3600(107)	3770(99)	3150
3	2900	2710	3740	3350	3790	3300
						234[*2]
			$LSD_{0.05}$ = 238[*1]			

[*1] Least significant difference between any means.

[*2] Least significance difference between means of two lime levels averaged over all genotypes.

Figures in the parenthesis are the % ratio to the high lime treatment.

TABLE 2. Effect of dolomitic lime application on the root characteristics of acid soil susceptible (S) and tolerant (T) varieties.

	Variety	Amount of lime applied (ppm) 0	25	50	100
Total root length (m)	Oryzica 1 (S)	42	283	406	514
	Sabana 6 (T)	161	436	538	318
Specific root length (m g-1)	Oryzica 1 (S)	95	63	71	78
	SAbana 6 (T)	69	68	61	49
Root/Top ratio	Oryzica 1 (S)	0.09	0.17	0.15	0.14
	Sabana 6 (T)	0.19	0.18	0.21	0.15

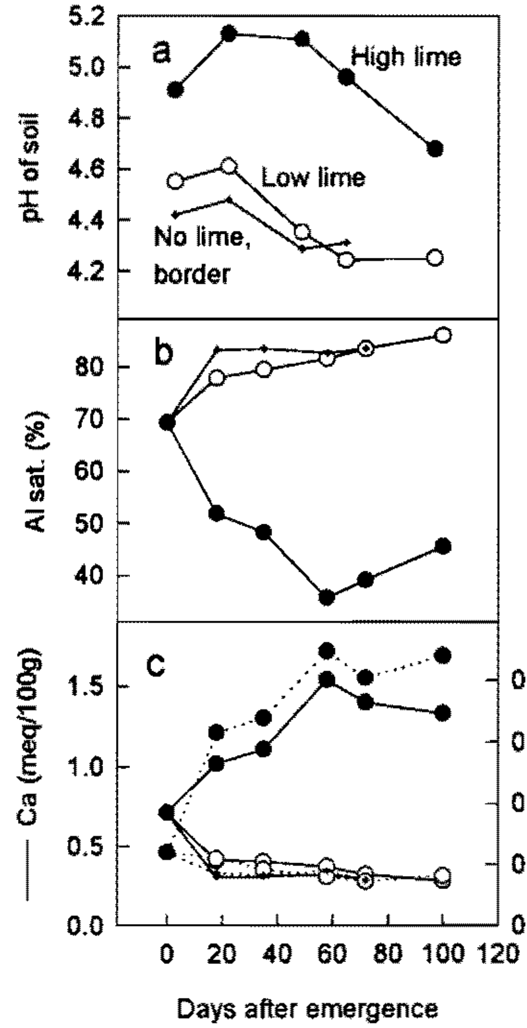


Fig.1. Changes of pH(a), aluminum saturation(b), and exchangeable Ca and Mg(c) of soil(0-20cm) during crop growth.

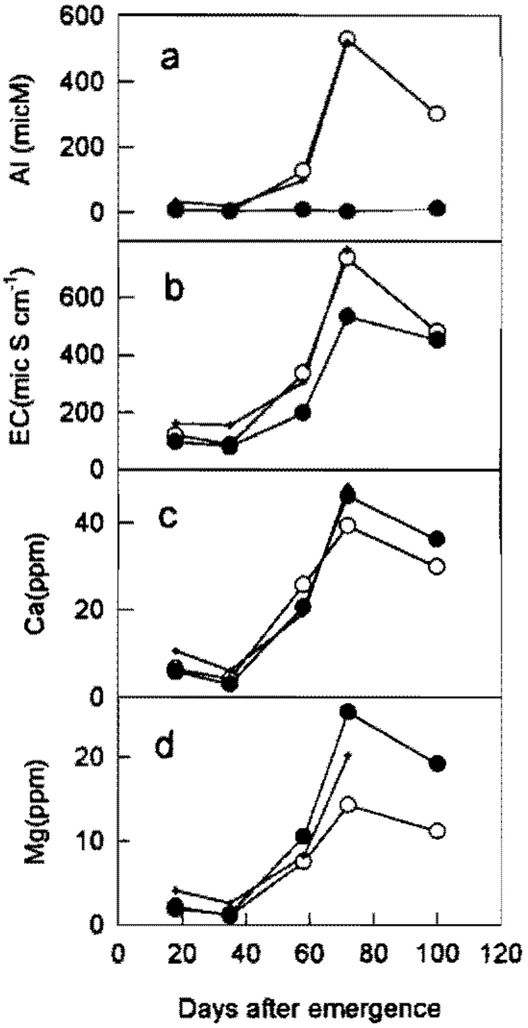


Fig.2. Changes of aluminium concentration(a), EC(b), and Ca(c) and Mg(d) concentration in soil solution (0-20cm) during crop growth. Symbols are the same as in Fig.1.

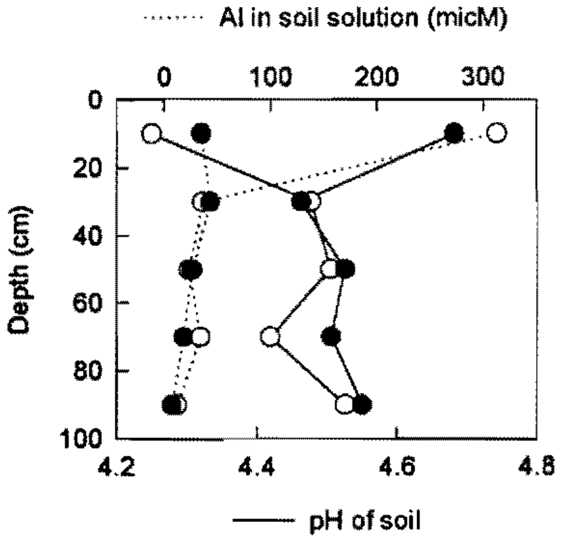


Fig.3 Distribution of soil pH and soil solution Al along soil depth at flowering.
(Symbols are the same as in Fig. 1)

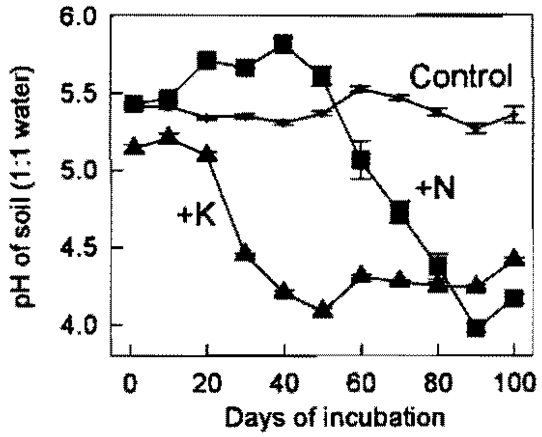


Fig.4.Effect of sequential fertilizers application on pH of a savanna soil (pot exp.)

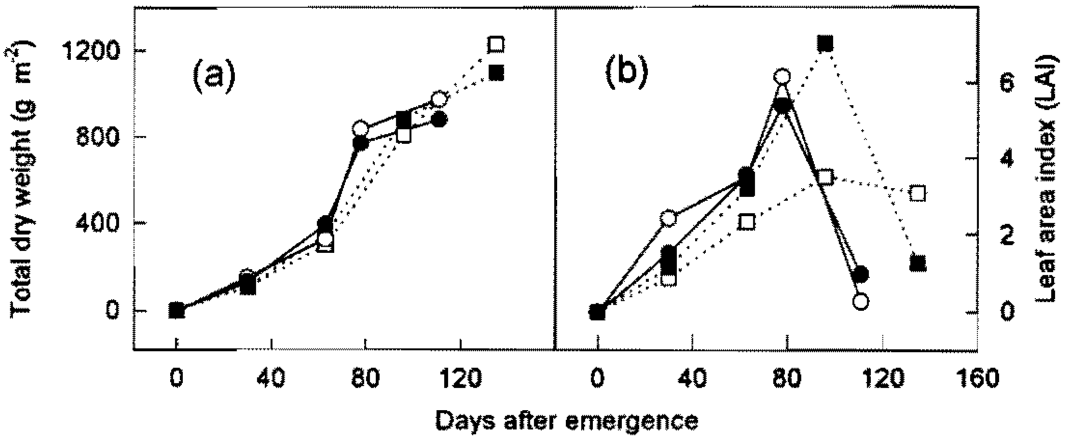


Fig.5. Changes of total dry weight (a) and Leaf area index(LAI) (b) during the growth of acid soil tolerant (circle) and susceptible (rectangle) genotypes with low (white) and high (black) lime application.

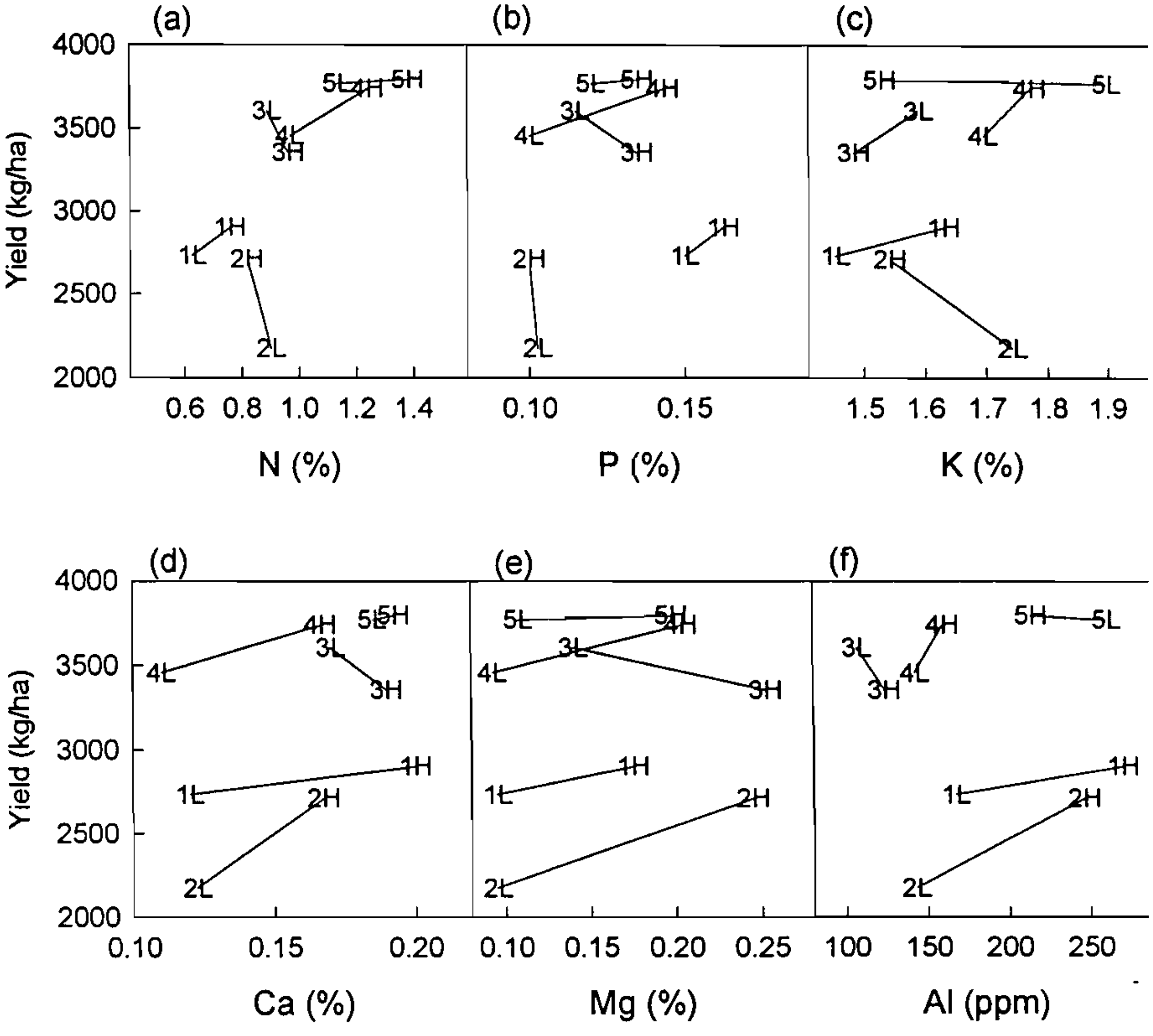


Fig.6. Relationship between element concentration of top at flowering and final yield (in 1993 at La Libertad).

Genotype : 1 - Oryzica Llanos 5
2 - IAC47
3 - CT9997
4 - Oryzica Sabana 6
5 - CT10037

Amount of dolomitic lime applied :
L - 0.3 t/ha
H - 3 t/ha

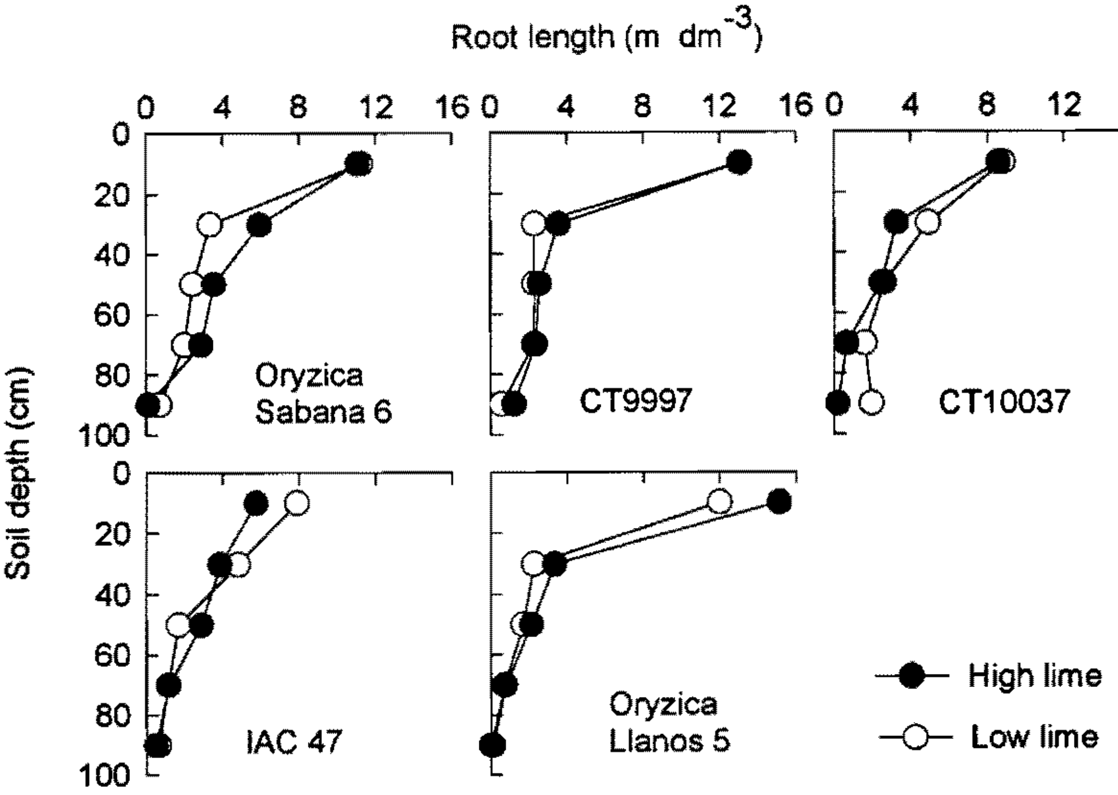


Fig.7. Genotypic difference of upland rice in the root length distribution along depth at flowering. (La Libertad, 1993)

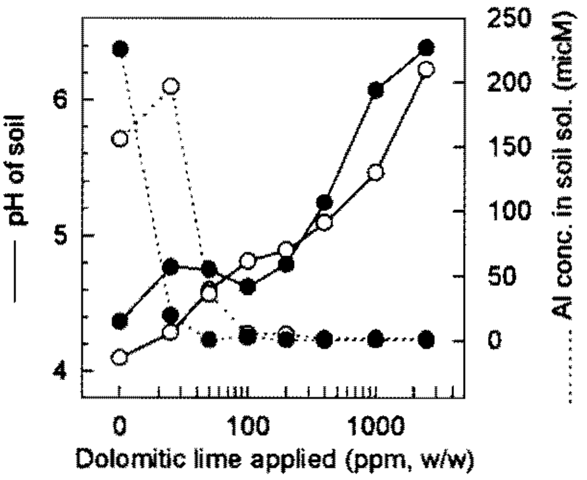


Fig.8. Effect of dolomitic lime application on the soil pH and Al concentration in soil solution for susceptible(○) and tolerant (●) varieties.

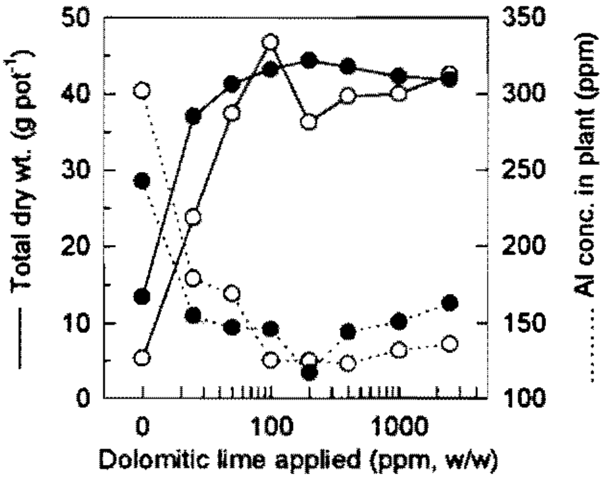


Fig.9. Effect of dolomitic lime application on the total dry weight and Al concentration in the top of upland rice varieties (at flowering). (The symbols are the same as in Fig.7.)

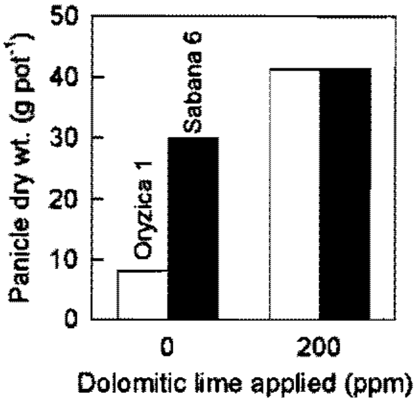


Fig.10. Panicle dry weight of Oryzica 1 (S) and Oryzica Sabana 6 (T) at low levels of lime application.

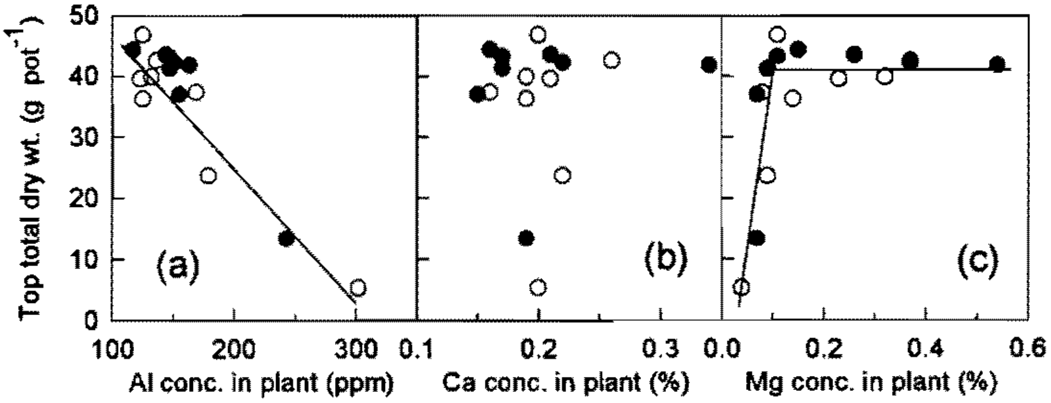


Fig.11. The relationship between top total dry weight and Al (a), Ca (b), and Mg (c) concentration in plant tissue for acid-soil susceptible (Oryzica 1, ○) and tolerant (Sabana 6, ●) upland rice at flowering. (Lines were drawn by hand.)

III. PROJECT 3
DURABLE BLAST RESISTANCE

A. ACTIVITY RP01. BLAST PATHOSYSTEM ANALYSIS AND BLAST RESISTANCE

Abstract. Blast is the most important disease in rice cultivation. Breeding for durable rice blast resistance has been one of the major efforts of the Rice Program in the last five years. Characterization of the genetic structure and virulence diversity of the blast pathogen is allowing rice scientists at CIAT to develop a novel breeding strategy for this type of resistance. The strategy is based on the relationship found between genetic families and virulence factors of the fungus that allows us to identify combinations of resistance genes which have no corresponding combinations of virulence genes in individual isolates of the fungus. The lack of this combinations in the pathogen is associated with the presence of genetic lineages. Resistance derived from this strategy is being demonstrated to be more durable than in the past.

Blast Pathosystem Analysis

Genetic structure and virulence diversity in the rice blast pathogen. The main objective of this activity is to characterize the genetic structure of the blast pathogen, particularly in documenting the hypothesized relationship between lineages identified by MGR-DNA fingerprinting analysis, and virulence in the fungus identified through greenhouse inoculations on different rice genotypes. This is an ongoing activity where blast isolates are recovered during the growing seasons from the Santa Rosa experiment station, La Libertad (ICA) in the Llanos, Altillanura savanna test sites, and other rice growing areas in Colombia. Rice genotypes sampled are: a) parents of breeding lines in the rice program, b) segregating breeding lines, c) potential sources of resistance, d) commercial rice varieties, and e) standard international rice differentials.

More than 100 blast isolates collected in the Altillanura Colombiana were analyzed during 1994 for their virulence spectrum and DNA-fingerprinting. These studies determined that *P. grisea* in this area is highly variable. There were isolates that exhibited a high compatibility frequency attacking 29 out of 48 rice cultivars tested. Table 1 shows the 11 more virulent isolates with their respective compatibility frequencies. However, only 11 isolates infected half or more of the 48 rice cultivars. On the other hand, 66 isolates infected 15 or less of the same cultivars, indicating that most of the isolates in the Altillanura still have a narrow spectrum of virulence. Six isolates infected only one or none of the cultivars.

Virulence frequencies determined for the population of the fungus studied showed the highest compatibility on the cultivars Aichi asahi, Usen, Fanny and Caloro, with virulence frequencies between 69.5 and 95 %. Nine cultivars were susceptible to more than 50% of the isolates while 18 cultivars were resistant to more than 90% of the isolates. There was no rice cultivar susceptible to all isolates, and the virulence frequencies on the cultivars K8, Oryzica Llanos 4 and Oryzica Llanos 5 was zero (Table 2).

A total of 44 international races was determined within the blast population studied, being the race groups IA and IB the most represented (56 and 19%, respectively). This population is characterized for exhibiting races different to those determined in other rice growing areas of Colombia in the past. This difference is most emphasized by the presence of the race group IB which has a low frequency in most parts of Colombia but is frequent in other countries like the USA and the upland rice growing areas of Brazil. The main characteristic of this race group is the presence of virulence factors on the rice cultivar Zenith. These results indicate that part of the blast population found in the Altillanura is not coming from other rice growing areas of Colombia and is most probably a native population. This suggestion has been supported by the lack of virulence of most of the Altillanura blast isolates on the most common commercial rice varieties grown in Colombia (Table 2) as well as by DNA-fingerprinting studies. More than 40% of the isolates tested did not exhibit virulence factors on the most common rice varieties Linea 2, Oryzica 1, and Cica 8. This native population has then probably survived on other grasses or weeds.

Due to the large number of races found in the Altillanura we recommend that the population dynamics of the fungus be studied on the basis of the virulence frequencies on relevant resistant genes and important rice genotypes and not on the race composition of the pathogen. This requires a constant monitoring and studies of virulence shifts in blast isolates collected from different rice sources in the area. On the basis of the virulence diversity found in the blast pathogen in the Altillanura Colombiana, we can consider this site as a potential "hot spot" ideal for breeding for durable blast resistance for the acid soil savannas. This suggestion has been supported by the results obtained in the characterization of the genetic structure of the fungus in this site using DNA- fingerprinting. The selection of resistance genes for a breeding program should be based on those genes for which the virulence frequencies in the whole blast pathogen population is low or tend to zero.

With the objective to group the blast isolates studied for the Altillanura Colombiana we conducted a cluster analysis on the basis of the frequencies of the virulence factors detected in the fungus population. All the virulence diversity was grouped in 24 virulence groups under a similarity coefficient of 75% (Figure 1). Information on the genetic structure of the fungus according to the DNA-profiles determined is also included in Figure 1. In general, the cluster analysis divided the blast population in two big groups with a similarity of 57%. Each of the big groups includes high virulent as well as low virulent isolates. Group 1 includes the virulence groups 1 to 10 with a range in the compatibility frequencies between 19 and 60%; the second includes groups 11 to 24 with a range of 0 to 46% in the compatibility frequencies.

Isolates within groups 1-10 are characterized for exhibiting a wide spectrum of virulence, where isolates belong mainly to genetic lineage SRL-6. Virulence group 10, however, was represented by six genetic lineages in 34 isolates sharing a large number of virulence factors (Figure 1). There was no virulence factor specific to any virulence group since all resistance genes were defeated by at least two different virulence groups (Table 3). Similarly, one international race was present in different virulence groups, although the race group IA predominate within the virulence groups 1 to 10 (Figure 1).

Virulence groups 11 to 24 exhibited in general a narrower spectrum of virulence and lower compatibility frequencies than groups 1 to 10. There was no relation between a genetic lineage and the spectrum of virulence of any group (Figure 1) within the blast pathogen found in the Altillanura. Virulence group 21 was represented by 7 genetic lineages in 33 blast isolates. Although most of the international races that belong to the race group IB were present in this big group, we observed a wide distribution of other race groups in one or several of the virulence groups determined (Figure 1). The only case were virulence factors were specific to a virulence group was for cultivars Cica 9 and Moroberekan, associated with the virulence groups 15 and 20, respectively. However, the number of isolates within each group was low (Table 3).

Table 3 shows that no resistance gene present in the group of cultivars used is effective by itself against the whole pathogen population, however, potential parents can be selected for genetic crosses that would yield resistant progeny combining resistance genes able to exclude all the groups of virulence determined in this study. For example, the genetic cross between the rice cultivars CT 6196-33-10-4-15 and IR 42, should in theory yield segregant lines that combine resistance genes that exclude all the virulence groups of the pathogen (Table 3). These two parents, although infected by 6 and 5 virulence groups, respectively, are not infected by the same virulence group or the same isolate. This indicates, that within the blast population studied, there are no individual isolates that combine virulence factors compatible with both potential parents. In the same way, it is possible to select other parents that would yield similar results.

Table 4 shows the spectrum of virulence for each genetic lineage determined in the pathogen population for the Altillanura. Nine of these lineages were found for the first time in Colombia and then denominated as Altillanura (ALL). As it was indicated in last year annual report, the predominant Altillanura genetic lineages are SRL-6 and ALL-7, with frequency of 50 and 32%, respectively. These two lineages exhibited a wider spectrum of virulence compared to the other lineages (Table 4). The high frequency of the Santa Rosa lineage (SRL-6) can be explained by the flow of spores from the adjacent irrigated and favored upland rice growing areas to the Altillanura. The high frequency of the lineage ALL-7 (not found in other rice areas of Colombia) is probably due to the effect of the resistance genes and/or the germplasm being developed for this ecosystem. While rice germplasm for the traditional rice areas of Colombia has been typically Indica, for the Altillanura predominates Japonica germplasm. It will be important to determine if a selection pressure for this genetic lineage is being imposed on the pathogen population in this ecosystem.

In general, the results found for the Altillanura Colombiana in this study do not suggest a direct association between the virulence spectrum and the genetic structure of the pathogen as we have found for blast isolates from other rice growing areas of Colombia collected on the commercial varieties developed in the last 20 years. This is probably due to the fact that in the Altillanura there has no been a selection pressure on the pathogen population for certain virulence genes since no commercial cultivars or specific resistance genes were released in this area in the past. This suggests that the blast pathogen in the Altillanura has a wide and unknown virulence potential and shifts within this population will depend on the resistance genes released for this ecosystem in the future. It will be very important to monitor continuously any shift in the virulence frequencies as well as the appearance of new virulence genes in order to develop durable blast resistance for the Altillanura.

While lineage ALL-7 exhibited a wide spectrum of virulence, most of the other lineages found and probably native of the Altillanura exhibited a narrow spectrum of virulence. Very few cultivars tested exhibited a specific interaction with a virulence factor found in a genetic lineage. We determined a specific interaction between factors of virulence in the genetic lineages ALL-7, SRL-4 and SRL-2 with the rice cultivars Moroberekan, Colombia 1 and Cica 9, respectively. Although most lineages shared several virulence factors, most of the cultivars are susceptible to less than 50% of the lineages.

As we have hypothesized in the last few years, any isolate within a genetic lineage can express any combination of virulence factors that are expressed in the spectrum of virulence of that genetic lineage by different isolates. If this case is true, the genetic cross suggested above between the cultivars CT 6196 and IR 42 could yield a resistance progeny without stability for blast resistance since the corresponding virulence factors for each progenitor, although present in different virulence groups, are within isolates of the same genetic lineage (Table 4). In this case the compatible isolates belong to the genetic lineage SRL-6. It will be useful to characterize more isolates from this genetic lineage as well as more isolates retrieved from both parents to determine if there are individual isolates that already combine the corresponding matching virulence factors for both parents.

However, other parents can be selected for genetic crosses or as sources of resistance genes that could yield breeding lines that exclude all the genetic lineages of the blast pathogen found in the Altillanura. For example, the cross between the parents IRAT 13 and Tetep should yield rice lines resistant to all the genetic lineages described in Table 4. Other potential parents for blast resistance for the acid savanna soils are being screened under greenhouse conditions with representative isolates of the different genetic families found in the Altillanura.

A total of 16 blast isolates representing all the virulence diversity found in the Altillanura were selected to screen potential parents for blast resistance under greenhouse conditions (Table 5). These isolates belong to six different genetic lineages and were classified in 10 groups of virulence. It is not necessary to include isolates of all genetic lineages since the spectrum of virulence of the genetic lineages not selected is included in those that were selected. As the blast pathogen may have an unknown potential for virulence in the Altillanura, it is recommended that those parents of most interest be planted under field conditions for collection of isolates present in low frequency to determine their virulence capacity and lineage structure. Controlled inoculations with this group of isolates will allow the identification of a true genetic resistance in selected parents as low frequency of compatible isolates under field conditions is common in the Altillanura allowing escapes to natural infection by the pathogen.

Breakdown of the resistance of the first rice variety released for the Altillanura Colombiana, Oryzica Sabana 6, occurred in 1993. DNA- fingerprinting analysis of blast isolates collected on single lesions observed in low frequency in Oryzica Sabana 6 prior to 1993, classified the isolates into the genetic lineage SRL-6. It was assumed that this lineage, SRL-6, would eventually breakdown the resistance of this variety, or would increase in frequency during the expression of a highly susceptible reaction, however, none of these isolates reinfected under greenhouse conditions Oryzica Sabana 6. DNA-fingerprinting analysis of compatible isolates collected during the year of the breakdown, yielded only the genetic lineage ALL-7, and no SRL-6. These isolates reinfected severely under greenhouse inoculations the variety Oryzica Sabana 6 (see last year annual report).

Since the genetic lineage ALL-7 had been detected in the Altillanura prior to 1993, we analyzed if virulence to Oryzica Sabana 6 was already present in the blast population collected during these studies or if a new pathotype and/or mutation was responsible for the breakdown. Table 6 shows that 12 blast isolates collected in the Altillanura prior to 1993 had virulence factors compatible with Oryzica Sabana 6. The isolates had been recovered from 9 different rice cultivars but none from Oryzica Sabana 6. Eight of the isolates had been characterized within genetic lineage ALL-7, while lineages SRL-6, SRL-4, and ALL-12 had one isolate each exhibiting virulence factors to the variety (Table 6). These studies are reporting the presence of virulence factors compatible to the variety Oryzica Sabana 6 in the pathogen population of the Altillanura prior to the breakdown, since this cultivar did not exhibit susceptibility to blast before 1993. The common breakdown occurred in this variety in different sites of the Altillanura during 1993, including sites 200 Km away of the main rice growing areas of the Altillanura, suggest that breakdown was not caused by an increase in frequency of any of the detected 8 ALL-7 isolates compatible with the variety, but a massive change within the whole population of the same genetic lineage present in a high frequency there.

The absence of symptoms exhibited by Oryzica Sabana 6 during 1992 does not allow to think in an increase in frequency of an existing compatible pathotype, supporting the idea of a massive shift in virulence within the genetic lineage ALL-7. If this is true, this observation supports our hypothesis that any isolate within a lineage is able to express any virulence factor present within the virulence spectrum of that lineage. It can not be explained at this time, however, what factors could favor the massive expression of a virulence factor in a large part of the individuals of a genetic family at a particular time in different sites. It could be the response to a climatic factor, or the response to the massive release of a resistance gene. More research needs to be conducted in the future to elucidate this host-pathogen interaction.

We recommend on the basis of the results obtained here, that in order to identify early virulence factors that could play an important role in the breakdown of the resistance of a cultivar, controlled monitoring of the pathogen be conducted not only from isolates recovered from the resistant variety, but from other cultivars planted in nurseries within the area where the resistant variety is grown commercially. More studies need to be conducted on isolates recovered from the cultivar Oryzica Sabana 6 prior to 1993 to strengthen this recommendation. It is also important to determine what will be the stability of this virulence factor for Oryzica Sabana 6 within the blast pathogen and what the frequency in the total population.

These studies continue giving the indication that the Altillanura Colombiana, as it is a new area for growing rice, and where a native blast population exists, is an ideal ecosystem to study and understand mechanisms that determine evolutive factors in the interaction between rice and the blast pathogen.

Testing the lineage exclusion hypothesis .The lineage exclusion hypothesis proposes that resistance genes can be found in rice which "exclude" entire lineages of the blast pathogen from being virulent. Our results have suggested that these genes should be more durable than race-resistance genes because factors which differentiate lineages are hypothesized to be more fundamental, "conserved" characters that are not easily overcome. The hypothesis is based on evidence accumulated to date that there is a high degree of specialization between blast lineages and the rice cultivars they are competent to attack; and that genetic distance is greater between lineages than within. For example, virulent isolates against cultivar Cica 9 are found in only two lineages of the fungus. Resistance genes in Cica 9 presumably protect it against the other lineages. If the hypothesis is valid, breeders could achieve broad-spectrum, durable resistance by crosses planned to accumulate "complementary" sources of resistance, i.e. those excluding all the different lineages.

To test this hypothesis, we need to identify and confirm the activity of resistance genes against particular lineages, and demonstrate that they can be pyramided in crosses, with concomitant pyramiding of resistance. We will test this by "dissecting" the resistance genes in the highly resistant variety Oryzica Llanos 5, and comparing them with genes found in the varieties' ancestors. Oryzica Llanos 5 shows a remarkable durability in resistance over space as well as over time. It has a virtually unmatched degree of resistance when evaluated in several highly blast conducive sites in Asia (Dr. R. Zeigler communication, IRRI). Oryzica Llanos 5 has been inoculated with more than 200 isolates from 19 Colombian genetic lineages at CIAT and with 202 isolates from six genetic lineages from the Philippines at IRRI (Dr. R. Zeigler communication, IRRI) and no compatible isolates have been detected for this variety. We will also study several crosses described in the annual report of 1993 for which different populations are being multiplied in the field.

Table 7 illustrates the susceptibility of the parental lines in Oryzica Llanos 5 pedigree to selected Colombian isolates of all genetic lineages of the blast pathogen. As the table indicates, the resistance in Oryzica Llanos 5 did not come from only one of its ancestors, since all were susceptible to at least some isolates to which the cultivar is resistant (Table 7), and since the lines also show susceptible reaction in the Santa Rosa fields where Oryzica Llanos 5 remains resistant. None of the lineages of the pathogen exhibited compatibility with all of the parental lines. The most virulent lineage was SRL-6, which infects three out of five parental lines, while cultivar Cica 9 and Colombia 1 exhibit specific lineage susceptibility (Table 7).

Table 8 shows the resistance spectra of Oryzica Llanos 5 parental lines to lineages showing compatibilities to at least one parent and the complementarity in resistance with respect to the lineages exhibited by each parent. The resistance in Oryzica Llanos 5 is then most probably multigenic as all its ancestors are susceptible to isolates from Santa Rosa. This type of complementarity in the resistance exhibited to different genetic lineages has been proposed as a possible means of obtaining durable blast resistance. It is however extremely important that for each genetic lineage of the pathogen a large sample of blast isolates collected from different sources be characterized for their virulence spectra to determine which combinations of virulence factors are absent or tend to zero and if those combinations are associated with isolates that belong to different genetic lineages of the pathogen.

Blast resistance. Population improvement methods used in cross-pollinated crops have not been extensively applied to rice. Thirty rice lines of diverse origin were selected as parents because of stability of the reaction to a range of leaf (Bl) and panicle (NBl) blast (*Pyricularia grisea* Sacc.) races during eight growing seasons at a "hot spot" site. Each parent was crossed to five others and each F_1 to three other F_1's to ensure recombination. The resulting seeds were bulked to form the GC-91 gene pool (C0P0).

Two populations were extracted from GC-91 with the following objectives: a) rapid fixation of major genes for high levels of resistance (population C1P1) and b) a combination of major and minor genes for an intermediate level of resistance (population C1P3).

The S_1 and S_2 lines were evaluated at Santa Rosa Experimental Station (SRES), the latter was also planted at Palmira Experimental Station (a blast-free site), and the best lines identified at SRES were crossed in Palmira. The major result during 1994, was the completion of the second cycle of selection, 17 and 21 lines were selected as parents. Each line was crossed to three other lines, three plants were used to represent a line in the crossing process, the bulked seed represents the C2P1 and C2P3, respectively. In the field, during the selection process, when compared to COPO and with the parents of cycle 1, these lines showed higher level of resistance in both cases. In 1995, a structure and multilocational test will be planed to evaluate the genetic progress of the recurrent selection strategies.

Table 1. Compatibility frequencies on 48 cultivars of the 11 most virulent rice blast isolates found in the Altillanura Colombiana, 1994.

Isolate	Cultivars attacked	Compatibility frequency (%)
Linea 6-7-1	29	60.4
Chokoto 7-1	28	58.3
Caloro 1-1	26	54.2
Dular 14-1	26	54.2
Bluebonnet 50-6-1	25	52.1
Oryzica Sabana 6-12-1	25	52.1
IRAT 13-13-1	25	52.1
Oryzica Sabana 6-2-1	25	52.1
Raminad STR 3-24-1	24	50.0
Ceysvoni 20-1	24	50.0
Dular 10-1	25	50.0

Table 2. Virulence frequencies of the Altillanura rice blast pathogen on 48 cultivars.

No.	Cultivar	No. of compatible isolates	Virulence frequency (%)
1	Aichi-Asahi	112	94.92
2	Usen	92	77.97
3	Fanny	85	72.03
4	Caloro	82	69.49
5	Taichun	79	66.95
6	Metica 1	68	57.63
7	Raminad STR3	66	55.93
8	IR 8	61	51.69
9	CICA 4	60	50.85
10	Zenith	58	49.15
11	K 59	58	49.15
12	Oryzica 1	58	49.15
13	Pi No.4	57	48.31
14	K 1	54	45.76
15	BL 1	53	44.07
16	IR 22	53	44.07
17	Kataktara DA2	51	43.22
18	Shin 2	49	41.53
19	Dular	47	39.83
20	CICA 7	47	39.83
21	CICA 6	42	35.59
22	Sha-Tia-Tsao	41	34.75
23	Bluebonnet 50	32	27.12
24	Kusabue	28	23.73
25	Kanto 51	21	17.8
26	Oryzica 3	14	11.86
27	Fujisaka 5	12	10.17
28	Peta	12	10.17
29	Oryzica Sabana 6	12	10.17
30	CT 6196-33-10-4-15	12	10.17
31	IR 42	9	7.63
32	NP 125	8	6.78
33	Fukunishiki	8	6.78
34	Tsuyuake T.C.W.C.	8	6.78
35	Linea 2	7	5.93
36	Chokoto	5	4.24
37	IRAT 13	5	4.24
38	Tetep	4	3.39
39	Ceysvoni	4	3.39
40	Oryzica 2	3	2.54
41	CICA 9	3	2.54
42	CICA 8	3	2.54
43	CT6947-7-1-1-1-7-M (Linea 6)	3	2.54
44	Colombia 1	3	2.54
45	Moroberekan	2	1.69
46	K8	0	0
47	Oryzica Llanos 4	0	0
48	Oryzica Llanos 5	0	0

TABLE 3. Virulence groups and virulence spectra of Altillanura blast isolates on 48 rice cultivars.

	Virulence group																								
Cultivar	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	Total
Aichi-Asahi (Pi-a)	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■		■	■	▨	■	■	■	22
Usen (Pi-a)	■			■	■		■	■	■	■	■	■	■		▨	■	■	■		■	▨	■	▨		18
Fanny	■	■	■	■	▨	■	■	■	■	■	■	■	■	■	■	■	■	■			▨	■	■	■	22
Caloro (Pi-k)		■	▨	■	■	■	■	▨	■	■	■	■	■		▨		■		■	▨	▨	▨	■		18
Taichung T.C.W.C.	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■			▨	■	▨	■	22
Metica 1	■			▨	■	■	■	■	■	■			▨	■	▨	■	■	■		▨	▨		▨	■	17
Raminad Str3	■	■	■		▨		■	■	■	▨	■	■	■		▨			■				■	▨	■	15
IR8	■	■	■	■	▨		■	■	■	■	■			▨	■						▨				13
Cica 4	■	■	■	■	▨		■	■	■	▨	■			▨	■		■								13
Zenith (Pi-z, Pi-a)	■			▨	▨	■	■	▨		▨	■		■			■				■	▨	■	■	■	14
K-59 (Pi-t)	■		■	■			■	■	▨	▨	■		■	■						▨	▨		▨	■	14
Oryzica 1	■	■		■			■	■	■	■		■		▨	▨		■				▨	▨			13
Pi n. 4 (Pi-ta)	■	■	■	■	■	■	■	■	▨	▨					■										11
K1 (Pi-ta)					▨		■	▨		▨	■		■			■	■		■	▨	▨	▨	■	■	14
BL1 (Pi-b)	■	■		▨	■	■	■	■		▨		■			▨						▨				10
IR22	■	■	■	▨	■		■	■	■	▨															9
Kataktara	■	■	▨	▨	■		■	■	▨	▨	■			▨		■			■						13
Shin2 (Pi-k)	■		▨	▨		■	▨	■	■	▨		■	■							▨			▨		12
Dular (Pi-k)	■	■	▨	■	■		■	■	■	▨	■				▨	■									12
Cica 7							■	■	▨	▨		■	▨		▨	■	■	■							9
Cica 6	■	■	■				■	■	■	▨				▨	▨	■	■							■	12
Sha-tiao-tsao (Pi-k)							▨			▨	■	■	■			■			■	▨	▨	▨	■		11
Bluebonnet 50 (Pi-a)	■		▨					▨		▨			■					■		■	▨				8
Kusabue (Pi-k)	■	■	▨				■	■	▨	▨	■		■	▨											10
Kanto 51 (Pi-k)	■	■	▨				■	▨	▨	▨	■	■	▨						■			■			12
Oryzica 3				■			▨	▨		▨									■						5
Fujisaka 5 (Pi-i, Pi-k)											■	■	■						■				■	■	6
Peta	■							▨		▨										▨	▨	■			6
Oryzica Sabana 6	■	■											■					■		▨	▨				6
Ct 6196-33-10-4-15	■							▨								■		■		▨	▨				6
IR42										▨	■		▨										▨	■	5
NP 125	■		▨					▨	▨														▨		6
Fukunishiki (Pi-z)	■							▨		▨			▨										▨		6
Tsuyuake (Pi-k ,Pi-m	■						▨	▨			■	■	■								▨				7
Linea 2	■							▨							▨					▨	▨				5
Chokoto (Pi-k, Pi-a)		■					■				■										▨				4
IRAT 13	■																			▨					2
Tetep (Pi-k)							▨				■								■		▨				4
Ceyavony		■	▨							▨															3
Oryzica 2							■		▨																2
Cica 9															■										1
Cica 8							▨				■										▨				2
Linea 6								▨																■	2
Colombia 1												■	▨											■	3
Moroberekan																				▨					1
K8																									0
Oryzica Llanos 5																									0
Oryzica Llanos 4																									0
Total de cultivares atacados.por cluster	25	19	19	15	16	9	30	32	22	30	22	15	22	11	17	13	11	9	9	16	22	12	18	13	
Isolates No./lineage	1	1	3	2	2	1	2	8	3	34	1	1	2	2	3	1	1	1	1	5	33	3	6	1	

■ Cultivar susceptible to all isolates of the group
▨ Cultivar susceptible to some isolates of the group

TABLE 4. Virulence spectra of 13 genetic lineages of the Altillanura blast pathogen in 48 rice cultivars.

Cultivar	Genetic lineages													
	ALL_7	ALL_8	ALL_9	ALL_10	ALL_13	ALL_15	ALL_16	ALL_18	ALL_19	SRL_2	SRL_4	SRL_5	SRL_6	TOTAL
Aichi-Asahi (Pi-a)	▨	■	■	■	▨				■	■	■	■	■	10
Usen (Pi-a)	▨	▨	■	■	▨					▨	▨	■	▨	9
Fanny	▨	■	■	■	■	■				■	■	■	▨	10
Caloro (Pi-k)	▨	▨	■	■	▨	■			■	▨	■	■	▨	13
Taichung T.C.W.C.	▨	▨	■	■	▨					■	■	■	▨	9
Metica 1	▨	▨	■							▨	■	▨	▨	7
Raminad Str3	▨	▨	■	■	▨					▨	■	■	▨	9
IR6	▨	▨	■							■	▨	■	▨	7
Cica 4	▨	▨	■							■	▨	■	▨	7
Zenith (Pi-z, Pi-a)	▨	▨	■	■	▨						▨	▨	▨	8
K-59 (Pi-t)	▨	▨	■	■	▨					▨	▨	■	▨	9
Oryzica 1	▨	▨	■							▨	▨	▨	▨	7
Pi n. 4 (Pi-ta)	▨	▨	■							■	▨	▨	▨	7
K1 (Pi-ta)	▨	▨	■	■	▨	■			■	▨	■	■	▨	11
BL1 (Pi-b)		▨	■							▨	▨	▨	▨	6
IR22	▨	▨	■								▨	▨	▨	5
Kataktara	▨	▨	■						■		▨	■	▨	7
Shin2 (Pi-k)			■		▨					▨	■	▨	▨	6
Dular (Pi-k)	▨	▨	■							▨		■	▨	6
Cica 7	▨	▨	■							▨	▨	▨	▨	7
Cica 6	▨	▨	■							▨	▨	▨	▨	7
Sha-tiao-tsao (Pi-k)	▨	■		■	▨				■	▨	■	▨	▨	9
Bluebonnet 50 (Pi-a)	▨				▨						▨		▨	4
Kusabue (Pi-k)		▨	■		▨						▨	■	▨	6
Kanto 51 (Pi-k)	▨	▨			▨				■			▨	▨	6
Oryzica 3									■			▨	▨	3
Fujisaka 5 (Pi-i, Pi-k)	▨			■	▨				■		▨	▨	▨	7
Peta	▨										▨		▨	3
Oryzica Sabana 6	▨				▨						▨		▨	4
Ct 6196-33-10-4-15	▨												▨	2
IR42				■							▨	▨	▨	4
NP 125	▨			■									▨	3
Fukunishiki (Pi-z)	▨										■		▨	3
Tsuyuake (Pi-k ,Pi-m)	▨	■			▨						▨	▨	▨	6
Linea 2	▨					■				▨			▨	4
Chokoto (Pi-k, Pi-a)		▨					■					▨	▨	4
IRAT 13	▨													1
Tetep (Pi-k)							■		■			▨	▨	4
Ceysvony											▨		▨	2
Oryzica 2		▨											▨	2
Cica 9										▨				1
Cica 8							■					▨	▨	3
Linea 6														0
Colombia 1											▨			1
Moroberekan	▨													1
K8														0
Oryzica Llanos 5														0
Oryzica Llanos 4														0
Cultivares atacados por linaje	32	26	22	13	17	4	3	0	9	21	31	31	40	
Isolates No./lineage	33	2	1	1	2	1	1	1	1	4	3	2	52	104

■ Cultivar susceptible to all isolates of a lineage
▨ Cultivar susceptible to some isolates of a lineage

Table 5. Rice blast isolates representing all the virulence diversity in the Altillanura.

Isolate	Lineage [1]	Group of virulence	Compatibility frequency (%)
Linea 6-7-1	ALL-7	1	60.41
Chokoto 78-1	SRL-6	7	58.33
Oryzica Sabana 6-12-1	(*)	8	52.08
Ceysvoni 20-1	SRL-4	10	50.00
Aichi-Asahi 17-1	SRL-4	13	43.75
Oryzica Sabana 6-9-1	SRL-2	15	27.08
Zenith 31-1	ALL-7	20	27.08
Ceysvoni 64-1	SRL-6	2	39.58
Caloro 1-1	ALL-8	7	54.16
Zenith 34-1	(*)	8	47.92
Raminad Str3- 24-1	SRL-6	8	52.08
Oryzica Sabana 6-2-1	(*)	10	52.08
Fanny 47-1	SRL-5	11	45.83
Colombia 1-6-1	(*)	12	31.25
CICA 9-38-1	SRL-2	15	20.83
Linea 6-9-1	(*)	20	18.75

1. Lineage determined by DNA-fingerprinting.

* Not determined.

Table 6. Altillanura Isolates of *Pyricularia grisea* compatible with the rice variety Oryzica Sabana 6.

Isolate	Virulence group	Compatibility Frecuency (%)	Lineage	Race	Year Colletion
Linea 6-7-1	1	60.41	ALL-7	IA 4	1991
Ceysvoni 64-1	2	39.58	SRL-6	IA 115	1991
IAC 165-7-1	13	35.52	ALL-12	IA 41	1991
Aichi-Asahi 17-1	13	43.75	SRL-4	IA 45	1991
Bluebonnet 50-3-1	18	18.75	ALL-7	IA 112	1991
IAC 165-5-1	20	14.58	ALL-7	IB 48	1990
Bluebonnet 50-5-1	20	18.75	ALL-7	IB 48	1991
Linea 6-9-1	20	18.75	(*)	IB 46	1991
Zenith 31-1	20	27.08	ALL-7	IB 45	1991
Linea 2-41-1	21	10.42	ALL-7	IB 47	1990
Peta 22-1	21	14.58	ALL-7	IB 45	1991
CT6946-9-1-2-2-1-M-2-1	21	16.67	ALL-7	IB 451990	

Table 7. Susceptibility of parental lines in Oryzica Llanos 5 pedigree to selected Colombian isolates of *Pyricularia grisea* from 13 genetic lineages. [1]

Parental lines[2]	MGR lineage susceptibility[3]	Isolates tested in greenhouse (No.)	Greenhouse evaluation[4] Reaction	Greenhouse evaluation[4] Maximum disease severity (%)	Maximum field reaction[5]
CICA 9	SRL-1	10	S	45	8
	SRL-2	10	S	64	
IR 36	SRL-5	10	R/S	16	9
	SRL-6	10	R/S	45	
CICA 7	SRL-3	6	R/S	6	8
	SRL-4	6	R/S	12	
	SRL-6	10	S	45	
5685	SRL-5	10	R/S	20	5
	SRL-6	10	R/S	82	
Colombia 1	SRL-4	6	R/S	10	7

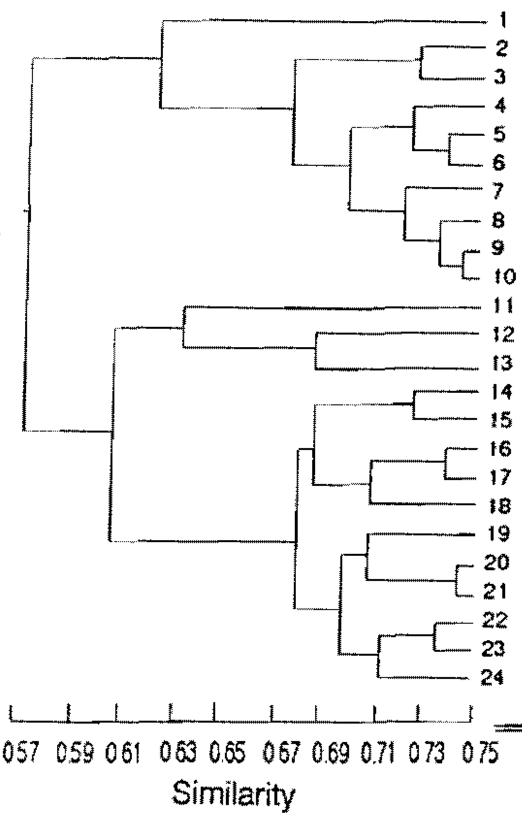
1. Lineage defined by similarity of banding pattern when probed with the repetitive probe MGR586 as described by Levy et al., 1993, and Correa et al., 1994. Lineages used were: SRL-1, SRL-2, SRL-3, SRL-4, SRL-5, SRL-6,ALL-7 (10 isolates), ALL-8 (2), ALL-9 (2), ALL-10 (6), ALL-11 (2), ALL-12 (2), ALL-13 (8).
2. The five closest parental lines in Oryzica Llanos 5 pedigree. Oryzica Llanos 5 exhibited an immune reaction to all isolates tested in the greenhouse.
3. Compatibility of lineage with parental line. Lineages not shown in table exhibited an incompatible reaction.
4. Reaction: R= all isolates incompatible with the parent in question. R/S= some isolates compatible and others incompatible with parent in question; S= all isolates compatible with the parent in question.
5. According to the Standard Evaluation System for rice (SES), where 1 = no disease; 9 maximum disease.

Table 8. Resistance spectra of Oryzica Llanos 5 parental lines to lineages showing compatibilities to at least one parent.

Parent	Lineage [1] SRL-1[2]	SRL-2	SRL-3	SRL-4	SRL-5	SRL-6
IR 36	R[3]	R	S	S	R	S
CICA 7	R	R	S	S	R	S
CICA 9	S	S	R	R	R	R
5685	R	R	R	R	S	S
Colombia 1	R	R	R	S	R	R

1. Lineages described by similarity of MGR586 DNA fingerprintings (Levy et al., 1993).
2. R= all isolates tested showed incompatible reaction; S= some isolates showed incompatible reactions and others were compatible.
3. Number of isolates per lineage: see Table 7.

Figure 1. Virulence groups of the blast pathogen in the Altillanura of Colombia.



Group	Number of isolates	Compatibility frequency (%)[a/]	Lineage	Race
1	1	60 41	ALL_7	IA4
2	1	39 58	SRL_6	IA115
3	3	25.00 - 35.52	SRL_6	IA84, IA116, IA127
4	2	29.17 - 33.33	SRL_6	IB39. ID7
5	2	25.00 - 29 17	SRL_6	IA39 ID7
6	1	18.75	SRL_6	IB63
7	2	54 16 - 58.33	SRL_6, ALL8	IA33, IA35
8	8	45.83 - 54.16	SRL_6	IA4, IA35, IA36, IA39, IA103
9	3	31.25 - 39.58	SRL_6	IA71, IA99. IA103
10	34	29 17 - 52.08	SRL_6, SRL_2. SRL_4. SRL_5, ALL_7, ALL_9	IA37, IA39, IA47, IA99,IA101, IA103, IA109, IA111. ID7, ID13
11	1	45.83	SRL_5	IA33
12	1	31.25	(*)	IA105
13	2	35.25 - 43.75	SRL_4, ALL_12	IA41, IA45
14	2	12.50 - 20 83	SRL_6. ALL_7	II-1
15	3	20.83 - 27.08	SRL_2	IA128, ID8, ID16
16	1	27.08	ALL_7	IB38
17	1	22.92	SRL_6	ID15
18	1	18.75	ALL_7	IA112
19	1	18.75	ALL_19	IF1
20	6	14 58 - 27 08	ALL_7	IB45. IB46, IB48,
21	33	00 00 - 16 67	SRL_6, ALL_7. ALL_ 8, ALL_12, ALL_15, ALL_16, ALL_18	IB46, IB47, IB48, ID13, ID15, ID16, IG2, IH1, II-1
22	3	18.75 - 22.92	ALL_7	IA41, IA43, IA44
23	6	18 75 - 27.08	SRL_6, SRL_4, ALL_10, ALL_17,	IA13, IA61, IB13,
24	1	27.08	(*)	IA64

[a/] Percentage of 48 cultivars attacked by the pathogen.

* Not determined.

IV. PROJECT 4
RICE TRAITS FOR ENHANCED COMPETITIVENESS

A. Activity RP52. Rice Traits for Competing with an Associated Pasture

Abstract. Rice traits to resist the competition of an associated pastureRice-based systems are relevant agropastoral alternatives for the acid-soil savannas. Competition between rice and some of the associated pastures can take a 5-30% toll on rice yields. Basic understanding of the mechanisms involved in rice-pasture competition is needed to guide breeding for specific key rice traits to withstand pasture interference. For this purpose, work was conducted in the Colombian Llanos, involving above- and below-ground growth analysis for eight rice cultivars and *Brachiaria decumbens,* also measuring PAR interception, and estimating root mass of both species using carbon isotope discrimination analysis. Under favourable rainfall (1585 mm) and nutrition, competition was mainly an above-ground process of light capture, starting only once the pasture became taller and leafier than rice 45-days after emergence (dae). Whereas rice height and root growth were not related to competition effects, LAI and PAR interception were strongly correlated with pasture suppression, and would thus be key traits in selecting for rice competitiveness against seedling *B. decumbens.* These traits must be recorded on rice growing in competition, and screened for after 45 dae. This work is sponsored by the British ODA, involving also CNPAF/EMBRAPA in the Brazilian Cerrado.

Objectives and Procedures

Improved sustainable agropastoral systems are an escape valve in many tropical countries as alternatives to further expansion of their agricultural frontiers into fragile environments such as the rain forests. Successful agropastoral alternatives are being developed for the savannas adjoining the margins of the rain forest. These are rice-based systems, where improved rice varieties act as the trigger that sets off the adoption of the whole rice-pasture system. The breeding of high-yielding rice varieties adapted to such environments is a recent achievement. More needs to be known about the crop-pasture interaction effects on rice performance. It has been observed that competition between rice and some of the associated pastures can take a 5-30% toll on rice yield potential, depending on the growth habit of rice and the intersown pasture. Rice traits for competitiveness against an associated pasture are poorly, and empirically , understood. Until now upland rice breeding has been conducted under monocrop conditions. Small numbers of advanced lines have been tested in a pasture association, but these empirical observations need to be strengthened by a better basic understanding of the mechanisms involved, leading to principles that could guide selection for specific key traits early in the breeding process. We need to know what specific traits are important, what are the tradeoffs among them and how they can be efficiently selected for. CIAT has acquired experience in rice-weed interactions (Fischer, 1993 and Fischer et al., 1993, 1994) which can serve as a perspective to expand our understanding of the rice/ pasture association. The present work is sponsored by an O.D.A. grant, and is conducted in partnership with CNPAF in Goiania, Brasil.

The work we report here was conducted at the I.C.A. Experiment Station at La Libertad, in the Colombian Llanos, seeking to understand the morpho-physiological implications for a successful rice pasture association, in terms of rice productivity and good pasture establishment, and to identify those traits that allow rice to withstand pasture competition.

Eight upland cultivars (Colombia 1, Line 2 (CT 6196-33-10-4-15-M), Oryzica Sabana 6, CT 10037-9-7-M-1-M, IRAT 216, TOX 1010-45-1-1, RHS 107-2-1-2TB-1JM, LINE 3 (CT 6196-33-11-1-3)) were grown (70 kg seed/ha) on an acid oxisol (4.4 % organic matter, pH 4.9, 4.6 ppm P, 0.21 meq/100 g Ca, 0.07 meq/100 g Mg, 0.08 meq/100 g K, 90.3 % Al saturation) in monocrop and in competition with *Brachiaria decumbens* (1.5 kg seed/ha). The experiment was fertilized with 300 kg/ha dolomitic lime, 60 kg P_2O_5/ha, 60 kg K_2O/ha, and 75 kg N/ha. Treatments were arranged within a randomized complete-blocks design with split plots and four replications. Competition or monocrop were the main plots treatments, and the cultivars were in the $47m^2$ subplots. Above- and below-ground rice and pasture parts were sequentially sampled. Rice and *Brachiaria* root dry matter were separated using the carbon isotope discrimination technique (Svejcar and Boutton, 1985). Percent PAR interception was determined for rice plants growing in competition by reading the incoming radiation above and below the rice canopy (after removing the pasture growth between two rice rows).

Competition Effects

Onset of interference. Interference, presumably competition (Radosevich and Holt, 1984), became evident in rice at the 45-dae[1] sampling (Figure 1). After which time, rice biomass, leaf area index (LAI), and tillering were reduced with respect to their growth in monoculture (Figure 1). Plant height was a growth parameter much less affected by the pasture's competition, and would no be a reliable indicator of rice-pasture interaction. Competitive growth reduction appeared somewhat later in the pasture (Figure 2), since its emergence and initial growth occurred somewhat later than with rice.

Growth parameters affected. Biomass, LAI and tillering were parameters that registered the onset of competition at the same time (Figure 1). The depressive effects of competition on those parameters was stronger in the least competitive cultivar (Colombia 1) than in Linea 3 which was the most competitive material (Figure 1). Reduction of rice growth due to *B. decumbens* competition became measurable only when the pasture developed a similar or higher LAI, and became taller that rice (Figure 3), i.e. when the pasture had an advantage to compete for light.

Root growth, either in monoculture or in competition, did not reflect the outcome of competitive interaction between both species (Table 1), reaffirming that under favourable rainfall (1585 mm from May to September) and nutrition, interference in this system would be mainly an aboveground process of light capture. Data in Table 1 also suggests that resource allocation to very deep rooting may weaken rice competitive ability, possibly by interfering with canopy growth.

Traits for screening. Correspondingly with Figures 1-3, correlations between rice and pasture growth became significant only after 63 dae (earlier non-significant correlations not shown) (Table 2). The pressure of the pasture depressed rice yields and growth, however light interception by rice canopies reduced pasture growth (Table 2). Competitive rice genotypes were those intercepting most incoming radiation (Table 3). LAI, followed by tillering were the rice canopy attributes most closely associated with PAR (photosynthetically active radiation) interception (Table 2). Since rice height exhibited little change under competitive pressure, and was poorly correlated with pasture growth inhibition and canopy PAR interception (Table 2), rice biomass, LAI and tillering would be the criteria for selecting competitive rice cultivars. Since light interception, which strongly correlated with LAI, was the parameter with the strongest effect on pasture growth inhibition (Table 2), it follows that a measure of LAI or of canopy light interception would be the two best criteria for screening rice for competitiveness against seedling *B. decumbens*. However, such selection criteria are valid only when they are recorded with both species competing. The same parameters measured in monoculture bore little relationship with rice competitiveness (Table 4).

The relatively late onset of competition implied that early screening for the above traits of rice competitiveness would not be reliable. Total rice biomass and leaf area, recorded in competition at 63 dae, were the earliest reliable indicators of rice competitiveness recorded (PAR interception was determined only at 90 dae) in this experiment (Table 5).

Biomass Partitioning

The harvest index (HI), as it is commonly used, relates to a genotype's partitioning of photosynthates into commercial yield. Much of the effort to improve rice plant types seeks to increase HI. Tall and leafy cultivars can be more competitive, but self shading and increased respiration usually result in lower HI values. In our case, HI was affected by competition, and HI under competition could not be predicted from monoculture values ($r=0.16$, $P>0.05$). Competitiveness (yield in competition/yield in mococulture) was associated with high HI when rice was grown in competition with *Brachiaria brizantha* ($r=0.87$, $P<0.1$), and with lower reduction of monoculture HI by competition ($r=0.91$, $P<0.01$).

Concluding Remarks

Linea 3 was the highest-yielding cultivar when growing together with *B. decumbens*, and the most competitive against this species (Table 3). However, rice can be a strong competitor, and still allow for considerable pasture production. Thus, Oryzica Sabana 6 fetched a similar yield as Linea 3, but tolerated more pasture growth (Table 3), highlighting its suitability for this kind of intercropping. According to the above results it would seem that productive rice plant types can have the means to compete with, or tolerate an intersown species such as *B. decumbens*. The need for more competitive, taller and leafier plants, that usually have less efficient plant types (Jennings and Aquino, 1968), does not appear to be justified at this point with the rice-pasture associations being developed for the acid-soil savannas of Colombia.

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Table 1. Correlations between rice root parameters determined in monoculture and in competition with *Brachiaria decumbens* biomass at 90 days after rice emergence, when this species grew in competition with rice.

Root parameter	Depth (cm)	Monoculture	Competition
Root length density		---------------- r ----------------	
	0-20	0.68	-
	20-40	0.38	-
	40-60	0.21	-
	60-80	0.03	-
	80-100	0.89	-
	0-100	0.79	-
Root mass [1]			
	0-20	0.21	-0.12
	20-40	-0.10	-0.10
	40-60	-0.27	0.16
	60-80	-0.29	0.86 **
	80-100	0.71 *[2]	-0.43
	0-100	0.14	-0.08

1. Root mass in competition was determined at harvestime.
2. * = $P < 0.05$, ** = $P < 0.01$.

Table 2. Correlations between rice and pasture parameteres when both species grew in competition.

		d.a.e. [1]	
Y	X	63	90
Rel. rice yield	Pasture biomass	0.48	-0.86 ** [2]
Rel. rice biomass	Pasture biomass	-0.38	-0.79 * [3]
Pasture biomass	PAR interception by rice	-	-0.78 *
" "	Rice LAI	-0.79 **	-0.71 * [3]
" "	Rice tillering	-0.27	-0.67 [4]
" "	Rice height	0.12	0.36
" "	Rice biomass	-0.70 *	-0.77 * [5]
PAR interception by rice	Rice LAI	-	0.90 **
	Rice tillering	-	0.79 **
	Rice height	-	0.51

1. Days after emergence.
2. * = $P < 0.05$, ** = $P < 0.01$.
3. $X' = \ln(X)$
4. $Y' = \ln(Y)$
5. $Y' = 1/Y$

Table 3. Biomass of *Brachiaria decumbens*, growth parameters and PAR interception at 90 d.a.e., and yield of eight upland rice cultivars when both species grew in competition.

Rice cultivar	Yield (kg/ha)	Rice biomass (g/m^2)[1]	Height (cm)	Tillers (g/m^2)[1]	LAI	Pasture biomass (g/m^2)[2]	PAR Interception (%)
Colombia 1	870	477	84	253	1.70	873	0.23
Linea 2	1208	389	74	210	3.10	396	0.20
O. Sabana 6	1975	344	78	278	2.90	356	0.14
CT 10037	1687	429	83	224	3.50	257	0.14
IRAT 216	1749	390	65	261	4.20	563	0.14
TOX 1010	814	328	74	204	1.70	386	0.21
RHS 107	279	280	85	170	1.50	758	0.27
Linea 3	2063	620	74	373	5.40	118	0.11
LSD	403	163	9	46	0.50	163	0.05
CV (%)	20	11	8	13	11	24	20

1. Days after emergence.
2. Dry matter.

Table 4. Correlations between rice parameters determined in monoculture (90 days after rice emergence) with pasture biomass, and relative rice yield in competition.

X (monoculture)	Y_1 Pasture biomass	Y_1 Rel. rice yield
	r	r
PAR interception	0.42 ns [1]	-0.62 ns
LAI	-0.30 "	0.00 "
Tillering	-0.20 "	0.39 "
Rice height	0.24 "	-0.30 "
Rice biomass	0.67 "	-0.50 "

[1] ns $P > 0.05$.

Table 5. Correlations between sequentially-recorded rice growth parameters and the biomass of *Brachiaria decumbens* harvested 90 days after rice emergence, when both species grew in competition.

Growth parameter	d.a.e.[1] 10	20	30	45	63
LAI	-0.27	-0.54	-0.53	-0.57	-0.85**[2]
Tillering	-0.48	-0.87**	-0.65	-0.29	-0.30
Height	0.05	0.32	0.35	-0.07	0.27
Biomass	-0.34	-0.65	-0.43	-0.63	-0.83**

1. Days after emergence.
2. $P < 0.01$.

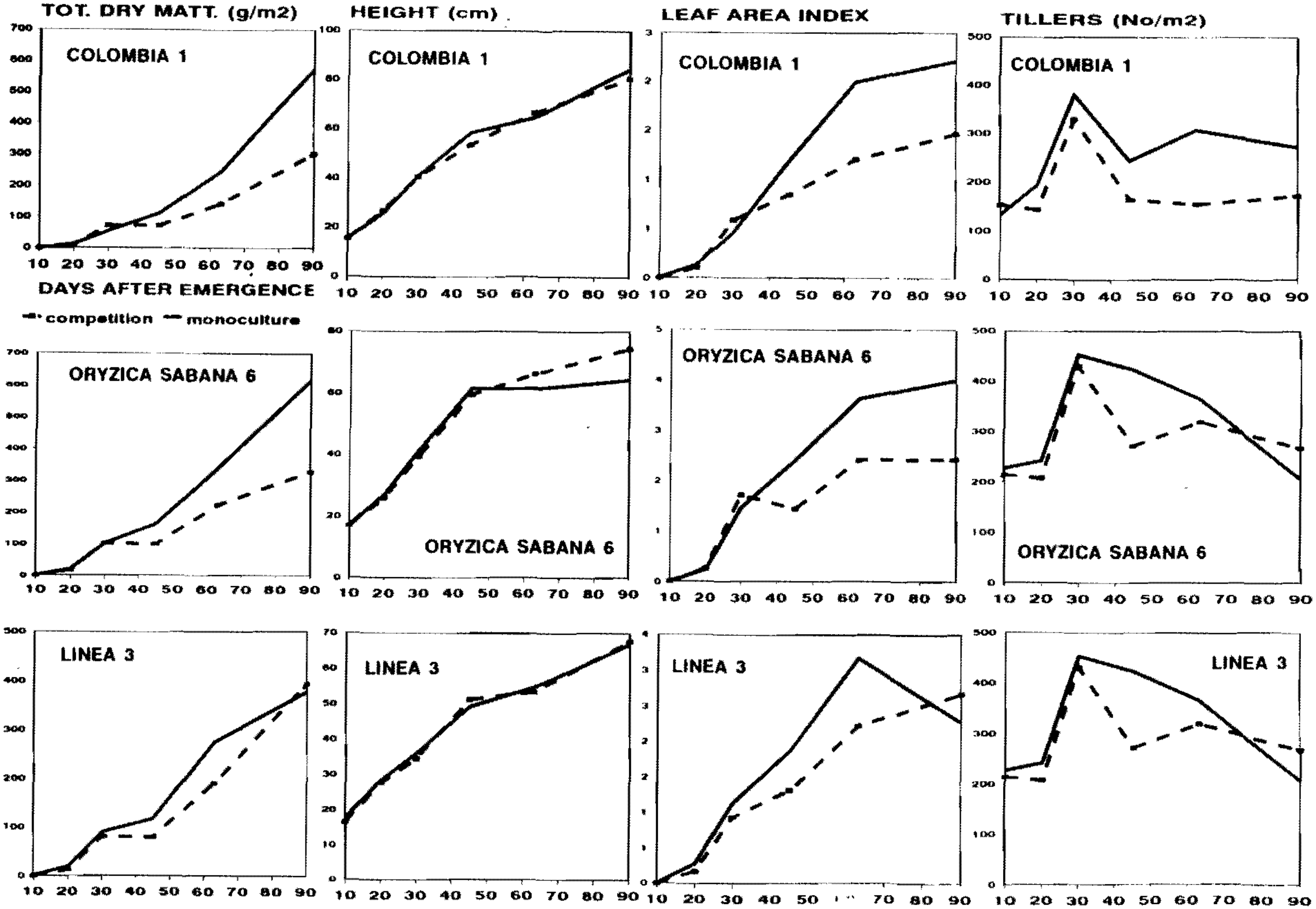
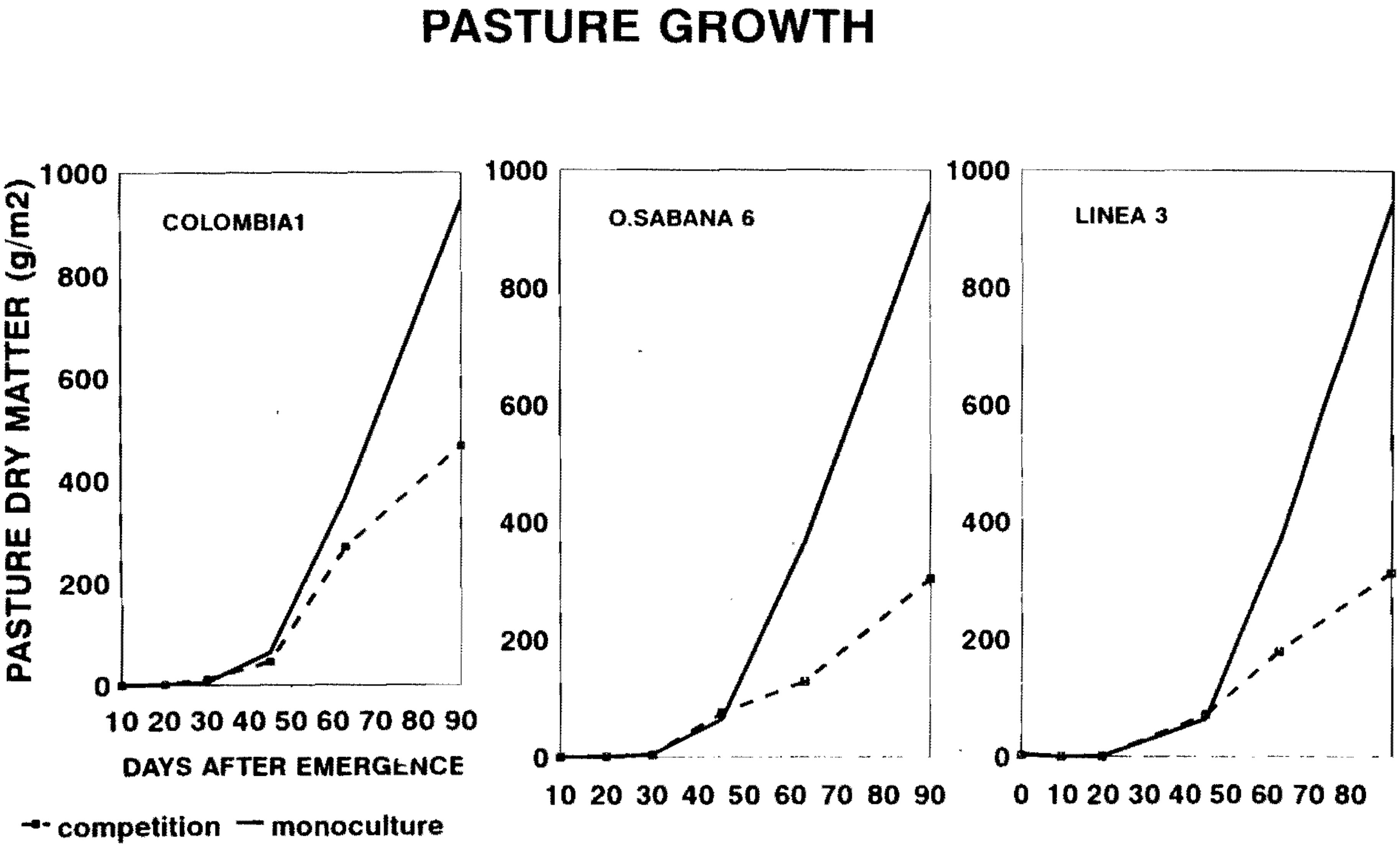


FIGURE 1. Biomass, height, leaf area index and tillering of three upland rice cultivars recorded sequentially in monoculture and in competition with *Brachiaria decumbens*.



PASTURE GROWTH

FIGURE 2. Sequential biomass of *Brachiaria decumbens* in monoculture and as affected by the competition of

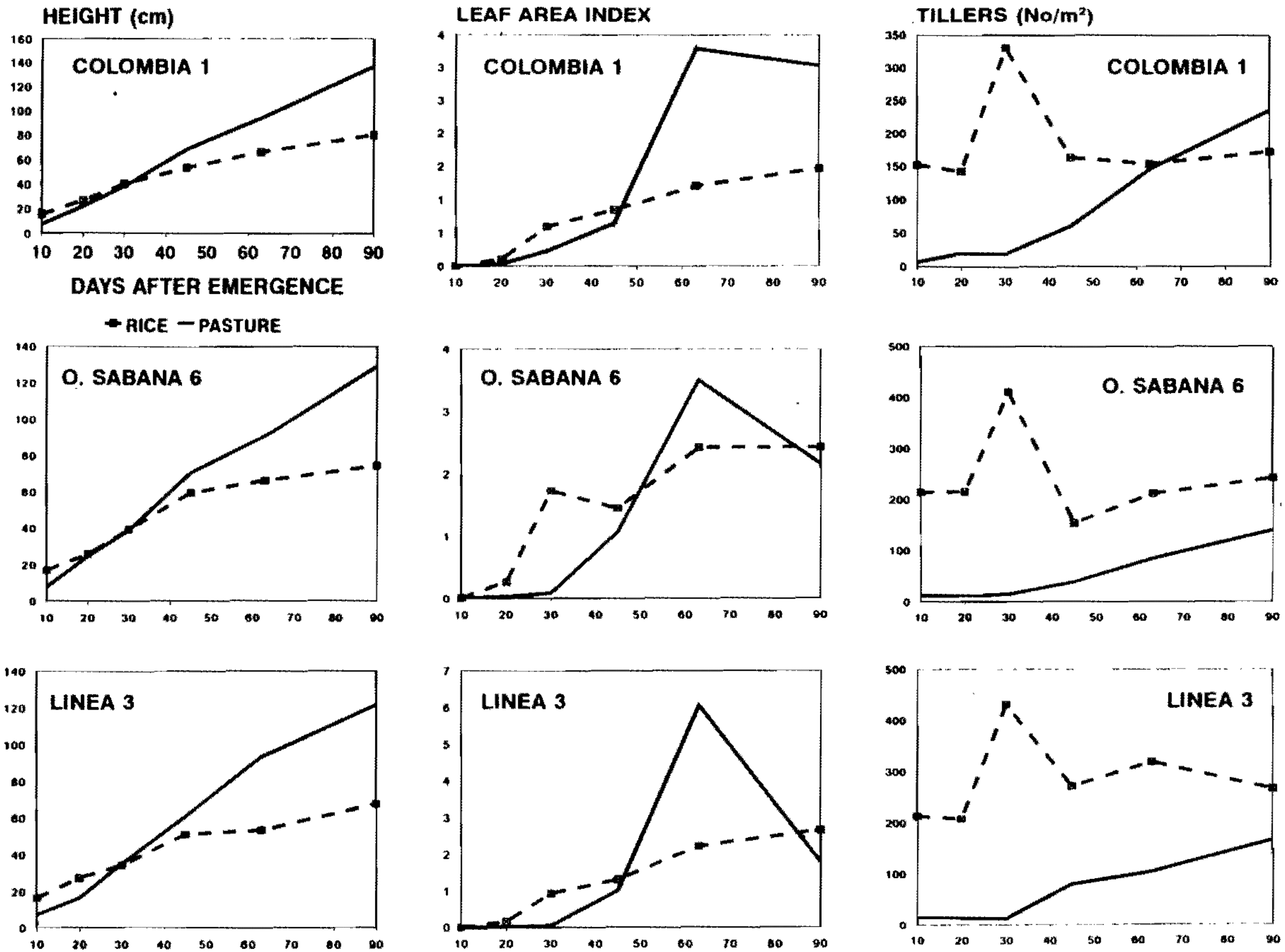


FIGURE 3. Sequential height, leaf area index and tillering of *Brachiaria decumbens* and three upland rice cultivars when both species grew in competition.

B. Activity RP02. Genotypes for water seeding

This activity seeks to identify genotypes with the ability to emerge through a water layer, or "anaerobic seeding tolerance", by i) acquiring the putative tolerant germplasm identified by IRRI (Dr. Yamauchi), ii) acquiring the screening technique developed at IRRI, and iii) screening the germplasm, plus CIAT lines.

Background

Latin America is in the midst of a dynamic transition in irrigated rice seeding systems. Building on IRRI work, we are attempting to assist this transition through genetic improvement.

Direct seeding onto the surface of puddled soils is becoming increasingly common because it is more efficent and economical than transplanting and gives better weed control than seeding into dry soil. A water layer is a highly effective, environmentally-benign weed control agent.

A major bottleneck in this transition is the lack of tolerance of rice of saturated, anaerobic conditions during seedling emergence. Seedlings need oxygen to respire and support growth, yet tropical water temperatures reduce the oxygen holding capacity of water and stimulate microbial growth which further consumes oxygen in the seedling zone. Poor stand establishment is the result. Farmers try to deal with this constraint by draining the water off their paddies during the seedling establishment period. However, this is costly in terms of adding another farm operation and in water wastage, and the drained water carries away soil and nutrients. Furthermore, imperfect leveling causes numerous puddles which result in pockets of stand failure and weeds despite field-scale drainage.

Yamauchi (1993) at IRRI addressed this problem by screening 660 germplasm accessions, including 256 lines from IRRI's International Rice Germplasm Center (IRGC) and 404 advanced but diverse breeding lines from INGER. He noted large differences in the ability to emerge through a water layer. If confirmed, this germplasm and screening technique could be a valuable addition to LAC irrigated breeding efforts.

Results

Seed of 124 rice lines was requested and received from IRRI on 29 April 1993. Colombian quarentine regulations in force at the time required that they undergo a severe heat treatment for control of grain discoloration bacteria. Following the treatment, they were sown in pots for seed increase on 9 June 1993. There was no germination for nearly all the lines. Apparently the heat treatment had killed the seed.

Following this problem, negotiations were pursued among CIAT, ICA (quarentine) and IRRI to try to find a solution. It was agreed that if IRRI would inspect and certify that the seed is free of these bacteria, the heat treatment could be foregone. Another seed set was requested on 9 September 1993, but the IRGC was undergoing a major re-organization which caused a considerable delay in being able to service this request. The second set, of 104 IRGC lines (the INGER lines were not received this time), was received on 20 April 1994.

These were supplemented with a number of other lines from CIAT and IRRI, particularly lines reputed to exhibit early vigor and weed competitiveness, which may or may not be traits related to anaerobic seeding tolerance. The majority were sown for seed increase on 13 May 1994. Large differences in vigor after emergence were apparent, although this was not a trial geared to collect data but rather to multiply seed. There is enormous diversity in morphological and agronomic characters in this germplasm set. Additional interesting lines were gathered over time and were sown for increase over the period 13-25 July. By the end of 1994, 1-7 kilograms of high quality fresh seed of each line was available for testing.

The total set of lines for testing now numbers 132. Efforts continue to acquire more promising lines. Screening technique development (Dr. A. Fischer) and screening is expected to commence in early 1995.

References

Yamauchi, M.; A. M. Aguilar; D. A. Vaughan, and D. V. Seshu. 1993. Rice (*Oryza sativa L.*) germplasm suitable for direct sowing under flooded soil surface. Euphytica, 67:177-184.

V. PROJECT 5

DIVERSIFIED *TAGOSODES*/RICE HOJA BLANCA VIRUS

Introduction

Rice hoja blanca virus (RHBV) causes severe recurrent epidemics in the Andean, Central American, and Caribbean countries of tropical America. A severe infection in susceptible varieties can cause losses of up to 100%. The planthopper insect *Tagosodes oryzicolus* (Muir) is a serious pest of rice that causes direct damage and is also the vector of RHBV. Since there is limited distribution of the varieties that are resistant to both the vector and the virus much of the crop is at risk. Many widely grown commercial varieties are resistant to the vector but are susceptible to the virus. The direct damage that is caused by the planthopper combined with the uncertainty of epidemics induces farmers to spray up to 5-6 times to control this planthopper vector of RHBV. In advanced lines and commercial varieties that have parentage for CIAT lines the resistance to the virus is from a single source. There is a need to identify and incorporate additional sources of resistance into rice germplasm pools to ensure stable and durable resistance. Moreover, the current source of resistance does not react equally with different vector/virus complexes. This project investigates this serious insect pest and it's relationship with RHBV.

A. ACTIVITY RP03: CHARACTERIZATION OF SOURCES OF RESISTANCE TO RHBV

Abstract. There are reports from Tolima in Colombia that the variety Llanos 5 is more susceptible to RHBV than previously thought. It was confirmed that even traditional genotype used as a source of resistance to RHBV, rice is susceptible when plants are juvenile. The most important finding, however, is that the CIAT rice resistant varieties are more susceptible when tested with the Tolima colony and virus isolate as compared with the CIAT colony and virus isolate. Although Colombia 1 remains an important source of RHBV resistance in the CIAT RHBV breeding program, changes in the selection strategy are being implemented to make the selection process more rigorous. These findings emphasize the importance of broadening the genetic basis of resistance to RHBV.

Research Activities

There are reports from Tolima in Colombia that the variety Llanos 5 was more susceptible to RHBV than previously thought. In Tolima, there have been fields of Llanos 5 that have from 5-15% of the plants infected with RHBV. This was surprising since Llanos 5 has Colombia 1 as the source of RHBV resistance and is characterized as highly resistant to RHBV infection. A set of experiments were performed to test the susceptibility of rice seedling to RHBV using the CIAT Tagosodes colony and virus isolate. This is the colony that has been used for several years to screening germplasm for resistance to RHBV. The results showed that the resistant varieties of Colombia 1, Blue Rose, and Llanos 5 were more susceptible when they are inoculated at 10-15 days post planting, and are highly resistant 20-25 days post planting. The varieties IRAT-124 and Oryzica 1 showed higher rates of infection at 10-25 days after inoculation. Bluebonnet 50 was the susceptible control and over 80% of the plants became susceptible at each date of inoculation. This data confirms that even rice with resistance to RHBV is susceptible when they are juvenile.

A colony of Tagosodes from the Tolima region was established and viruliferous planthoppers were selected. The colony was infested with the RHBV isolate from the Tolima region. A series of experiments were made to compare the CIAT colony and virus isolate with those from Tolima. The results of one experiment involving eight varieties are shown in Table 1. The most important finding is that the CIAT resistant varieties are more susceptible when they are tested against the Tolima colony and virus isolate as compared with the CIAT colony and virus isolate. For the varieties Colombia 1 and Llanos 5, the number of infected plants were significantly higher when they are challenged using the Tolima vector/virus complex than the older CIAT colony. The variety Colombia 1 was the variety most resistant to RHBV, and is still considered an important parent for RHBV resistance breeding. Llanos 5 was highly susceptible 20 days after planting and only showed moderate resistance 25 days after planting. Even then 17% of the plants became infected with RHBV using the Tolima colony.

Since the variety Llanos 5 has been widely grown in the field, the resistance to RHBV has been less than expected. The plants have a stage where they are susceptible to infection with RHBV. The utility of this variety may be extended by a single insecticide spray after the seedling emerge. This variety is RHBV resistant and Colombia 1 remains an important component in the CIAT RHBV breeding program.

Table 1. A comparison of eight rice varieties inoculated at five day intervals after planting. The CIAT colony is control vector/virus complex and is compared to a newly established colony with planthoppers and virus isolate collected from the Tolima valley. The percentages (%) were calculated by dividing the plants infected by the total number or plants in the individual trials.

	CIAT Colony Inoculation date*				Tolima Colony Inoculation date*			
Variety	10 days	15 days	20 days	25 days	15 days	20 days	20 days	25 days
Blubonnet	96%	94%	77%	91%	73%	66%	71%	56%
Llanos 5	15%	0%	1%	0%	46%	38%	50%	13%
Colombia 1	7%	0%	1%	1%	49%	16%	15%	17%
Oryzica 1	33%	15%	7%	14%	37%	27%	25%	28%
IRAT-124	32%	34%	21%	12%	57%	35%	42%	33%
CICA 8	79%	47%	62%	55%	67%	57%	66%	70%
CT 8008	41%	32%	24%	15%	57%	32%	51%	45%
CT 8837	60%	34%	49%	37%	59%	48%	45%	45%

* Dates are days after seeding.

Additional Sources of Resistance to *Tagosodes* and RHBV

In order to broaden the genetic base for resistance to RHBV, ten different rice lines have been identified as resistance to RHBV. At least some of the resistant genes appear to be different from the resistance in the variety Colombia 1. These have been tested for resistance and although none confer immunity, they should be useful in broadening the genetic basis of resistance to RHBV.

B. ACTIVITY RP03: CONTROL OF RHBV THROUGH COAT PROTEIN MEDIATED CROSS PROTECTION AND ANTI-SENSE RNA STRATEGIES

The preparation of cDNA libraries and the molecular characterization of RHBV has led to the design of novel virus-resistant strategies to genetically engineer commercially-grown rice cultivars. Two different strategies are being attempted: a) the nucleocapsid (NC) cross protection and b) the antisense-gene down regulation of the major NS4 non-structural protein. The down regulation of this protein may be a novel method of producing virus-resistant plants by breaking the cycle of transmission.

Transgenic plants have the NS4 antisense and the NC constructs have been identified. The NS4 antisense was expressed as RNA. This significant development allows for the analysis of the effect of the major non-structural gene and to determine the down regulation of this viral gene. There will be continuing analysis of transgenic rice containing both genes and of the progeny of these plants for their reaction to RHBV.

Background

The preparation of cDNA libraries and the molecular characterization of RHBV has led to the design of novel virus-resistant strategies to genetically engineer commercially-grown rice cultivar. Two different strategies are being attempted: a) the nucleocapsid (NC) cross protection and b) the antisense-gene down regulation of the major NS4 non-structural protein. The NC-mediated cross protection has been successful for the tenuivirus RStV. The strategy for the expression of the RNA4 is to determine the function of the major NS4 protein (Hayakawa et al., 1992) The hypothesis is that this protein is "helper factor" and is needed for virus transmission. The down regulation of this protein may be a novel method of producing viral resistant plants by breaking the cycle of transmission.

Results

Last year, we reported the initial progress attained in the direct deliver of genes into immature embryos or immature panicle-derived calli, using DNA-coated gold particles accelerated by the PDS-1000/He system. Three tropical irrigated Latin American indicas varieties (Oryzica 1, Cica 8 and Inti) and two upland materials (CT 6241-17-1-5-1 and Oryzica Sabana 6) are used as targets.

Co-transformation experiments were conducted using equal amounts of the pAct1D construct containing the GUS reporter gene under the control of the rice actin-1 promoter, and a construct containing the hph selective gene encoding for hygromycin resistance (Hyg ^{r}) driven by the 35S CaMV promoter. Two days after shooting two consecutive shots at 1100 psi / 1300 psi and 25 mm Hg, 33% to 100 % of the callus derived from the bombarded explants show GUS transient expression. These shooting conditions did not affect the callus induction from the bombarded tissues (41-95%), and there were between 4 to 19 blue spots per 1-2 mm diameter callus. The selection of putative transgenic rice tissue was performed by maintaining the bombarded calli in a step-wise selection on culture medium containing 30 mg/l hygromycin B (hyg B) followed by 50 mg/l hyg B throughout plant regeneration. Four to 85% of the bombarded explants developed Hyg ^{r} clusters after two weeks of selection on 30 mg/l hyg B containing medium. Between 64% and 96% of these resistant clusters show Hyg ^{r} at 50 mg/l, giving an average of 0.2 - 2.2 Hyg ^{r} cell clusters per original bombarded explant. Evaluations of the β-glucoronidase expression of 156 Hyg ^{r}-calli recovered from 50 mg/l hyg B containing medium indicated that 46.4 calli + 3.9 were also co-transformed with the GUS gene.

From 27% to 100% of the Hyg ^{r} calli regenerated at least one Hyg ^{r} plant on medium containing 50 mg/l hyg B (Table 1). These results indicate that the efficiency of recovering putative transgenic plants highly depends on the genotype. One Hyg ^{r} plant line might be recovered from 2 to 33 explants initially bombarded (Table 1). Some of the putative transgenic plants were evaluated by Southern blot analysis to confirm the integration of the hph into the rice genome. Results suggest that 3 of 5 Cica 8 plants and 3 of 4 CT 6241-17-1-5-1 plants analyzed have the hph gene. Single (Figure 1A) or multiple (Figure 1B) copies of the hph were noted. Only plants recovered from 50 mg/l hyg B regeneration medium contain the hph gene (Figure 1A, lanes 2 and 4; and Figure 1B lanes 1,3 and 5), in contrast to plants regenerated from calli induced on hyg B but differentiated without the selection agent (Figure 1A, lanes 7 -15), which did not show the hph gene.

The segregation of the Hyg ^{r} trait among offspring of the transgenic plants was demonstrated by germinating R1 seeds on medium containing 50 mg/l hyg B (Table 2). A segregation of 3:1 among offspring of four transgenic plants was noted (Table 2), indicating Mendelian inheritance from single genetic locus of a functional hph gene. On the other hand, six transgenic plants showed a skewed segregation pattern, in which the number of Hyg ^{r} offspring was significantly lower than the expected 3:1 (Table 2). Similar results had been reported in transgenic rice. Possible interpretation of these results may include the linkage of the transgene with semidominant or dominant lethal mutations, inactivation of the transgene by methylation, and/or excision of the transgene from the genome. The inheritance of the GUS gene was also evaluated on selfed-progeny from three transgenic plants showing high level of GUS expression (Table 3). In these case only one plant (CM-12) showed a lower number of offspring GUS$^+$ than the expected and the β-glucoronidase expression was diminished respect to the original transgenic plant, probably indicating inactivation of the GUS gene. Plants CM-12 and CM-17 were co-transformed with both genes (Table 2 and 3).

During the preliminary experiments to check plants containing the hygromycin gene and later with the RHBV constructions several detection methods were tried. Our original assays for Southern and Northern hybridization took two to three weeks for results and it is probable that some transformed plants were not detected with our methodology. The conditions were optimized and the detection of single genes now takes 3 to 7 days. PCR based assays were also tried, and the detection of single copy genes in positive control plants was inconsistent. In our laboratory, this method is considered unsatisfactory for the initial screen for transgenic plants. We are interested in learning if there are reliable PCR methods for the detection of single genes.

The direct gene transfer of the RHBV genes was initiated. The RHBV-NC construct contained the RHBV-NC driven by the 35S CaMV promoter and followed by a pNeo polyadenylation signal. The construct also contains the 35S CaMV - hph gene as the selective marker. A similar plasmid construct was made for the antisense RHBV-NS4 gene. After the complete step-wise selection process throughout plant regeneration on 50 mg/l hyg B, a total of 165 plants from the antisense RHBV-NS4 and 187 plants from the RHBV-NC bombardments had been recovered.

Preliminary analyses of Southern blot analysis from genomic DNA and Northern blot of 38 plants recovered from the antisense RHBV-NS4 bombardments indicated that 2 of these plants (5.3%) contain and express the antisense-RNA4 gene. The identification of transgenic plants that express the RHBV antisense is significant progress that allows for the analysis of the affect of the major non-structural gene and to determine the down regulation of this viral gene confers resistance to RHBV. Twenty one of 31 plants analyzed from RHBV-NC experiments contain the RHBV gene. In all cases, larger NC fragments than the expected length were visualized on the Southern blots. These plants will be analyzed by Northern and Western analysis to determine if the NC-gene is being expressed correctly. Apparently, a variety of integration patterns had been obtained in other works when circular plasmid is used. Therefore, future experiments will include the linearization of the expression vector before bombardment.

Analyses to confirm the integrative transformation for the RHBV-NC and the antisense RHBV-NS4 genes by Southern hybridizations will continue. The progeny from the putative transgenic plants will be tested for the inheritance and expression of the RHBV genes, and for resistance to RHBV using viruliferous plant hoppers. For NC transformed plants there resistance to RHBV will be analyzed. The NS4 transformed plants will be inoculated and evaluated for resistance to RHBV. Susceptible plants will be analyzed to determine the level of NS4 expression and used as source plants to determine the effect on the transmission of RHBV.

Table 1. Hygromycin resistant plant lines obtained from immature embryos or immature panicle-derived callus after selection on 50 mg/l hygromycin B.

Rice Genotype	Explant	Hyg ^{r} callus Line	Hyg ^{r} plant line No.	Hyg ^{r} plant line (%)	Explants/ Hyg ^{r} line
O. Sabana 6	im.e.	23	23	100.0	10.9
CT 6241	im.e.	122	33	27.1	1.9
BR-IRGA 409	im.e.	113	51	45.1	8.9
Inti	im.e.	24	11	45.8	33.0
CICA 8	callus	68	36	52.9	2.0

Table 2. Inheritance of Hyg^{r} in the R1 generation.

Transgenic RO Rice Line	R1 Seeds Germinated	Well-grown seedlings	Dead seedlings	Ratio	x^2	Probability
CT 6241-17-1-5-1						
CM-1	47	35	12	3:1	0	1.00
CM-3	32	19	13	2:1	0.55	0.46
CM-11	25	10	15	1:1	0.64	0.42
CM-12	21	14	7	3:1	1.05	0.31
CM-17	26	19	7	3:1	0.21	0.64
CICA 8						
IM-1	363	155	208	1:1.3	0.10	0.75
IM-2	175	58	117	1:2	0	1.00
IM-3	70	44	26	2:1	0.58	0.45
IM-5	275	194	81	3:1	0.07	0.79
IM-7	363	155	208	1:1.3	0.10	0.75

Data was collected 2 weeks after the seeds were germinated in the light on hyg B (50 mg/l) containing medium. All control seedlings were dead.

Table 3. Inheritance of the GUS gene in the R1 generation.

Transgenic RO Rice Line	R1 Seeds Germinated	GUS+ seedlings	GUS- seedlings	Ratio	x^2	Probability
T 6241-17-1-5-1						
CM-3	25	0	25	——	——	——
CM-12	45	20+	25	1:1	0.56	0.46
CM-16	16	14++	2	3:1	1.33	0.25
CM-17	25	25+++	0	1:0	0	1.00

Data was collected 5 days after the seeds were germinated on MS medium without hormone in the light. All control seedlings were GUS-. ß-glucoronidase expression: $^{+}$ faint blue, $^{++}$ light blue, and $^{+++}$ dark blue, respectively, was noted on roots, seed endosperm and primary leaves.

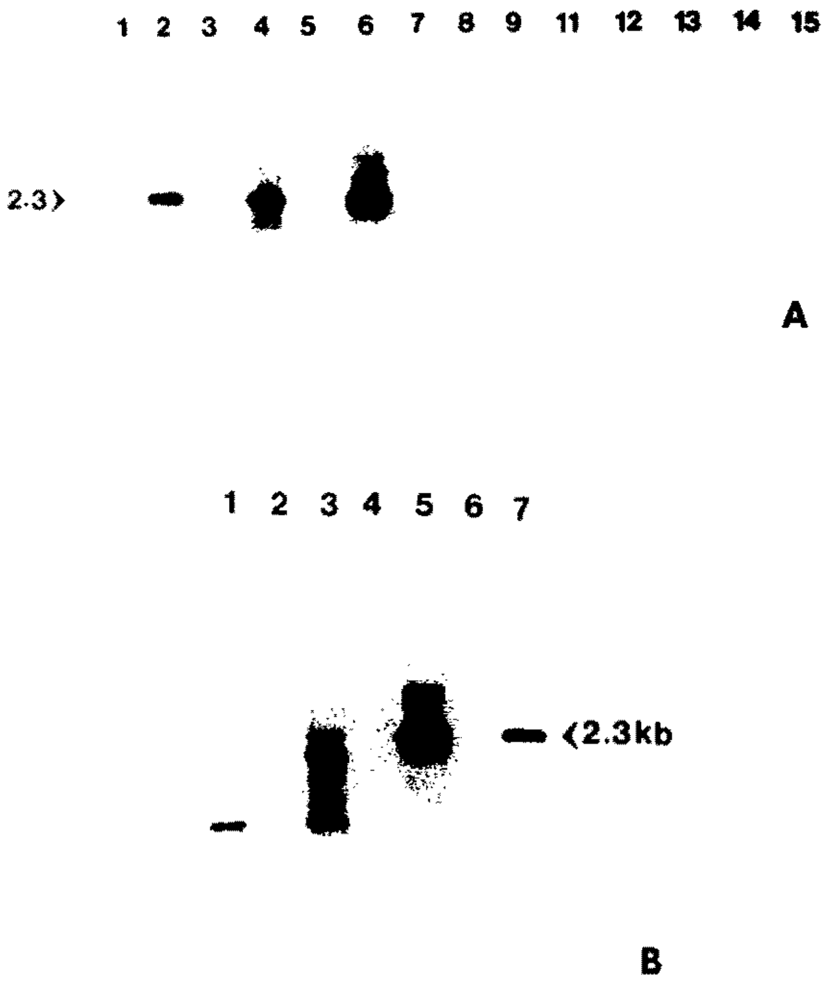


Figure 1.- Southern blot hybridization reaction of DNA of R0 transgenic rice plants using a KpN 2.3 Kb-restriction probe containing the hph gene. (**A**) Lanes 1-4 Cica 8 plants recovered from 50 mg/l hygromycin-regeneration medium after 3-4 weeks of selection. Lane 5 negative control. Lane 6 positive control. Lanes 7-15 plants recovered from regeneration medium without hygromycin. (**B**) Lanes 1,3 and 5 CT 6241 plants recovered from 50 mg/l hyg B-containing medium. Lane 6 negative control. Lane 7 positive control.

VI. PROJECT 6
COMPONENTS FOR INTEGRATED PEST MANAGEMENT

A. Activity RP04: Yield loss functions for multispecies weed interference

Abstract. This project attempts to develop components and methodologies for IPM, and to assist national programs in formulating rice IPM projects and seeking funding (CIAT's Action Plan and position paper on IPM). Weeds of rice in LAC cost 218 million US$ a year, and herbicide consumption in is on the increase. Direct-seeded rice is often sprayed with herbicide mixtures up to three or four times per season, and tropical rice can be grown twice a year. Late herbicide applications are often not economical. This study developed a methodology to derive economic thresholds for multi-species weed infestations in direct-seeded rice, with options to remove some site specificity constraints. Such thresholds are the key to unlock IPM for weeds in rice, and could reduce herbicide applications by up to 30% A simple, and biologically realistic rectangular hyperbola was fitted to predict yield losses from weed infestations This model can be adjusted to account for relevant site constraints such as differences in growing seasons, and in the interval between crop and weed emergence. Yield loss predictions can be made from simple visual estimation of weed cover. The model derived was incorporated into a simple decision support prototype, programmed in LOTUS^{R}, for making economic decisions on weed control. The methodology derived has been presented at different meetings in Latin America, and to the Colombian federation of rice growers (FEDEARROZ), who have considered this a prioritary area for work.

Introduction

Activities in this project seek to be consistent with our Action Plan (CIAT, 1994) and CIAT's position paper on IPM (CIAT, 1994), namely they focus on the development of components and methodologies for IPM, and serving as a bridge between advanced institutions in the developing countries and researchers in the developing world. The term pest refers to any kind of organism that is harmful to rice production and quality (CIAT, 1994).

Through the introduction of the concepts of action and economic damage thresholds, and together with knowledge on natural enemies, IPM made great progress in reducing pesticide abuse in the control of diverse pests. This has not been the case with weeds, a pest of rice that in LAC costs of 218 million US$ a year, or 45 % of the total expenditure on chemical pesticides in rice in the region. Unlike with insecticides, herbicide consumption is on the increase. This is aggravated by poor knowledge on safety measures, and on techniques for applying pesticides correctly. Therefore, decision rules are needed, like the economic thresholds used with insects, so that farmers can determine when weed control is needed, and what control measure is economically justified.

Rice farmers spray mixtures of herbicides up to three or four times during the growing season. This usually results from poor water control and/or poor land levelling, which do not allow farmers to suppress weed growth with a permanent flood. Such late herbicide applications are often not economically justified, and the use of economic thresholds could have great impact in reducing herbicide abuse (Fischer and Ramirez, 1993).

Unlike most insects, weed infestations usually consist of mixtures of species, which has been a constraint for developing adequate models relating yield losses to weed infestations. Most reports of weed thresholds for rice are based on one-species infestations (Smith, 1988). A simple, but sound function is needed, so that yield losses can be predicted from field weed infestations. We have previously reported (Fischer and Ramirez, 1993) on an approach where a given mixed-weed infestation was quantified as the sum of the individuals present per unit area (density), each species weighed by its relative competitiveness. The relative competitiveness was determined experimentally for each species. The resulting weighed density (competitive load) was the input variable in a model for yield loss prediction. One drawback of this approach is that competition effects among weeds is not considered. Another problem often encountered with regressions relating weed density to crop yield loss (Smith, 1988), is the use of unrealistic equations that fail to account for basic biological mechanisms (Cousens et al., 1987). Simulation models can be useful (Kropff and van Laar, 1993) but require a certain level of training, and their parametrization, validation, and use still involve a certain level of difficulty. Access to simulation is quite restricted to most fieldmen in the region. Cousens et al. (1987) proposed a rectangular hyperbolic equation:

where YL is the yield loss/ha as percent of the weed-free yield, i is the yield loss per individual weed as weed density D tends to zero, and a is the asymptotic yield loss as D becomes very large. The coefficients a and i are estimated by non-linear regression. This model can be improved using a parameter more closely related to competition than the number of plants per unit area, which counts as equal plants of different size and competitiveness. Also, a descriptor of weed density should allow to lump together the different species present in a given weed infestation, so that only one variable is used as input. Kropff and van Laar (1993) suggested that the Relative Leaf Area of weeds (weed leaf area/(weed+crop leaf area)), can be used to quantify mixed-species weed infestations when recorded soon after crop emergence, which could also account for differences in the relative time of emergence between weeds and the crop.

The objective of this study was to develop, for intermittently irrigated rice, an approach for deriving economic thresholds for multi-species weed infestations, aimed at reducing herbicide use, particularly against late-emerging weeds. A means to account for differences in the relative time of emergence of weeds and rice will be explored.

Procedure

Two field experiments were conducted on the first and second semester, with rice "Oryzica 1" growing under intermittent irrigation (soil maintained near field capacity). Treatments were arranged within a randomized split-plot design with four replications. Rice was seeded at 75, 140, 200, 250, and 300 kg/ha(main plots)[3]. In the first semester, weeds were allowed to emerge at two dates, while in the second experiment only one late weed emergence was allowed (Table 1). Weed infestations resulted from spontaneous emergence. Within areas of uniform weed infestation (sub plots), weed density was evaluated 20 days after their emergence. Thus, the number of weed stems per 0.25 m^2(STM), weed leaf area (LA), dry matter (DM) and visual cover (a relative parameter: weed cover/crop+weed cover) were determined, and the relative weed stem number (RST), weed leaf area (RLA) and relative weed dry matter (RDM) were calculated. Weed infestations were assessed again 55 days after rice emergence. The prevailing weeds were: Leptochloa filiformis, Echinochloa colona, E. crus-galli, and Eleusine indica, less relevant weeds were Eclipta alba and Ludwigia sp. Data were subjected to non-linear regression analysis.

Results and Discussion

Early and late weed emergence. The rectangular hyperbolic model fitted the data realistically (Figure 1), regression parameters for both experiments appear on Table 2. The spread of points around the regression lines results mainly from the different rice seeding densities used. While i reflected the different intensity of competition effects between early and late weed emergence, a was not an indicator of such effects (Table 2 and Figure 1). In some cases, constraints to the value of a had to be imposed to obtain a good fit, and unrealistic values sometimes resulted (Table 2). Therefore, if a is to be used as an indicator of competitiveness (Cousens et al., 1987) for comparing weed species, or management alternatives, it should be within the same date of weed emergence.

The relative time of emergence of rice and the weeds had a striking effect in the yield losses inflicted by weeds. In the first semester, late emerging weeds only reduced yields by about 20 % at the highest weed density (Figure 1), confirming previous observations (Fischer and Ramirez, 1993). Stem counts (STM or RST) provided the poorest discrimination between early and late competition (Table 2), illustrating the convenience of describing weed infestations with parameters more closely associated to competitive interactions between rice and weeds, particularly when weeds differ considerably in size. If rice is well fertilized and irrigated, competition until canopy closure should be mainly for light. Therefore, the combined leaf area of a given weed mixture, or its RLA should provide an adequate description of the competitive pressure of such weed mixture, and thus a good input parameter for the hyperbolic yield loss model. This is confirmed by our data (Table 2 and Figure 1). Since RDM also gave a good fit, a combined estimate of leaf area and dry matter would be even better still, given that competition regulates dry matter distribution among species. The visual assessment of relative weed cover, integrates actual leaf cover with a subjective estimate of growth, and resulted in a very good fit for predicting rice losses from early weed competition. A parameter of easy field use by trained fieldmen.

Modifying the value of i in the hyperbolic model proposed, allowed to account successfully for differences in the period between crop and weed emergence (Figure 2). Therefore, a relationship between different periods of relative crop and weed emergence and i could be derived experimentally, so that corrections in the model can be introduced as needed.

Late assessment of weed densities. Early- and late-emerged weed infestations were assessed again at about 40 and 20 days after the early and the late weed emergence, respectively. The purpose was to identify weed density descriptors that could account for the difference in relative time of emergence. Such descriptor should allow to describe the effects of early and late competition on rice yields by one single mathematical relationship. Data in this second weed evaluation showed greater spread than in the earlier ones (lower r^2 values in Table 3 than in Table 2). When pooled data from early and late weed infestations were fitted together r^2 values were slightly smaller than when only data from early competition were used. The relative parameters (RLA, RST, and RDM) did not provide better fit than the absolute ones (Table 2), as proposed by Kropff and van Laar (1993).

First vs. second semester. The second semester is usually a more favourable season for plant growth, mainly because of higher irradiance. Under such favourable conditions, weed competition was more severe, as shown by the increased i values (Table 2, late emergence). The change in i was smallest when the multi-species weed infestations were quantified in terms of RLA (Table 2). Meaning, that leaf area changed less than other growth parameters across growing seasons, and thus RLA would be a more suitable input for a model predicting yield losses using pooled data from both seasons. A model to simulate competition can be of help to find a meaningful relationship between i and a given weather parameter (such as irradiance). With such relationship, and historic weather information, the model (i) can be adjusted for predicting yield losses from mixed-weed infestations across different growing seasons.

Economic thresholds. Table 4 presents the output of a simple decision model based on a weed density vs. yield loss regression equation. The prototype model was programmed in LOTUS using macros, which makes it usable and modifiable by almost anyone, and provides basic assistance for making economic decisions about herbicide use. However, weed control can be diversified by incorporating in the model parameters for other weed management alternatives if their cost is estimated.

Conclusions

A simple, and biologically realistic model is used for describing the hyperbolic relationship between density of multi-species weed infestation and rice yield loss. This model has been successfully used with a wide range of data sets (Cousens, et al. 1987), and depending on the input variable and adjustments, it can account for relevant site constraints such as differences in growing seasons, and in the interval between crop and weed emergence. Experienced fieldmen can make yield loss predictions using as input a simple visual estimation of weed cover, as an alternative to the usual laborious and inaccurate weed counts. This is a biologically plausible alternative (Cousens, et al. 1987), that can allow for sound yield loss predictions in the implementation of economic thresholds for mixed-species weed infestations. Such thresholds are the key to unlock IPM for weeds in rice, and have the potential to reduce herbicide applications by up to 30% (Fischer and Ramirez, 1993). These concepts have been conveyed in meetings throughout Latin America, and in Colombia the Federation of rice growers (FEDEARROZ) has considered this a prioritary area of work in its series of Workshops on Weed Control throughout the Colombian rice growing areas.

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B. ACTIVITY RP54: LATIN AMERICAN RICE IPM WORKSHOP

Executive Summary

October 23-28, 1994, a FAO-sponsored workshop on IPM in rice for LAC was held at CIAT with participants from Venezuela, Ecuador, Colombia, Cuba and Brazil. IPM in rice was reviewed, and a project proposal to fund technology transfer and adaptive research by each country will be written.

Activity

On October 23-28, 1994, a workshop on IPM in rice for Latin America was held at CIAT sponsored by FAO. Participants represented National Programs and private institutions from Venezuela, Ecuador, Colombia, Cuba and Brazil. The situation of IPM in rice was reviewed, and constraints were identified. Although a holistic, multidisciplinary approach was emphasized, in general weed management was identified as an area that lags behind other disciplines in IPM implementation, and which requires special attention. The results of this analysis form the basis for preparing a project proposal to fund technology transfer and adaptive research accounting for each country's specific problems. The project will have a steering committee and a coordinator, and will contemplate training and technical exchange among countries. Such undertaking will be a commitment of the new fund for irrigated rice in LAC (FLAR) jointly with FAO.

Table 1. Times of rice and weed emergence for the first and second growing season in Palmira.

Crop emergence			Weed emergence			
	date	gdd[1]		date	dae[2]	gdd
1st season	May 2	170	Early Late	May 20 May 30	18 28	431 565
2nd season	Oct. 16	126		Nov. 16	31	557

[1]. Cummulative growth degree days with base 10C counted after seeding the crop.
[2]. Days after rice emergence.

Table 2. Parameters of rectangular hyperbolic models describing yield loss as a funtion of weed density (as leaf area, dry matter, and visual estimation of cover), for two growing seasons and different intervals between weed and crop emergence.

Season	Parameter[2]	Stems	Leaf area	Dry matter	Relative No. stems	Relative leaf area	Relative dry matter	Cover
		(No./0.25m²)	(cm²/0.25m²)	(g/0.25m²)	(%)			
First								
Early	a	200	73.7	74.2	200	69.2	68.6	92.2
(431)[1]	i	.39	0.41	32.6	1.18	13.1	12.1	2.65
	r^2	0.81	0.69	0.67	0.74	0.77	0.74	0.86
Late	a	100	97.3	45	100	100	100	96.3
(565)	i	0.24	0.016	1.37	0.52	0.93	0.79	0.42
	r^2	0.32	0.26	0.24	0.35	0.34	0.34	0.32
Second								
Late	a	100	66.5	64.2	100	100.8	83.8	91.4
(557)	i	0.61	0.039	4.05	1.08	1.47	2.02	1.22
	r^2	0.29	0.35	0.34	0.34	0.45	0.43	0.43

[1] Accumulated growth degree days (Tmax−Tmin)/2−10 since rice seeding.

[2] For Yield loss(%)= ix/(1+ix/a), x is weed density (as leaf area, dry matter, relative leaf area, relative dry matter, or percent cover), a is the asymptotic yield loss (%) and i is the yield loss per individual weed as weed density tends to zero.

Table 3. Parameters of rectangular hyperbolic models describing yield loss as a funtion of weed density (in terms of number of stems, leaf area, and dry matter), assessed 55 days after rice emergence in plots where weeds emerged at two different times with respect to the crop. Equations were fitted to data from each emergence group, and also to pooled data from both groups together.

Season & emergence	Parameter[1]	Stems	Leaf area	Dry matter	Relative No. stems	Relative leaf area	Relative dry matter
		(No./0.25m^2)	(cm^2/0.25m^2)	(g/0.25m^2)	------	--(%)--	--------
First experiment							
Early	a	187	111	97	100	78.7	86.8
	i	0.50	0.06	4.3	1.48	4.2	3.27
	r^2	0.54	0.56	0.55	0.50	0.58	0.52
Late	a	100	100	100	100	100	100
	i	0.28	0.16	1.07	0.59	0.94	0.79
	r^2	0.31	0.24	0.20	0.37	0.37	0.33
Both	a	100	100	100	100	100	111
	i	0.52	0.04	2.73	1.14	2.15	1.76
	r^2	0.54	0.45	0.42	0.51	0.48	0.44

[1] For Yield loss(%)= $ix/(1+ix/a)$, x is weed density (as leaf area, dry matter, relative leaf area, relative dry matter, or peercent cover), a is the asymptotic yield loss (%) and i is the yield loss per individual weed plant as weed density density tends to zero.

Table 4. **Economic Thresholds Model for Weed Control in Rice, a Prototype**

Model: LN(Yield)=6.48−0.007xX
Input: weed density (g dry matter/0.25m²)
Rice density: 100 kg seed/ha
Estimated max. weed−free yield: 6520 kg/ha

Output 1

Weed density (g/0.25m²)	Expected Yield (kg/ha)	Percent Yield Loss	Expected Loss (US$/ha)
0	6520	0.00	0
1	6474	0.71	8
2	6429	1.40	16
3	6384	2.09	24
4	6340	2.76	32
5	6295	3.45	40
6	6225	4.52	47
7	6208	4.79	55

Output 2

Decision Matrix for herbicide use
a) Weeds emerging 15 dae

Max. Expected Yield (kg/ha): 6520
Weed Density (g/0.25m²): 4
Expected Yield loss (%): 2.76
Gross Margin
(standard herbicide mixture): −17
Decision: DO NOT APPLY

Outputs 3 and 4 are similar to Output 2, but referring to late and very late post−emergent weed control. The prototype was developed by Dr. Alvaro Ramirez of the Rice Program's Economy Section.

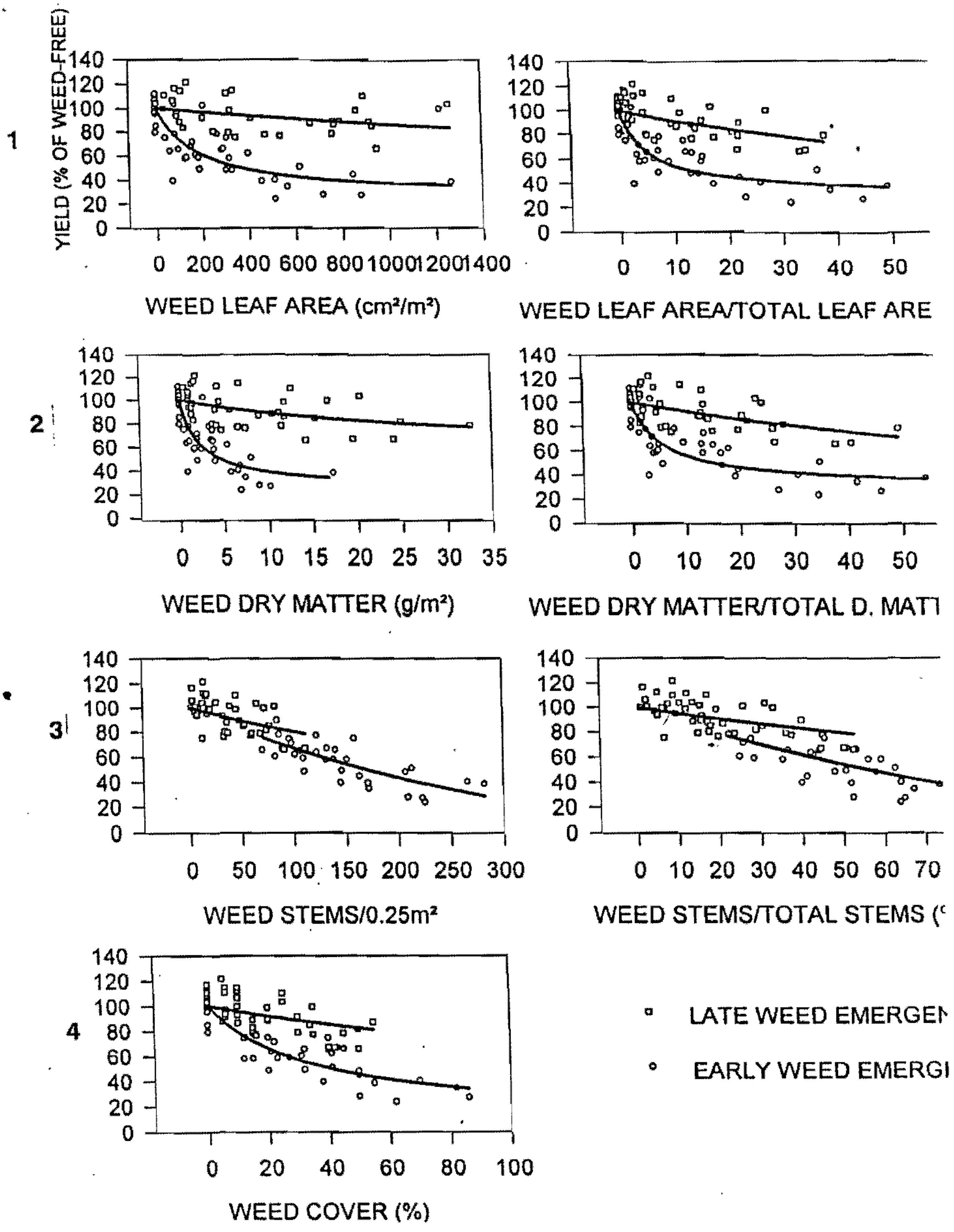
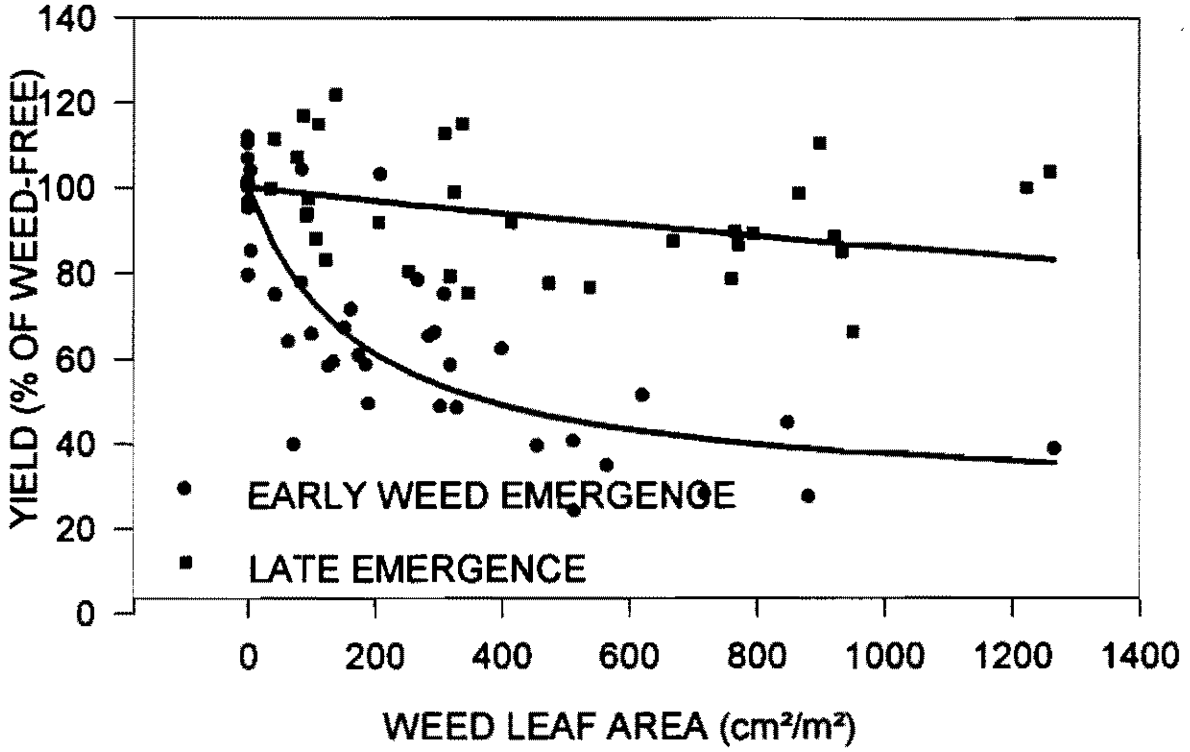


FIGURE 1. Effect of early and late weed infestations on rice yields during the f semester and different descriptors of weed density. Regression parameters app on Table 2.



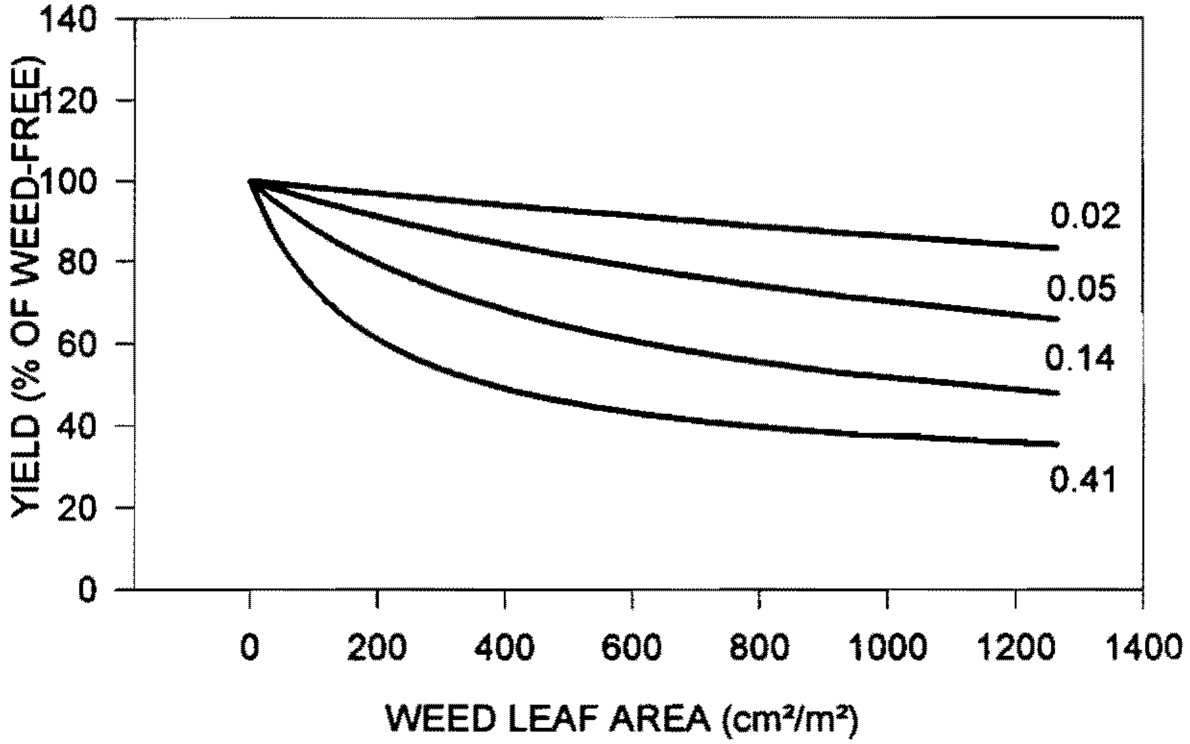


Figure 2. Adjustments of the coefficient i in the rectangular hyperbolic model to account for different periods between weed and crop emergence; i values are indicated for the curves of the lower graph.

VII. PROJECT 7 INFORMATION AND TECHNOLOGY SHARING

Abstract. A Latin American Rice Facts Sheet is nearing completion, a handy yet detailed summary of the key facts regarding rice production, trade, consumption and the adoption of improved varieties across countries and in different agro-ecologies.

Vigorous efforts continued to seek renewed funding for the rice germplasm network, INGER-LAC, in close coordination with IRRI. A comprehensive proposal was prepared for joint submission. Although these efforts have not yet succeeded in finding a willing donor, CIAT and IRRI continued to keep INGER-LAC alive by sharing the costs in a bridging mode during 1994.

A. ACTIVITY RL02: LATIN AMERICAN RICE FACT SHEETS

Stemming from related sheets published by IRRI for global rice and for cassava by CIAT, a spreadsheet was prepared and formatted for publication, showing data for populations, income, rice production, trade, self-sufficiency and related parameters, and breakdowns of production and improved variety adoption by agro-ecosystem (irrigated, rainfed lowland and upland). The data were aggregated by country and sub-region. The advanced draft will be finalized and published in early 1995.

B. ACTIVITY RL53. HIGHLIGHTS OF INGER-LATIN AMERICA IN 1993-1994

Abstract. The support to INGER-LAC activities has been kept at its minimum level since 1993, due to lack of funds for the Latin America component of the global network. In 1993, 81 sets were dispatched to 14 countries in LAC. Data on 44 nurseries were returned to the regional coordinator at CIAT, giving a return rate of 54.3%. The average rate of data return over the last 5 years was 46.1%. In 1994, 99 nurseries were distributed, the data is just beginning to return. During the period covered by this report (1993-94), the region released 18 varieties, 10 of which (55.5%) were materials exchanged through INGER. In the six varieties bred locally, 4 of the 13 parents used in the crosses were distributed through the network. In this period various publications were completed and distributed to NARS: a) INGER Nursery Results - 1991, b) IV Breeders Workshop Report - 1992, c) INGER Nursery Results - 1992, d) INGER Steering Committee Meeting - 1993, and INGER Annual report 1994. Due to lack of funds, only one meeting took place during this period, the " IX International Rice Research Conference for Latin America (IRRC-LAC) - 1994." The meeting was attended by 297 participants from 21 countries. The steering committee of INGER-LAC met in 1993 and 1994 to help prepare a proposal for continuing the network. CIAT is leading the search for a potential donor.

Background

INGER-LAC Phase III expired at the end of 1991. Prior to this, a proposal for the next Phase had been submitted to the UNDP regional program, but was turned down. UNDP advised CIAT that its member countries were no longer placing a priority for its dwindling support funds on agriculture, and preferred to obtain help in industrial development rather than research.

Although renewed special-project funding was not obtained, IRRI generously stepped in and continued to pay the salary and operations for INGER-LAC during 1992 and 1993. The INGER coordinator resigned in early 1993, however and IRRI decided to close the position, throwing the network into a crisis.

CIAT's DG contacted IRRI's in a letter dated 17 May 1993 to address the situation, which resulted in a meeting among CIAT and IRRI Directors at the CGIAR Mid-Term Meeting in Puerto Rico on May 28. In that important meeting it was decided that continuity for INGER-LAC must be provided, and that it must continue as a joint CIAT-IRRI effort. CIAT would propose a bridging budget for 1994, to be funded by the two institutions. IRRI would send Drs. Jackson and Choudhary to CIAT to follow up on that, and to start the development, with CIAT of a new proposal for 1995 onwards. It would be discussed with a jointly-funded meeting of the Steering Committee later in 1993, and then jointly submitted to donors.

Drs. Jackson and Chaudhary visited CIAT in June of 1993, discussions were held, and a joint memo (Winslow/Jackson) went to both CIAT and IRRI DG's with recommended funding responsibilities for 1993-4, and an outline for the '95-onwards proposal. It was eventually accepted by both DG's, with small modifications.

A meeting of the INGER-LAC Steering Committee was held as planned, from 1 to 3 November 1993. Drs. Bernardo and Chaudhary from IRRI attended. The Committee approved a set of guidelines for the new proposal, and a time frame. CIAT was to draft the proposal, and send it to IRRI by mid-January 1994. IRRI would modify if necessary and become responsible for submitting it to donors by March, 1994.

1994 Developments

M. Winslow prepared a detailed and comprehensive draft proposal, with help from other scientists, especially C. Martinez and E. Guimaraes. It was sent by courier to IRRI on January 21, 1994. IRRI sent the final, reviewed copy back to CIAT on 2 June 1994.

In the IRRI cover letter, however it was indicated that CIAT should take the lead in seeking funding for the proposal, from Latin American donors. This was a change in the previous understanding, that IRRI would submit it to global donors in the context of this being a component of a global INGER, as described earlier. CIAT sought clarification of this and in a letter of 21 June, F. Bernardo confirmed IRRI's decision, indicating that IRRI needed to focus on its own INGER funding drive, which would not include the LAC component.

At this point, of course CIAT had to reassess its approach. On September 16 Dr. Havener proposed a meeting during the upcoming Centers Week, which Dr. Lampe accepted. Shortly thereafter, on September 16 Dr. Lampe sent a message informing CIAT and WARDA that IRRI was organizing a donors meeting for Centers Week to drum up support for the INGER 2000 global proposal, which did not include the INGER-LAC component proposal. Communications ensued which were unsuccessful in changing IRRI's position on the matter. Dr. Scowcroft attended the donors meeting but the INGER-LAC proposal remained separate.

Despite this difficulty, the Centers agreed to jointly bridge-fund INGER-LAC for a second year (1995) while fundseeking continued.

In summary, funding for a rice germplasm network no longer appears to be a top priority for our traditional donors, resulting in the difficulties described above. The attempt at a truly inter-institutional project submission (CIAT-IRRI) proceeds in good faith although there are bumps along the way. The cooperation in bridging the '94-95 funding gap has been exemplary.

C. ACTIVITY RP54: CRIN INTERPHASE ACTIVITY

Background to Funding Drive

Phase I of CRIN expired at the end of 1992, although it was extended without additional funds to June 30, 1993.

CIAT had prepared a proposal for Phase II of CRIN in 1992 which was widely circulated among Caribbean countries. Subsequently, the EC (potential donor) commissioned a study to develop a Caribbean Regional Agricultural Programme for Lome IV funding, including a project called "Development of an Integrated Rice Industry". It was discussed by regional representatives (CARIFORUM) in a May 26-28, 1993 meeting in the Dominican Republic. Subsequent discussions on May 31 in Jamaica between CARIFORUM and EC recommended that CRIN be included as a subcomponent within that Integrated Rice project. CARDI was given lead responsibility for preparing the Integrated Rice project. Dr. Thomas Carr, CRIN Steering Commitee Chairman explained CIAT's role in Phase I to the project drafting team; nevertheless they decided that CARDI should play the lead role in the new phase of CRIN.

Dr. Winslow contacted CARDI in October 1993 and offered CIAT's assistance or active participation in Phase II. CARDI did express interest in obtaining CIAT's help in drafting the new proposal during 1994, and indicated it would be similar to, and indeed based upon CIAT's earlier proposal. They suggested they would call a workshop to draft it early in 1994 which they would like CIAT to attend, but we heard nothing further after that. They also requested CIAT's input into a bridging proposal for 1994 they wished to submit to IDB, which Dr. Winslow provided on 10 November 1993. Unfortunately, as we understand it there was subsequently a change in strategy at CARDI and that proposal was not submitted.

1994 Developments

Early in 1994, CIAT received a visit from a promient rice miller in Guyana, Mr. Beni Sankar who expressed great interest in CIAT intensifying its work in that area. He agreed to help promote the CRIN proposal within the new Caribbean Rice Association he was helping to establish.

We tried to re-initiate contact with CARDI in mid-1994 as M. Winslow drafted a letter sent by W. Scowcroft on 28 July to CARDI's new Executive Director, Dr. Hayden Blades. In Dr. Blades reply of August 17 he re-confirmed CARDI's interest to lead a reactivation of the network, possibly with the involvement of the Caribbean Rice Association. He also re-stated CARDI's interest to convene of a meeting on CRIN, and work in "joint venture activities" in rice and other CIAT crops. However no meeting was convened by CARDI during the remainder of the year.

Notwithstanding the frustration on the fundseeking side, an important CRIN publication was produced in 1994. The Proceedings of a Monitoring Tour and Workshop on IPM in the Caribbean (held during Phase I) were published, by IICA. 50 copies were ordered by the CIAT Rice Program.