Annual Report 2000

IP-4 Improved Rice Germplasm for Latin America and the Caribbean

Executive Summary

The CIAT IP-4 project to improve rice germplasm for Latin America and the Caribbean (LAC) has been continuously changing throughout its three decades of existence to meet the needs of the rice farmers. It places special emphasis on the small landholders, our partners and the external funding environment. The project is regional in focus. Our comparative advantage is the ability to address constraints and opportunities that are regional in scope yet distinctive to LAC. This executive summary reflects our strategy to solve these constraints by highlighting some of the research that is being done and to indicate where there are additional needs and opportunities.

Output 1. Enhancing Gene Pools

The enhancement of gene pools is the heart of the rice project. This is a collaborative effort with partners throughout the world. Increasing the genetic diversity of commercial varieties depends on having enhanced germplasm pools to use as parents in crosses. In collaboration with IRRI, we are adapting the "new plant type" to conditions in Latin America. Conventional crosses were made and evaluated. To accelerate the process, we are also using anther culture to produce double haploids of the best lines and these are being evaluated for plant type, grain quality, yield and adaptation to pests, diseases and non biological constraints, like cold and iron toxicity. During the last year, the anther culture laboratory at CIAT produced more that 7,200 double haploids that are being used in many of the breeding efforts at CIAT as well as by FLAR and national programs.

Wild species are another source to broaden the genetic base of rice germplasm. Unfortunately crosses with wild species also introduce many undesirable traits. Wide crosses are useful to map areas with potential desirable traits in the rice genome because the parents have a greater number of differences that can be detected using molecular techniques. In collaboration with WARDA many interspecies crosses including *O. sativa* Bg90-2/ *O. rufipogon* were made, and together with the CIAT project SB-2 and Cornell at least 25 putative quantitative trait loci (QTLs) of important agronomic traits were identified. These efforts are creating novel germplasm pools that will be the basis for much of the new diversity in the commercial varieties of the future.

Recurrent selection is the systematic selection of desirable individuals from a population followed by recombination of the selected individuals to form new populations. The male sterile trait is used to enhance the cycle process of recurrent selection. This is one of the major strategies of the rice project to produce enhanced gene pools. CIAT and CIRAD have a history of collaboration, and two CIRAD rice scientists are stationed at CIAT. Many enhanced populations are under development and this process is so flexible that the same populations often become the basis for enhanced gene pools for many different localities. These enhanced gene pools are designed to overcome specific constraints. One germplasm pool was developed for cold tolerance in upland rice using a source from Madagascar. This gene pool was targeted for development of varieties for small upland farmers. Another of the germplasm pools is selecting materials the are adapted to the altillanura of Colombia. Many different types of enhanced gene pools were sent this year for evaluation by NARs and NGOs.

Output 2. Characterizing Rice pests and the genetics of resistance

There are several pest and disease problems that are unique to Latin America. These include specific races of rice blast and *Rhizoctonia*, rice hoja blanca virus (RHBV), *Tagosodes orizicolus* and a disease recently introduced from Africa into Latin America crinkling disease or entorchamiento. During this last year there were increasing reports of other pests and diseases such as *Sarocladium*, a fungus disease causing sheath rot. The challenge of the CIAT rice project will be to broaden it scope and to promote integrated pest and disease management solutions.

Developing varieties with durable resistance to rice blast has long been an elusive goal. CIAT and its partners using selection in hot spot breeding sites have increased significantly the level of resistance to rice blast and this is reflected in some of the commercial varieties. Still there are reports of breakdown of the blast resistance and more progress is needed. A molecular understanding of the host/pathogen interaction is critical to develop more systematic breeding methods.

This year a new method to evaluate the genetic structure of the blast fungus was established and is being transferred to our partners in the region. There is additional evidence that the combination of the blast resistance genes Pi-1, Pi-2 and Pi-11 should confer durable resistance. In collaboration with CIRAD, additional blast resistance genes are being identified. More than 50 potential donors of blast resistance genes are identified for use in breeding programs. Applying recurrent selection to develop gene pools with partial resistance that can be useful to develop lines with durable resistance is another activity in which progress is reported. We are encouraging efforts to identify local populations, know the reaction to the resistance genes and use molecular methods in conjunction with hot spot breeding to finally develop a large number of commercial varieties with durable resistance.

The complex of rice hoja blanca virus and the planthopper *T. orizicolus* have been a focus of CIAT research for many years. Nevertheless until recently most of the commercial varieties were highly susceptible to the hoja blanca disease. With improved screening methodologies each year there are varieties being release with increasing levels of resistance to both the virus and the insect. One new variety and several advanced lines have more resistance to RHBV than the principal source of virus resistance. This is probably due to increased resistance to the vector. Today Colombian and Venezuelan rice farmers have more germplasm options, but there still is a need to promote varieties for other countries. The research this year changed the focus from developing additional control and screening techniques to the understanding of the mechanisms of resistance to RHBV and *T. orizicolus*. This is being coupled with efforts to develop molecular markers to specific components of resistance and to a more systematic approach to developing highly resistant varieties.

Crinkling disease or entorchamiento is a complex of the fungal vector *Polymyxa graminis* and rice stripe necrotic virus (RSNV). This problem has spread throughout Colombia during the last decade and now is in Panama. It is expected that this will soon be a regional problem. In collaboration with FEDEARROZ, both management practices and germplasm development are being investigated to control the disease. This year, the methods of evaluating germplasm continued to be improved. A highly reproducible method of screening germplasm in the greenhouse has been developed and many commercial and advanced lines were screened. The are moderately good sources of resistance in the rice germplasm, and *O. glaberrima* appears to be an even better source. We are beginning to develop enhanced germplasm pools with multiple source of resistance to entorchamiento.

CIAT has been developing transgenic rice with resistance to RHBV for several years. This year permission to begin field experiments was granted by the Colombian government and the transgenic rice with greenhouse resistance to RHBV are being tested in the field. This is also allows for the first time, the screening of large populations. This was the second year of collaborative research with Rutgers University to develop transgenic rice with resistance to multiple diseases using a novel gene (PAP). Transgenic plants were produced, they are expressing the protein and are in the process of being evaluated to resistance to sheath blight.

Output 3. Enhancing Regional Rice Research Capacities and Prioritizing Needs with Emphasis on the Small Farmers

CIAT is a founding member of FLAR, and we have a special relationship with them. Being driven by the specific requests of the FLAR members, they must respond quickly to their needs. Therefore this is an important avenue for the CIAT rice project to understand the needs and perspective of the farmers. CIAT and FLAR have to continue to explore ways to collaborate more effectively to help ensure the success Latin American rice farmers.

A regional study was made of the yield gap. This is the difference between the potential yield of a variety and actual yields at the farm level. This shows that there is a potential to increase rice production approximately 20% without much additional cost to the farmers. If practices are adopted to reduce the yield gap, Latin American rice will become even more competitive in the global market. This year FLAR members released 12 varieties. There is a perception that the research and new varieties benefits the larger more affluent rice farmers. The study concludes that within the same agro-ecosystem farmers regardless of size, land tenure, type of technology, and social variables such as age and experience are likely to obtain similar yields. This suggests that rice technologies are neutral, relatively simple and quickly adopted. This means that the small rice farmers are benefiting from the technologies generated by CIAT and our partners.

Conclusion

The IP-4 rice project has had a very successful year with significant research advances at all levels from basic research to applied research in collaboration with a wide range of partners. This is laying the foundation for future varieties with higher and more stable yields, better quality, durable resistance to biotic and abiotic stresses. Our past efforts are bearing fruit as the countries throughout the region release new varieties and are once again producing enough rice to fulfill the demands of the growing populations. With the large resource base of land with adequate~~ly~~ water, Latin American countries have the potential to become major rice exporters. For this to happen, the research that will allow increasing yields and global competitiveness must continue.

CIAT has as its mission the alleviation of poverty and a special obligation to assure that the products of our research are reaching the small poor farmers. Rice is a crop where the improved technologies have had a highly beneficial effect by directly increasing the income of all the rice farmers, both large and small. This is contributing to economic growth of regions where small farmers also obtain off farm income associated with the expansion of this crop. The rice project is seeking to strengthen the alliances that will increase opportunities to have more direct impact with the poorest rice farmers. We have already set out the basis to work with all our partners to make this a reality.

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Research Highlights

Output 1. Enhancing gene pools

1.A. Rice improvement using conventional breeding and gene pools and populations with recessive male-sterile genes.

- CIAT and CIRAD lines for upland conditions were released as varieties in Brazil as BONANÇA and CARISMA; in Bolivia a CIRAD line was released as JASAYE and in Colombia a CIAT line "Línea 30" is to be released next year.
- In China FCRI/YAAS released the variety YUNLU 29, from a cross between a Chinese line and IRAT 216.
- Four cycles of upland population enhancement by mass recurrent selection for both sexes for resistance to rice Hoja Blanca virus and blast, and major agronomic traits was made for the populations PCT-4, PCT-A, and PCT-5. These enhanced populations are being used for line development.
- Two cycles of recurrent selection based on S_2 line evaluation were completed for the Population PCT-4.
- Creation of a formal group named "Grupo de Mejoramiento Genético Avanzado de Arroz" (GRUMEGA) coordinated by CIAT/CIRAD and EMBRAPA.
- Site-specific composite populations are being developed in collaboration with organizations in Venezuela, Chile, Uruguay, Brazil, and China.
- Fixed line development by Partners in Colombia (Fedearroz), Argentina (University of La Plata and Corrientes, Chile (INIA Quilamapu), Venezuela (Fundación Danac) and Cuba (IIA).
- One cycle of population enhancement by recurrent selection in Chile of population PQUI-1 for cold tolerance and grain yield, and in Venezuela of population PFD-1 for grain yield and quality is completed.

I.B. Developing upland rice for small landholders

- Two special projects were obtained to continue research on the upland rice for hillsides for small landholders.
- A new collaboration with partners of Central America has been developed and the partnership with China has been reinforced.
- The first recurrent population with narrow genetic basis of upland rice for hillsides has been provided to 7 country partners.

I.C. Advance and evaluation of inter-specific gene pools

- Parallel AB-QTL studies suggest that some regions of the rice genome harbor genes for improvement of cultivated rice.
- Data indicate that QTLs derived from *O.rufipogon* are expressed in different genetic backgrounds and environments.

- Twenty five putative QTLs derived from *O.rufipogon* affecting several important agronomic traits n phenotype in Bg90-2/*O.rufipogon* have shown consistent grain yield through different generations. They were identified in Caiapo/*O.rufipogon* cross whilst 22 in the Bg90-2/O.rufipogon.
- Breeding lines selected based on phenotype in Bg90-2/*O.rufipogon* have shown consistent grain yield through different generations.

I.D. Introgression of new plant type genes into LAC's gene pools

- New plant type traits have been introgressed in germplasm from Latin America. Both conventional lines and double haploid lines with the traits fixed by anther culture have been selected and are showing promising results.

I.E. The use of anther culture and *in vitro* culture for enhancement of gene pools

- Total of 7,200 doubled haploids lines were generated from rice anther cultured for the various breeding efforts stationed at CIAT. Three hundred R2 lines and nine hundred R3 lines were distributed this year to national program in Latin America and FLAR.

OUTPUT 2. CHARACTERIZING RICE PESTS AND THE GENETICS OF RESISTANCE

2.A. Characterization and genetics of resistance to rice blast, sheath blight and grain discoloration

- The combination of the blast resistance genes Pi-1, Pi-2, and Pi-11 was identified as the most appropriate to confer durable resistance to all genetic lineages and virulence spectrum of the pathogen.
- A blast nursery with more than 50 potential donors of resistance genes was initiated for routine testing of stability and distribution in the region.
- A rep-PCR technique for the characterization of the genetic structure of blast populations was established and is being transferred to blast researchers in the region.
- The wild rice *Oryza rufipogum* and the Asian rice cultivar Remadja were identified as potential sources of resistance genes to sheath blight.
- Seven sources of high levels of resistance to grain discoloration including five upland and two irrigated lines were identified.
- A backcross program for the introgression of blast resistance genes into rice cultivars was initiated.

2.B. Characterizing and using partial resistance for the control of rice blast

- Seventeen F5 lines with cold resistant, very early, and with a parent with a high partial resistance to rice blast disease, were selected by the FLAR, because they were immune to rice blast in Santa Rosa hot spot trials.

- A complete cycle of recurrent selection for the partial and complete resistance to rice blast disease, and for other agronomic traits was evaluated and shows promising genetic progress for resistance to rice blast.
- The first five recurrent populations with a narrow genetic basis, for the different types of rice cropping systems, have been sent to 10 country partners in Latin America, Africa, Asia and Europe.
- A new collaboration with partners of Central America has been developed and the partnership with China has been reinforced.

2.C. Characterization of the complex of rice hoja blanca virus and *T. orizicolus*

- New varieties with high levels of resistance to RHBV and *T. orizicolus* were released in Colombia and Venezuela during the last year. This is giving the farmers more options and should contribute to prevent outbreaks of RHBV and lower the use of pesticides.
- Two new varieties and some advanced lines have higher resistance to RHBV than Colombia 1, which is considered the prime source of resistance to the virus. This demonstrates the progress that is being made through conventional breeding.
- Progress is being made to understand the mechanisms of resistance to RHBV and *T. orizicolus*. This should lead to more systematic development of germplasm pools.
- Highly resistant varieties have multiple types of resistance to *T. orizicolus* and RHBV.
- It was determined that the variety Fedearroz 50 has both antixinosis and antibiosis to *T. orizicolus*. Although biotypes often develop overcome the resistance, it is possible that complex resistance of Fedearroz 50 will make it a durable variety.
- This year a study was made to determine if there are *T. orizicolus* biotypes. Using biological traits and molecular methods, it was concluded that there are no distinct biotypes of *T. orizicolus* in Colombia.

2.D. Foreign genes as novel sources of resistance to rice hoja blanca virus and *Rhizoctonia solani*

- A total of 421 selected transgenic lines representing various generations, and F2 populations derived from crosses with different varieties will be planted in the field on November 2000. These lines will be evaluated for RHBV resistance and agronomic traits following International as well as the Colombian environmental biosafety regulations at Palmira experimental station. The approval for field testing by the Colombian Biosafety Committee was issued on September 2000.
- Rice was successfully transformed with the RHBV NS4 gene.
- A total of 35 independent transgenic events carrying the PAPI deletion mutant gene, and 50 independent transgenic events carrying the PAPII gene had been generated up to now. A first set of plant tissue was sent to Rutgers University this summer for analysis and plants with PAP gene expression were identified based on Western analysis. PAP expressing plants will be evaluated for sheath blight resistance under greenhouse conditions.

2.E. Characterization of entorchamiento: a complex of *Polymyxa graminis* and rice stripe necrotic virus

- A greenhouse method that gives consistently high levels of disease pressure was developed and is being used to screen rice germplasm for resistance to entorchamiento.
- Wild species especially *Oryza glaberrima* appear to be the best sources of resistance and it may be possible to develop rice varieties that are immune to entorchamiento.

Output 3. Enhancing Regional Rice Research Capacities and Prioritizing Needs with Emphasis on the Small Farmers

3.A. FLAR and economics of rice production systems

- A total of 12 varieties were released this year by FLAR members.
- A study based on panel data obtained from 180 rice producers over the 1991-98 period in Colombia revealed that the new technologies have been readily adopted by all types of farmers.
- Within highly homogeneous edapho-climatic conditions (at the municipality level), farmers are likely to obtain very similar yields. Yield is independent of the rice grower's individual skills, the type of technology and social variables such as age, experience in farming and in rice production and level of education; it is also independent of farm size or type of tenure.

3.B. Rice Economics

- The producers' classification as good or bad performer is variable, and it differs from semester to semester. The changes observed in performance most likely respond to variables that cannot be controlled and that randomly affect the rice operation. There do not seem to be farmers with consistently “superior” packages, practices and performance, suggesting that rice technologies are neutral, quite universal, relatively simple, and easily and quickly adopted.

Project IP-4. Improved Rice Germplasm for Latin America and the Caribbean

Project Goal

To improve the nutritional and economic well-being of rice growers and low income consumers in Latin America and the Caribbean through sustainable increases in rice production and productivity

Project Purpose

To increase rice genetic diversity and enhance gene pools for higher, more stable yields with lower unit production costs that propiciate lower prices to consumers and reduce environmental hazards

- Enhancing Gene Pools
- Characterizing Rice Pests and the Genetics of Resistance
- Enhancing Regional Rice Research Capacities and Prioritizing Needs with Emphasis on the Small Farmers

Project Log-Frame

Narrative Summary	Measurable Indicators	Means of Verification	Important Assumptions
Goal Germplasm of beans, cassava, tropical forages, rice and their wild relatives collected, conserved and enhanced and made accessible to NARS and other partners.	• A sufficient number of accessions (of beans, cassava and tropical forages) representing genetic diversity are conserved and managed ex-situ. • Strategies and guidelines for in-situ management of biodiversity of beans, cassava and tropical forages have been developed and tested with users. • Accessible germplasm of beans, cassava, tropical forages and rice meet NARS standards in terms of productivity, stability, agronomic traits and user needs. • Techniques and relevant information for more efficient and reliable germplasm improvement are accessible to users.	• CIAT's germplasm bank inventories. • Partners technical reports. • Annual reports.	
Purpose To increase rice genetic diversity and enhance gene pools for higher, more stable yields with lower unit production costs that propiciate lower prices to consumers and reduce environmental hazards.	• Evaluations of yield potential (interspecific, wide, elite crosses and recurrent selection). • Continued use of improved germplasm by NARS. • Monitoring rice production practices and markets. • IPM practices in place for stable production and cleaner environment. • Rice lines selected with desired gene traits. • Potential sources for high levels of biotic and abiotic stress resistance.	• Databases. • Project, CIAT and NARS annual reports. • Publications. • Promotional Activities (conferences, training, workshops, field days)	• Stability (internal and external) • National policies favor adoption of new technology.
Outputs 1. Enhancing Gene Pools. 2. Characterizing Rice Pests and the Genetics of Resistance. 3. Enhancing Regional Rice Research Capacities and Prioritizing Needs with Emphasis on the Small Farmers	• Pathogen/pest variation and source of resistance identified. • IPM strategies. • Workshops. • Training courses. • Farmers' surveys.	• Project progress report for 2000. • Publications. • Project progress and workshop reports	• Continued support from CIAT/CIRAD/FLAR. • Continued adequate funding. • Recommendations adopted by NARS and implemented by farmers.

Narrative Summary	Measurable Indicators	Means of Verification	Important Assumptions
OUTPUT 1. ENHANCING GENE POOLS **<u>Activities</u>** A. Rice improvement using conventional breeding and gene pools/populations with recesive male-sterile genes. - Evaluation of savannas upland rice lines in Latin American countries. B. Developing upland rice for small landholders C. Advance and evaluation of inter-specific gene pools. D. Introgression of new plant type genes into LAC's gene pools. E. The use of anther culture and in vitro culture for enhancement of gene pools.	• Rice populations developed and improved (tolerance soil acidity; resistance to blast, RHBV, *T. orizicolus* (13); good grain quality; early maturity. • Number of field trials planted and lines selected. • Populations distributed to NARS for line development. • Populations developed (14); populations in process (12); populations yield tested/molecular characterized (4). Partners (WARDA, CIRAD, EMBRAPA, CORNELL). • Number of crosses made (433); tropical irrigated (226), temperate (155), upland (52). Number of selected lines. • Double haploids: interspecific crosses (386), acceleration breeding populations (815), somaclones (3758-Venezuela; 4440-Colombia)	• Project progress report for 2000. • Field visits and evaluations in testing sites. • Breeding populations distributed to LAC. • Breeding populations in storage and field. • Best lines and QTL'S identified. • Breeding populations in storage and field. . • Double haploids in storage • Publications.	• Continued support from CIAT/CIRAD/FLAR. • Adequate funding and timely release of budget. • Favorable climate. • Continued financial support for anther culture lab. • Crosses, field support and operational costs provided by FLAR.

Narrative Summary	Measurable Indicators	Means of Verification	Important Assumptions
OUTPUT 2. CHARACTERIZING RICE PESTS AND THE GENETICS OF RESISTANCE **<u>Activities</u>** A. Characterizing the interactions of host plant resistance to rice blast, sheath blight and grain discoloration B. Characterizing and using partial and complete resistance for the control of rice blast. C. Characterizing the interactions of host plant rice hoja blanca virus and *T. orizicolus* complex D. Foreign genes as novel sources of resistance to rice hoja blanca virus and *Rhizoctonia solani* E. Characterizing the interactions of host plant, *Polymyxa graminis* and rice stripe necrotic virus that causes entorchamiento.	• Virulence spectrum and genetic structure of rice pathogens. • Molecular markers associated and number of resistance genes. • Sources of complete, complementary and partial resistance. • Rice lines with diversified resistance to RHBV and *T. orizicolus*. • Understanding components of resistance to the RHBV complex. • Crop management components developed. • Transgenic lines with RHBV-viral genes with reduced symptoms produced and evaluated. • Transgenes introgressed into commercial cultivars. • Using novel genes for multicomponent resistance to rice pathogens. • Characterization of the RSNV and vector complex. • Development of germplasm evaluation methods.	• Collection of rice pathogens. • Database of resistance sources • Crosses made among resistance sources. • F7 lines with stable blast resistance combining genes Pi-1 and Pi-2. • Rice genome map with blast resistance genes mapped. • Rice progress report for 2000 • Publications • Publication and diagnostic kit available. • Resistant germplasm selected under artificial conditions.	• Rice crosses and populations developed by breeders. • Biotech. Unit identify molecular markers associated with resistance. • Continue collaboration with FLAR. • Continue adequate funding from Colombia and Rockefeller. • Continue support and adequate funding from CIAT, CIRAD, and FLAR. • Continued funding from Colombia, Rockefeller, Colciencias. • Permission for field testing of transgenic plants is granted. • Continued support and adequate funding.
OUTPUT 3. ENHANCING REGIONAL RICE RESEARCH CAPACITIES AND PRIORITIZING NEEDS WITH EMPHASIS ON THE SMALL FARMERS **<u>Activities</u>** A. FLAR and economics of rice production systems - Analysis of national rice samples in Colombia. - Creation of a network of rice economics in Latin America (RECAL). - FLAR breeding and crop management activities in LAC (training). - Promotional and diffusion of activities and research impact. B. Rice Economics	• Costs and coefficients of production. • National breeding plans written. • Number of scientists trained. • Published reports of courses. • FLAR publications. • Budget.	• Rice progress report for 2000.	• Special funds continue. • Recommendations adopted by farmers. • Adequate funding and timely release of budget.