CIAT International

Volume 12 No. 1 June 1993 ISSN 0120-4084

Know Your Enemy:

Biotech Advance Holds Key to Defeating World's Most Serious Rice Disease

Examining a "DNA fingerprint" of strains of the fungus that causes blast, the most widespread and damaging disease of rice, is Dr. Fernando Correa, CIAT rice pathologist.

Epidemics of rice blast, the most widespread and damaging disease of rice, have devastated crops across Asia, Africa, and Latin America for centuries. Farmers control the disease with heavy applications of costly and environmentally damaging pesticides, but recent research offers hope for nonchemical control.

"The pathogen that causes blast is so diverse and complex that breeding for resistance is an endless struggle," says Dr. Fernando Correa, CIAT rice pathologist. "Most improved rice varieties, initially resistant, became susceptible within a few seasons after release."

"The problem with breeding for rice blast resistance was that the target was enormous, with a tiny bull's-eye—and there were no circles," says Dr. Morris Levy, evolutionary biologist at Purdue University, USA, who works closely with CIAT.

Categorizing the races into families

In 1989, repeated sequences of DNA of the fungi that attack rice were discovered by Dr. John Hamer, then with du Pont de Nemours and now a molecular biologist at Purdue. Such repeated sequences would allow scientists, using "DNA fingerprinting," to understand the genetic organization of the fungus populations, and to

CIAT International

Vol. 12 No. 1 June 1993
ISSN 0120-4084

CIAT International is published three times a year to highlight results of CIAT's research in progress and international collaborative activities. Its contents may be quoted freely or reprinted with proper credit given to the source. A copy of the reprint or notice to the publisher would be appreciated.

For more information on CIAT and its research programs, contact CIAT's Communications Unit, Apartado Aéreo 6713, Cali, Colombia; telephone 57-23-675050; telex 05769 CIAT CO; FAX 57-23-647243; EMAIL CGI301.

The International Center for Tropical Agriculture (CIAT, from the Spanish acronym) is dedicated to the alleviation of hunger and poverty in developing countries of the tropics by applying science to agriculture to increase production while sustaining the natural resource base.

CIAT is one of the 18 international centers sponsored by the Consultative Group on International Agricultural Research (CGIAR), a group of 40 nations and international agencies that fund research for development. The Centers focus on the crops and livestock that provide 75% of the food for the developing world.

categorize races into families with similar genetic background. That opened the door to better understanding of the blast problem.

CIAT scientists found that "pathotypes" within families of the fungus attack only certain rices. Conversely, researchers have identified rice varieties that resist one or more specific blast families.

"It was like hunting 10 different criminals, then learning that they all work together and live in the same house," Levy points out. "Now we are learning to know the enemy."

Resistance is inherited

Meanwhile, in 1989, two CIAT experimental lines were released as varieties *Oryzica Llanos 4* and *5* by the Colombian Institute of Agriculture. The new rices, now planted on more than 15,000 hectares, have remained resistant to blast in farmers' fields for 5 years—far longer than previous improved rices.

"We couldn't fully explain why the resistance of those two varieties was so durable," Correa says. "Their parents were susceptible."

Fingerprinting and pathotyping are helping solve the mystery. One ancestor of the new varieties was susceptible to only one family of the fungus, but resistant to the rest. Another ancestor, was likewise resistant to all but one blast family.

"Each parent was killed by that blast family to which it was susceptible," Correa says. "But progeny of the cross inherited resistance to both groups of blast families."

"Those findings enabled CIAT scientists to develop a new strategy of 'tagging' and combining genes that confer resistance to specific blast families, rather than to individual strains," says Dr. Joseph M. Tohme, CIAT plant geneticist. "That will eventually allow scientists to deploy highly resistant rice varieties to counter fungus families in different countries and ecosystems."

Trailing the fungus

A global atlas of the rice blast fungus—a "guidebook" to help scientists set genetic barriers against blast—is now being developed by Purdue scientists in collaboration with CIAT and the Philippine-based International Rice Research Institute (IRRI).

"Now we have a feel for how the fungus will change," Levy says. "That should help scientists breed against the fungus of today, and also against the likely fungus of tomorrow."

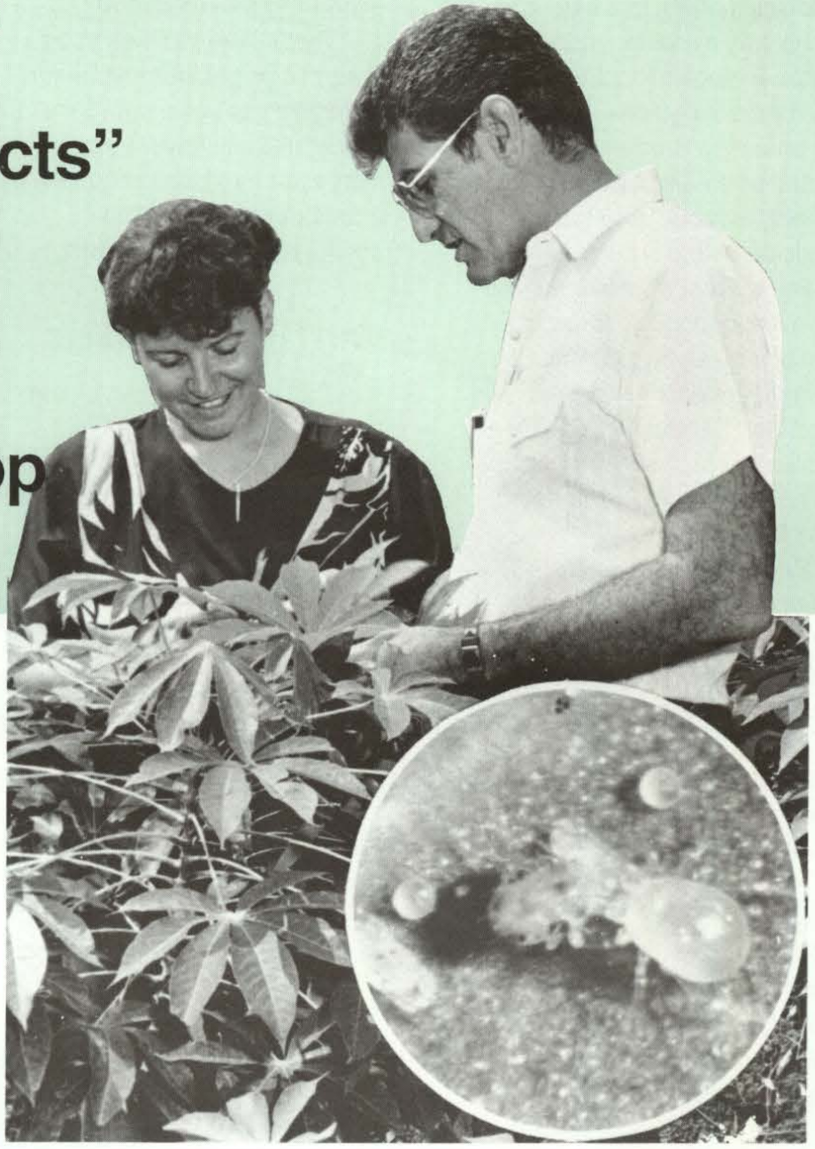
"For the world's 1.5 billion people in developing countries who rely on rice as their basic staple, that is a real advantage", says Dr. Alvaro Ramírez, CIAT rice economist. "The potential return from rice varieties with durable resistance to blast in Latin America alone has been estimated at more than US$400 million per year, when the disease is severe."

"The methodologies, once applied to other crops and pathogens, can vastly reduce the use of dangerous pesticides," Correa says, "and provide further proof that good science is an excellent investment."

The research is funded by the Rockefeller Foundation International Rice Biotechnology Program.

by **Alexandra Walter**
photo by **Fernando Pino**

"Friendly Insects" Battle Across Continents to Save a Neglected Crop



Examining mite damage to cassava leaves are Dr. Ann Braun (left) and Dr. Anthony Bellotti, CIAT Cassava Program entomologists.

Inset: Mites vs. mites: a "friendly" mite feeds on the cassava green mite.

Scientists have teamed up with some unusual allies—tiny wasps and an invisible fungus disease—in a nonchemical battle against cassava pests in Africa and South America.

Cassava is one of the most important food crops of the tropics, but is little known elsewhere. Portuguese traders brought the starchy root crop, a native of Latin America, to Africa 4 centuries ago. Today, 40% of the world's cassava is grown in Africa—more than in its native Latin America.

"Unfortunately, some uninvited guests crossed the Atlantic with the cassava plant," says Dr. Anthony Bellotti, CIAT entomologist.

"No one knows when the cassava mealybug entered Africa, but it first caused serious damage in Zaire, where cassava provides half the total energy intake, in the early 1970s," Bellotti, a specialist in integrated pest management (IPM), or ecologically based pest control, explains. "The mealybug had no effective natural enemies in Africa, and cassava farmers can't afford pesticides. So nothing could stop its rapid spread across more than 30 African countries."

Releasing the enemy

Scientists at the International Institute of Tropical Agriculture (IITA), CIAT's sister International

Center in Nigeria, knew that biological control is a safe and cheap way to control insect pests. Biological control is environmentally friendly because it is based on preservation of natural enemies of pests, or "friendly insects," and keeping pesticide use to a minimum.

But without effective natural enemies, biological control of the cassava mealybug in Africa seemed impossible, Bellotti explains. Because of CIAT's knowledge of cassava pests in Latin America, IITA requested assistance.

Perhaps natural enemies that control the mealybug in its native South America could be released in Africa. The problem was: the mealybug was unknown in the Americas.

In 1980, Paraguayan cassava fields were found infested with mealybugs—with wasps, in turn, parasitizing the mealybugs.

"The reason the mealybug was unknown in tropical America was that the wasp, its natural enemy, had kept it under control," Bellotti explains. Entomologists collected and shipped wasps to Africa. There, IITA found a way to package and drop these "friendly insects" into affected areas by airplane. Meanwhile, IITA entomologists, funded through GTZ, the German technical assistance agency, discovered additional natural enemies of the mealybug in South America that were eventually released in Africa.

"That's how the mealybug's enemy brought the pest under biological control in sub-Saharan Africa," Bellotti says. Farmers increased cassava production by 2 tons per hectare. The cost/benefit ratio was 149:1.

The fight continues

CIAT and IITA are now joining forces in a new pest management campaign targeted at other cassava pests such as whiteflies, the cassava green mite, the cassava hornworm, grasshoppers, storage pests, and root rot and virus diseases.

"Pest problems are similar on both continents, so some crop protection practices can also be similar," CIAT cassava entomologist Dr. Ann Braun explains. Parallel efforts will give economies of scale by sharing of information, responsibilities, and resources.

"We hope to reach an ecological balance between cassava pests and their natural enemies," Braun adds.

The next major target was the exotic cassava green mite, another South American pest that spread through Africa's cassava belt in the 1970s, cutting yields by 30 to 80%. Phytoseiid mites—again, natural enemies from South America—were identified and deployed against the green mite in Africa.

"Thus, we pitted mites against mites," Braun says.

A fungus disease that attacks the green mite in dry areas of tropical America is another potential ally for farmers in Africa and northeastern Brazil.

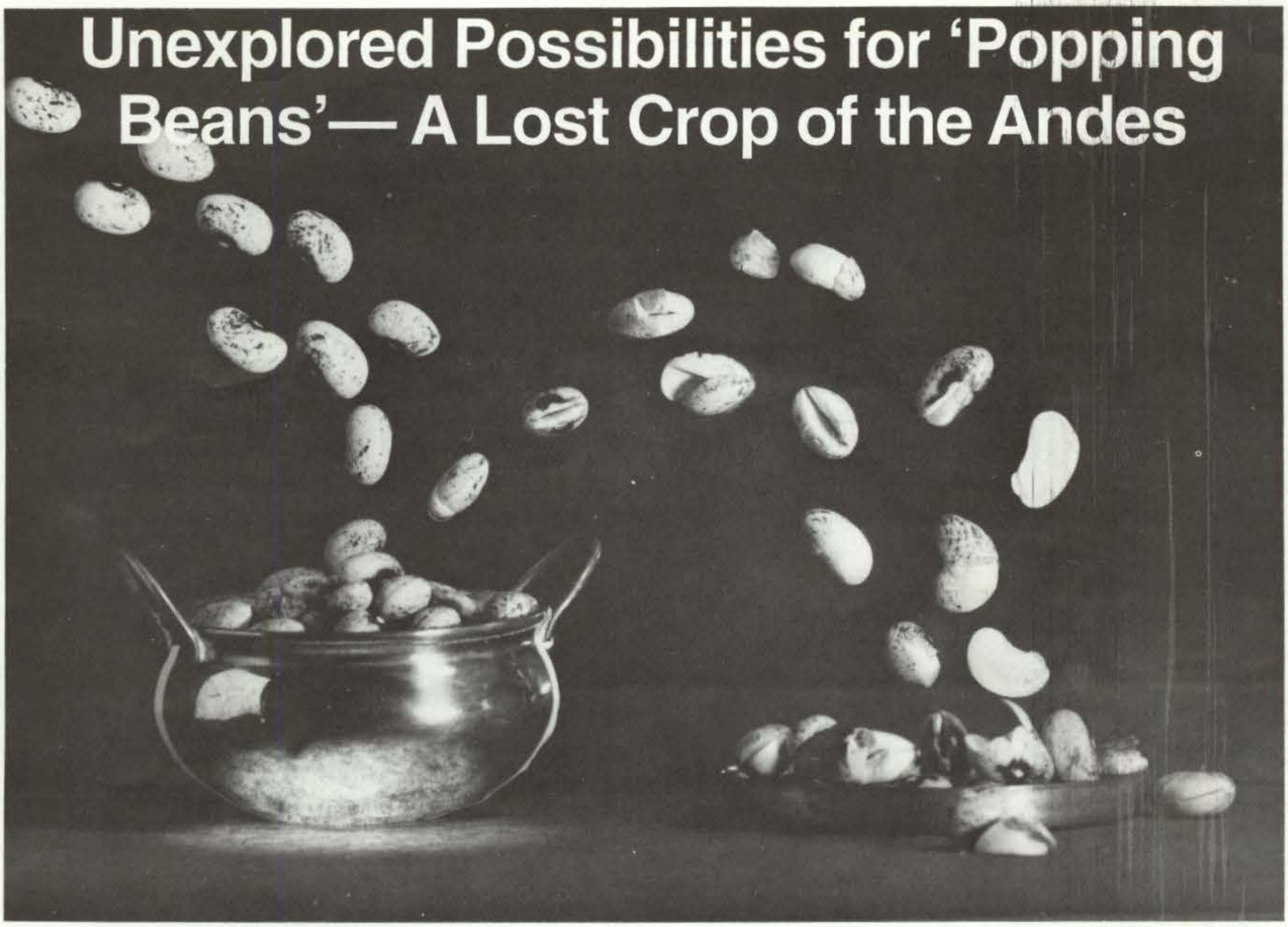
"This project is vital because cassava is increasing in importance as a food and feed crop for rapidly growing urban and rural populations in the tropics," Braun says. Cassava is a major food for more than 200 million Africans. Brazil is one of the world's largest cassava producers. Small-scale farmers grow most cassava, in both Africa and Latin America, on farms of less than a hectare.

CIAT will work in Brazil with the Empresa Brasileira de Pesquisa Agropecuária (EMBRAPA). IITA will spearhead the effort in West Africa in collaboration with national programs in Ghana, Benin, Nigeria, and Cameroon. The United Nations Development Programme will provide funds.

by **Bill Hardy**
photo by **Mauricio Antorveza**

Cassava is a major food for more than 200 million Africans. Brazil is one of the world's largest cassava producers. Small-scale farmers grow most cassava, in both Africa and Latin America, on farms of less than a hectare.

Unexplored Possibilities for 'Popping Beans'— A Lost Crop of the Andes



Ñuñas are considered one of the *lost crops of the Andes*. The beans are prepared like popcorn—heated in a hot frying pan until they double in size and burst. CIAT has directed some research to improve ñuñas but generally, they remain unknown, unappreciated, and unimproved by modern society. Uncooked ñuñas are in the pot to the left; 'popped' ñuñas are to the right.

Ñuñas, or 'popping beans,' a staple food of South American Indians for thousands of years, are almost unknown to the modern world. They are often called a *lost crop of the Andes*.

"Ñuñas are prepared like popcorn—toasted in a hot frying pan until they double in size and burst. Andean Indians eat them as a snack, a side dish, or in soups," says Dr. Julia Kornegay, CIAT bean breeder. Kornegay is one of the few scientists who have tried to improve yields and adaptability of the ñuñas.

Ñuñas existed well before the Inca Empire, and may be the oldest of all beans. The common bean is the staple food and main source of protein for 300 million of the poorest people in Latin America. But high in the Andes, water boils at such a low temperature that beans require hours of cooking to be edible—using precious firewood, a scarce commodity in the treeless highlands. "But a few minutes of frying will pop the ñuñas. That saves money and trees," Kornegay says.

Breeding for better traits

Several traits limit the growth of ñuñas to their native Andes. First, daylength must be short. That apparently has restricted ñuñas to equatorial zones. "If this trait cannot be changed, then ñuñas will remain forever 'lost' in the Andes," Kornegay says, "unless a local system is developed to grow and market the beans from there."

Also, ñuñas normally grow at altitudes higher than 2,500 meters. "We have grown ñuñas at 1,700 meters at the CIAT station in Popayan, Colombia," reports Dr. Jeffrey White, CIAT bean physiologist. "They produced seed, but didn't yield well."

"Ñuñas are also susceptible to most bean diseases, another reason why farmers grow them less and less," Kornegay says. "In fact, the crop is probably disappearing."

Kornegay has crossed popping bean varieties with disease-resistant common beans and sent the progeny to Peru, where local scientists select for disease resistance. "But when crossbred with ordinary beans, the ñuñas' offspring lose their popping ability," Kornegay says. "Special breeding techniques are needed to recover that trait."

About 30 types of ñuñas differ in seed size, shape, and color, but all taste similar. "They are valued mostly for the popping trait, which varies among strains;" Kornegay says. "Ñuñas can retain their popping ability for years, if stored at low temperature and low humidity. But they lose the popping trait in a few months, if stored improperly."

Assuring the market

Most ñuñas are grown for home consumption; few reach local markets. Ñuñas are not sold outside the Andes. Although CIAT receives requests for ñuña seed, few come from Latin America.

Kornegay would like to see popping beans marketed internationally, to create jobs and generate income in the Andes. "Peruvian farmers would probably grow the beans commercially if they had a secure market," she says.

"Ñuñas have a lot of starch so their flavor is flat, dry and powdery," Kornegay adds. "But popped ñuñas are soft and taste like a mix of peanuts and popcorn. Ñuñas can be popped in a microwave oven, so they could be marketed as a quick, high-protein snack food in the industrial nations."

Ancient Andean farmers developed an amazingly productive agriculture that included roots, grain legumes, vegetables, fruits, and nuts. Some of those traditional crops, like potatoes and common beans, left the Andes and are now part of the international diet. "Ñuñas could be another example," Kornegay says, "but that would require more research and funds to develop improved varieties that will grow over a wider ecological range, and with genetic resistance to diseases."

The ñuñas have scarcely been studied. "The popping bean remains unknown, unappreciated, and unimproved by modern society," Kornegay says.

by **Loretta Ferguson**
photo by **Mauricio Antorveza**

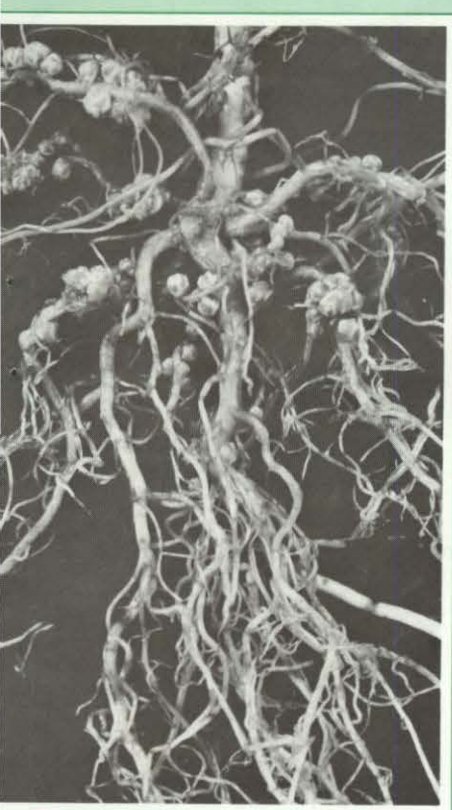
Bacte
Help B
Capture Nitrogen from the Air

Healthy bean roots show nodules formed by colonies of bacteria, which use nitrogen gas from the air to digest the carbohydrates that they draw from the plant. The plant, in turn, feeds on the resulting nitrogenous compounds. The relationship between the plant and the bacteria is "symbiotic".

Bacteria tha
air—instead of ni
available to farme
world's leading re
beans grow in po

The nitrogen-f
"Rhizocaj" at one
as urea. "It is jus
maize, which req
Pineda, CIAT mic

ia
eans



e bean plant use "free" nitrogen gas in the
om a sack of purchased fertilizer—are now
Andes of Peru, announce scientists at the
enter for beans. These bacteria also help
vhere nitrogen fertilizers are not used.
teria are mixed with peat and sold as
e price of common nitrogen fertilizers such
tive, particularly for intercrops of beans and
amounts of nitrogen," says Paulina
st and agronomist. "One hectare of bean plants uses as much as 136 kg of nitrogen."

A simple process

The farmer mixes bean seeds with sugar and water, adds the product, mixes again until the seeds are well coated, and plants in the usual way. Rhizocaj is sold in 50-g packets, enough for 5 kg of seeds, through the Universidad Nacional de Cajamarca, Peru.

"The relationship between the bean plant and bacteria is symbiotic, that is, mutually beneficial," Pineda explains. "As the bean grows, the bacteria form colonies, seen as nodules along the roots. The bacteria draw and digest carbohydrates from the plant, using nitrogen gas from the air. The gas converts into nitrogenous compounds on which the plant feeds."

Universities in Latin America and the USA have successfully developed similar products for other legumes. Results were good in Cuba, but variable in Mexico and, until recently, attempts in South America had failed. Rhizocaj was developed over 4 years (1988-1991) for Peruvian small farmers by CIAT's Regional Bean Project for the Andean Zone (PROFRIZA in Spanish), the Universidad Nacional de Cajamarca, and the Instituto Nacional de Investigaciones Agrícolas y Agroindustriales (INIAA).

Strains should be adaptable

"Only some strains of the *Rhizobium phaseoli* bacterium symbiose effectively with beans to substitute for fertilizers in farmers' fields," Pineda says, "And they must be able to compete with native strains." Although somewhat effective native strains do not produce enough nitrogen for farmers' needs. "Commercially viable strains have to be adaptable," Pineda adds, "that is, they must symbiose with different bean varieties under varied environmental conditions.

"I'm happy because, in a drought year, I got a harvest from bean seeds mixed with Rhizocaj".

"Farmers are enthusiastic about Rhizocaj—but it's only for the mountains," Pineda says. "We are still to find useful strains for Peru's coastal regions."

"I'm happy because, in a drought year, I got a harvest from bean seeds mixed with Rhizocaj, says farmer José Blas Sánchez-Heredia from Uchucla Chulit, Cajamarca, Peru. "I got nothing from untreated bean seeds."

If funding permits, PROFRIZA will test Rhizocaj in the highlands of Ecuador. In Bolivia, sales have already begun in Santa Cruz Department.

by **Elizabeth de Páez**
photo by **Mauricio Antorveza**

You're Covered!

Cover Legumes for Savannas and Degraded Environments

South American savannas cover an area 4 times the size of France across Colombia, Venezuela, Brazil, and Bolivia.

Pasture legumes benefit both animals and degraded land, and have the potential to increase farm production in the vast savannas that cover 240 million hectares, 12% of South America.

"Two savanna scenarios are emerging," explains Dr. Richard Thomas, CIAT nitrogen cycling specialist. CIAT scientists work to develop sustainable farming systems for acid-soil savannas through pasture legumes.

"In one scenario, more efficient agricultural systems must be developed for the savannas of Venezuela and Brazil, plagued by debt burdens and increasing land degradation," Thomas says. "In the other scenario—Colombia and Bolivia—there is an opportunity to open underused land."

These two savanna regions—covering an area 4 times the size of France—have common problems: low soil fertility and high acidity as a result of intense rainfall, leaching, and high decomposition of soil organic matter. "Inputs such as lime and fertilizer may not be readily available or may be too expensive for farmers, so we are selecting plants that adapt to this harsh environment," Thomas adds. "Forage legumes may be the answer."

The South American savannas...cattle, *vaqueros*, and endless pale-green plains beneath a clear blue sky. The savannas cover 12 percent of South America and produce almost $15.5 billion worth of beef and milk annually.

Increased production

Forage legumes pull nitrogen from the air and "fix" it into their tissues, Thomas explains. When the plant tissue decomposes, the nitrogen can be transferred to the soil and used by other plants. Legumes thus act as a "free" nitrogen fertilizer. Simultaneously, they build soil organic matter.

"In Colombia's savannas, grass-legume pastures have more than doubled liveweight gain per head of cattle per hectare, and increased meat and milk productivity by 10 times compared with a managed native savanna," Thomas says.

"Cows on forages may also bear their first calves up to 30% earlier, and intervals between calves may shorten by 22%. These improvements in animal performance on grass-legume pastures have been maintained over periods of 4 to 10 years."

Reduced erosion and enriched soils

Legume material that does not decompose completely within 1 year enters the soil organic matter pool and can subsequently be used for pastures or crops. Rice yields were compared after 8-year-old grass and grass-legume pastures—with 25 kg of phosphorus but no nitrogen fertilizer—in the Colombian savannas. Rice after a pure grass pasture yielded 1.4 tons/ha. After the grass-legume pasture, rice yielded 3.1 tons/ha, an increase of 1.7 tons.

"Grass-legume pastures are also used to recuperate degraded land in Peru's forest margins," Thomas explains. "And they protect Colombian hillsides that have been eroded by poor farming practices". The legumes cover the soil rapidly, reducing erosion and building organic matter.

Farmers use legumes as an alternative nitrogen source in Colombia's coffee zone, where small farmers apply as much as 250 kg of nitrogen per hectare per year. As a ground cover, the legumes help prevent fertilizer from leaching into groundwater.

by **Bill Hardy**
photo by **Alexandra Walter**

Cassava Turns to Cyanide for Self-defense

Cassava is a staple food of 500 million persons in developing countries. Its dependable production and end-use versatility make it a driving force for regional development.

Cassava, the staple food of 500 million persons in developing countries, may use the poison cyanide to fight insects, such as the burrowing bug. This possible defense mechanism was discussed at the first international scientific meeting of the Cassava Biotechnology Network (CBN) held 25-28 August 1992 in Cartagena, Colombia, an important cassava-growing region.

The purpose was to examine the use of biotechnology to overcome constraints to cassava production and develop new uses for the crop. The 125 participants from 28 countries included biotechnologists, socioeconomists, and other scientists from national agricultural research systems, nongovernmental organizations, CIAT, and the International Institute of Tropical Agriculture (IITA), in Nigeria.

Scientists discussed how cyanogenic compounds, which occur naturally in cassava, can affect human health. "When drought or economic problems cause food scarcities, cassava is often the only crop available for food," explains Dr. Christopher Wheatley, CIAT cassava quality and utilization specialist. "Processing tends to be rushed because the need for food is urgent. Cyanide elimination becomes less efficient. This can sometimes lead to cyanide-induced health problems."

Multiple uses and different solutions

"Understanding how and why the plant produces cyanide was a highlight of the meeting," Wheatley adds. "We can potentially use that knowledge to increase farm production and provide better quality cassava for different end uses."

"Cassava is important in seasonally dry and infertile environments because it yields more carbohydrate than most crops, it has a flexible harvest period (thus providing food when other crops cannot), and its uses are varied," says Dr. Ann Marie Thro, CBN coordinator. "This combination—dependable production and end-use versatility—makes cassava a driving force for development."

But cassava also has a few constraints. It deteriorates rapidly after harvest and is susceptible to some insects and diseases, Thro points out. "Biotechnology may offer feasible and economic solutions to such problems. It could also provide opportunities to produce high-quality starches for specific end uses."

"Biotechnology will obviously play a more important role in cassava germplasm activities, especially conservation and characterization," explains Dr. William Roca, an organizer of the CBN meeting and head of CIAT's Biotechnology Research Unit. "Biochemical markers helped scientists to identify duplicates among the 5,000 varieties in the cassava collection of the CIAT gene bank. DNA markers help further characterize the collection and thus reduce the number of accessions."

Advances in research

Scientists have been working on the development of genetic maps to increase the efficiency of genetic improvement. Participants stated that a first map could be generated faster than before. But the quality of a map depends heavily on the molecular tools and genetic stocks used, and wrong or false maps can easily be generated.

Other discussion topics included tissue culture and cryopreservation to lower the cost of germplasm conservation, molecular biology of stress tolerance in cassava, and characterization of genes and biochemical pathways controlling nutritional and quality factors.

"CIAT is one of six advanced laboratories in the world using embryogenesis to transfer genes in cassava."

Progress has been made in cassava research. "'Recalcitrant' cassava cultivars were previously hard to work with, but are now producing embryos with satisfactory efficiency. The mass production of embryos has also been improved," Roca explains. "CIAT is one of six advanced laboratories in the world using embryogenesis to transfer genes in cassava."

In recent years, cassava production has increased substantially in Africa. Surplus production has gone into processing. Participants recommended biotechnology research in processing, especially in fermentation, to develop additional uses for cassava.

Working groups highlighted several areas of cassava research with future priority: molecular maps and studies on variability in wild species; transformation and regeneration ("genetic engineering"); improvement of culinary and industrial quality; the ecology, physiology, and manipulation of cyanogenesis; the integration of farmer, processor, and national program priorities into the biotechnological research agenda; and increased involvement of socioeconomists in research and development projects.

CIAT organized the meeting. Sponsors were the Directorate General of International Cooperation (DGIS) of the Dutch Foreign Ministry and the Rockefeller Foundation.

by **Bill Hardy**
photo **CIAT files**

The CIAT Board Appoints New Chairperson, Four New Members

Dr. Lucia Vaccaro, CIAT's new chairman, addresses the CIAT staff.

Dr. Lucia Pearson de Vaccaro is the new chairperson of the CIAT Board of Trustees. Four other new members have also joined the Board.

Vaccaro is the first woman to serve as chairperson of the board of any Center sponsored by the Consultative Group on International Agricultural Research. She is an animal breeder and professor at the Faculty of Agronomy, Universidad Central de Venezuela, Maracay. Vaccaro replaces Dr. Frederick Hutchinson, board chairman from 1988 to 1992 and president of the University of Maine, USA.

Before becoming chairman, Vaccaro served on CIAT's Board of Trustees since 1988 as a member of the Program Committee. She joined the Universidad Central de Venezuela in 1981, after having worked at six universities in England, Peru, USA, and Venezuela; the Department of Agriculture, United Kingdom; and the Instituto Veterinario de Investigaciones Tropicales y de Altura (IVITA), Peru. She received her bachelor's degree from the University of Cambridge and her Ph.D. from the University of Leeds, England.

"Dr. Vaccaro's able leadership—amply demonstrated during her participation in board committees and international fora such as those of the Consultative Group on International Agricultural Research—brings CIAT a very special human dimension—essential for the continued nurturing of the 'CIAT family'," says Dr. Gustavo Nores, CIAT's director general.

New board members

Robert D. Havener, president and chief executive officer of Winrock International, Morrilton, AR, USA, from 1985 to 1993. Havener also served as director general of the International Maize and Wheat Improvement Center (CIMMYT), Mexico, from 1978 to 1985.

Dr. Samuel C. Jutzi, agricultural economist and agronomist, is professor at the Faculty of International Agriculture, University of Kassel, Germany. Jutzi's research interests are germplasm development and cropping systems.

Dr. Paul L. G. Vlek, soil nutrients specialist, is professor and director of the Institute of Agronomy and Animal Health in the Tropics, Georg August University, Göttingen, Germany. Vlek's main research interest is the sustainable management of farming systems and their natural resources.

Dr. Martin S. Wolfe, specialist in disease and pest management, is professor of phytopathology at the Swiss Federal Institute of Technology, Zürich, Switzerland.

Departing members, who finished their terms of service in 1992, were Dr. Alvaro Umaña, environmental engineer and economist from San José, Costa Rica; and Dr. Leopoldo Gahamanyi, agronomist and pedologist from Butare, Rwanda.

by **Elizabeth de Páez**
photo by **Sieglinde Espino**