# Bintu and Her New Rice for Africa:

## *Breaking the shackles of slash-and-burn farming in the world's poorest region*

This is Bintu. She's typical of 20 million rice farmers in West and Central Africa, the world's poorest region. More than half of the population survives, somehow, on less than one US dollar a day.

Most of the rice farmers are women, who are bound to an environmentally degrading, slash-and-burn farming system, with shifting cultivation.

Bintu farms about 1 hectare in southern Côte d'Ivoire.

Like her ancestors, Bintu clears brush from new land, then plants upland, or dryland rice. She burns the brush, temporarily releasing nutrients into the fragile soil. Bintu then plants rice seeds by hand in the ashes. She uses neither fertilizer nor pesticides, and produces less than 1 tonne per hectare. Bintu harvests the crop panicle by panicle, with whatever help she can find. Nutrient-robbing weeds grow faster after each harvest. After two or three crops, Bintu must move on, to clear new fields.

Traditionally, farmers like Bintu left the land fallow for 10 years or more, before returning to clear and plant it again. But Bintu doesn't have that option. Too many mouths must be fed. The population of her village, like villages across West and Central Africa, is growing by an incredible 3% per year. And the increasing size and number of villages are making new land increasingly scarce.

So Bintu must return to burn and plant the same land again after only 3 or 4 years. That's not enough time for the soil to recover its fertility. And Bintu can't stay ahead of the weeds, which grow 70% more aggressively on land re-cleared after such a short fallow.

After one or two harvests, Bintu moves on to repeat this vicious and seemingly endless cycle of ecological destruction and poverty.

But a new type of rice, tailored specifically for Africa, may break the shackles of slash-and-burn rice farming. Scientists call the new type *NERICA*, for *NE*w *RIC*e for *A*frica.

The NERICAs are also sometimes called *interspecifics*, because they bridge the genetic gap between the two distinct species of rice. They have a radically different plant type that combines the hardiness and weed suppression of the African rice species with the productivity of the rices of Asia.

The new rices for Africa are spreading faster than any new farm technology, ever, in Africa. Twenty thousand farmers in Guinea are growing them on 5000 hectares.

The NERICA seeds offer hope for Bintu, for millions of poor farmers like her, and for countless others who struggle in urban squalor, spending most of their meager income on rice.

This is the story of Bintu, and the *New Rice for Africa*.

## Rice in West and Central Africa

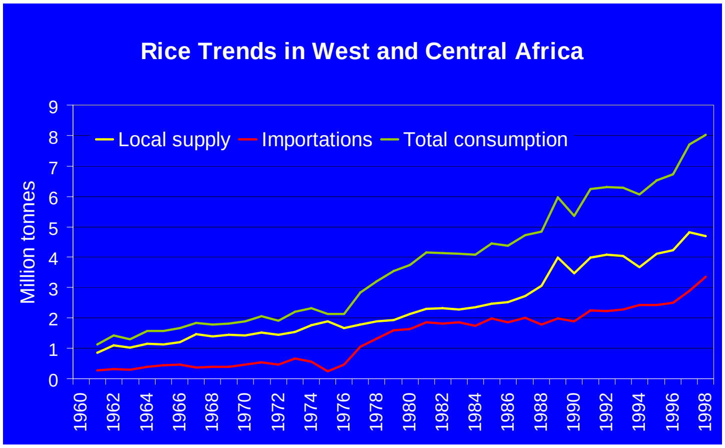
Nowhere is the struggle for food more desperate than in West and Central Africa—home to 240 million, one of every three persons on the continent.

"Keep in mind that 'food' means 'rice' for many people in West Africa today," says Dr Kanayo F. Nwanze, director general of the West Africa Rice Development Association (WARDA), based in Côte d'Ivoire.

"Ironically, rice was considered a luxury food only two decades ago," Nwanze adds. "Today, it's the staple. Rice now contributes more calories and protein than any other cereal in humid West and Central Africa, and about the same as all roots and tubers combined. Demand for rice is growing faster here than anywhere in the world."

In three decades, rice imports have increased over 12 fold, to about 3.2 million tonnes a year, at a staggering cost of US$1 billion. That's a cruel price for the most impoverished region on earth. And demand for more rice is growing by 5% every year.

Urbanization and population growth fuel the increasing demand. As rural people migrate to the towns and cities to find work, they take more meals—mostly rice—in the markets and at workplaces. Women who enter the workforce use more rice because they can prepare it quickly and easily.




**Why Bintu?**

- There are about 1.64 million hectares of rainfed upland rice in West and Central Africa, employing about 70% of the region's rice farmers
- Some 80% of the upland cultivation is slash-and-burn agriculture
- The majority of upland rice farmers in the region are women
- The major labor-intensive activities in upland rice cropping—namely, land clearing, weeding and harvesting—are mostly carried out by women and children.

About 40% of West Africa's 4.1 million hectares of rice is upland, or dryland, grown like maize. And 80% of the upland rice is slash-and-burn, like Bintu farms.

Each slash-and-burn crop produces less than before—and puts still more pressure on a fragile ecosystem.

## Bintu and the rices of Africa and Asia

Bintu and fellow farmers have no choice but to continually clear land, grow a few crops, and move on to clear still more land. The types of rice currently available *force* them to continue this system.

Bintu can't grow the high-yielding rice varieties that have revolutionized production in Asia. The semi-dwarf varieties don't compete well with African weeds, or tolerate drought and local pests in rainfed farming systems in Africa. And African farmers are far too poor to invest much in pesticides, herbicides, or fertilizers.

Instead, Bintu grows a tall variety of *Oryza sativa*, the Asian species of rice that entered Africa 500 years ago. HerAsian rice variety produces a fair amount of grain, but growing it means continually clearing new land to stay ahead of weeds, its main enemy.

Bintu also grows a small plot of a special rice that her mother, and grandmother, grew. She calls it *malbe*, but its scientific name is *Oryza glaberrima*. It evolved in Africa as a distinct rice species. African farmers have grown *glaberrima* for more than 3500 years.

Weeds aren't much of a problem in Bintu's strange-looking African rice. *Glaberrima* grows fast, covering the ground quickly, and its wide, droopy leaves shade out, or smother weeds. The African rice needs little care, and resists the drought and pests that make Asian rices hard to grow.

Bintu especially likes how the African rice tastes. It's a delicacy, served at village festivals and weddings.

But Bintu could never feed her family by growing *glaberrima*, much less sell surplus rice for a profit. Her African rice yields abysmally low, because it lodges, or falls over, when grain heads fill. It also shatters easily, wasting more precious grain.

So Bintu's African rice is now a luxury—but to feed her family, she's bound to the Asian species, and to slash-and-burn farming.

For years, scientists have wanted to combine the ruggedness of the African rice with the productivity of the Asian species. But the two species evolved separately over millennia. They are so different that offspring from their crosses have been sterile. Efforts to combine their best genetic traits always failed.

Until now.

*A field of* Oryza glaberrima*, the African species of rice. Note how the strange-looking rice lodges, or falls over.*

## Genetic treasures hidden in seeds

In 1991, Dr Monty Jones led a team of scientists at the West Africa Rice Development Association (WARDA) in a new breeding effort to unlock and combine the genetic potential of the Asian and African rices.

Key to the effort was WARDA's rice gene bank of 16,000 rice varieties which are preserved as seed in cold storage, duplicated at the International Institute for Tropical Agriculture (IITA) in Nigeria, and the International Rice Research Institute (IRRI), Philippines.

Among the preserved varieties are 1500 *O. glaberrimas*, like Bintu grows. Many of those hardy *glaberrima*s would be extinct, had their seeds not been collected and preserved, because African farmers had abandoned them to grow their distant Asian cousins.

"Genetic treasures are hidden in these seeds," Jones says, holding a handful of *glaberrima* seeds from the gene bank.

The WARDA team would unlock those treasures, and put them to work, to improve the lives of farmers like Bintu.

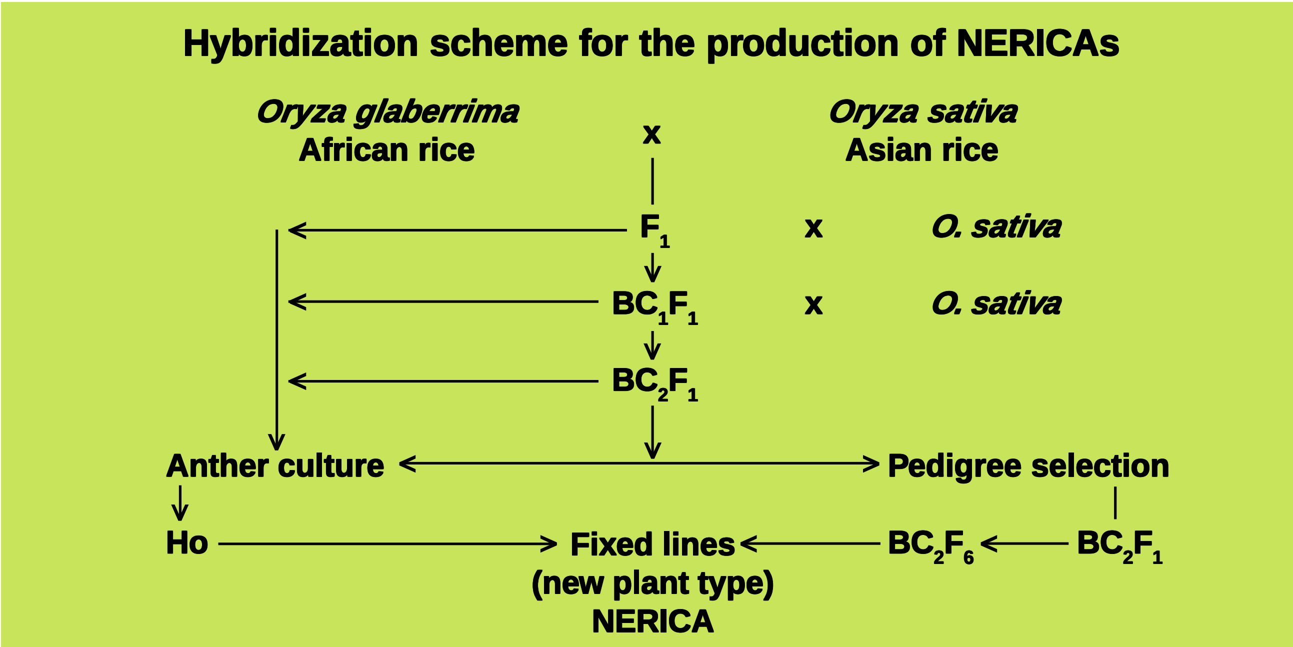
## Breeding strategy

Jones and his group used molecular biology to overcome sterility, the main problem in crossing the species, and to speed the breeding process. WARDA made 'wide crosses' of the African and Asian rices, then removed the fertilized embryos by embryo-rescue, and grew them in artificial media.

Breeders then backcrossed the progeny, twice, to the Asian parent to recombine the genomes, or genetic backgrounds, of the distinctly different species. Backcrossing allowed introgression, or mergence, of useful genes such as those that control the wide, droopy leaves, from the rugged *O. glaberrimas* into the more productive *O. sativa* background.

Anther-culture helped the breeders 'fix' progeny lines rapidly, and retain recombinant lines—with the combined traits of both the African and Asian parents.

"With conventional breeding, the progeny of a cross 'segregate,' providing large numbers of different plant types," Jones explains. It then takes five to seven generations to isolate and purify, or




select, a line with a desired combination of genetic traits. For upland rice, that can mean 5 to 7 years—because usually, only one crop per year can be grown.

"With anther-culture, a line can be selected after only one generation, and a new variety can be developed in 18 to 24 months."

By the mid-1990s, WARDA scientists were testing the NERICAs, the *new rices for Africa*, in rainfed conditions.

### Traits of the *new rices for Africa*

Genetic differences in the two species made breeding difficult. "But those differences also gave the new rices high levels of *heterosis* or *hybrid vigor*," Jones says. Heterosis is the phenomenon by which the progeny of two genetically different parents grow faster, yield more, or resist stresses better than either parent.

*A higher yield ceiling.* The *NERICAs* have raised the 'yield ceiling' of upland rice by 50%. The maximum potential production for upland rice was previously estimated at 4 tonnes per hectare. The new rices can, in the best of conditions, produce 6 t/ha.

"That gives us new goals to shoot for," Jones says.

*‘Papa NERICA,’ upland-rice breeder Monty Jones assesses ‘his babies’ in the field.*

“In farmers’ fields in Guinea, the NERICAs are yielding as high as 2.5 tonnes per hectare with few inputs. A few farmers are harvesting 5 tonnes or more with just minimum increase in fertilizer use,” Jones says. “We’re talking about 25% to 250% production increases.”

The new rices are taller than *O. glaberrima*, which makes harvesting easier—especially if the farmer has a baby strapped to her back.

*Weed suppression.* Weeding accounts for 30 to 40% of all labor invested in a crop. Women and children do most of the weeding.

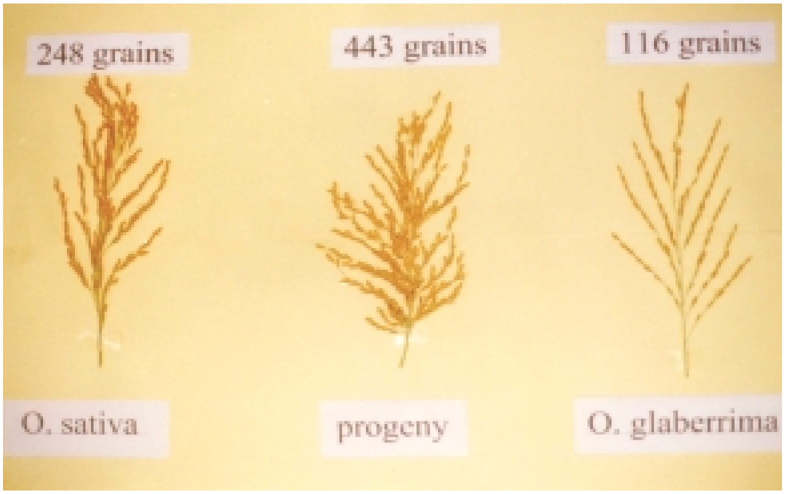
The NERICAs have wide, droopy leaves, inherited from their African parent, that smother weeds in early growth. That reduces the need for weeding, and allows farmers to work the same land longer, rather than constantly clearing new land.

However, those droopy leaves grow erect, like leaves of the Asian parent, when the new rice enters the reproductive stage, where grain is produced. The erect leaves capture more sunlight and increase photosynthesis, and grain production.

Stems of the new rices are strong, so they can support heavy heads of grain without falling over. The new rices produce more tillers, with longer grain-bearing panicles, than either parent. Like *O. sativa*, the new rice holds the grains tightly, not allowing them to shatter to the ground.

*Panicle structure.* WARDA also changed the structure of the panicles. Main branches from panicles of *O. glaberrima* hold only single grains, so each produces only 75 to 180 grains. Main branches on the Asian rices produce several ‘forks,’ each holding 3 or 4 grains, so a panicle may produce 250 grains. The NERICAs inherited the forked branches and thus, with their longer panicles, can carry more than 400 grains.

Oryza glaberrima *shades out, or smothers, weeds.*




*Heterosis in action: the NERICAs inherit panicles with secondary branches from the Asian parent (*Oryza sativa*), but produce considerably more grains than either parent.*

*Shorter growth duration means sustainable double cropping.* The NERICAs also change the growth duration of upland rice. Typical upland rice varieties mature in 150 to 170 days. Improved semidwarfs, in Africa, mature in 120 to 140 days. But the new rices mature in 90 to 100 days.

The shorter time from seed to seed allows farmers to grow two crops during one rainy season. The second crop can be a legume such as mucuna or soybean.

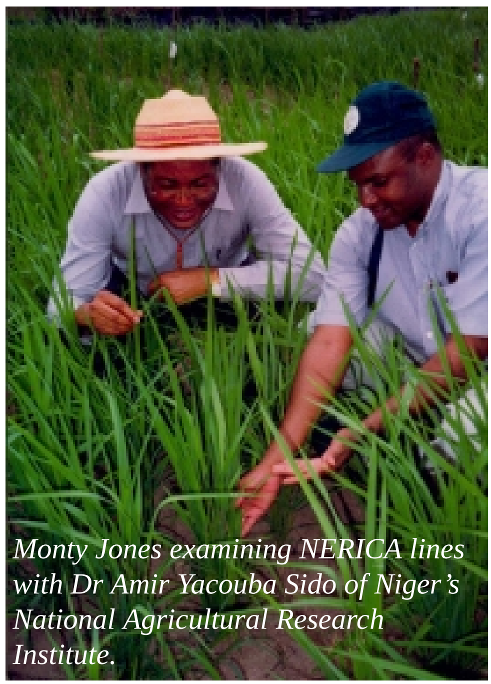
"Double-cropping with a legume is a beautiful system for upland rice," Jones says. The profuse growth of the legumes smothers out weeds. That also means fewer weeds in the next rice crop to follow.

After harvest, the farmer can slash and incorporate the legume into the soil—adding 60 kilograms of nitrogen per hectare.

Yields of rice grown after legumes are 30% higher than yields of rice grown after a natural 'weedy' fallow.

With the rice–legume system, farmers can remain on the same land (because it's now more productive), rather than leaving their weed-choked and nutrient-depleted fields after a few crops, to clear more land.

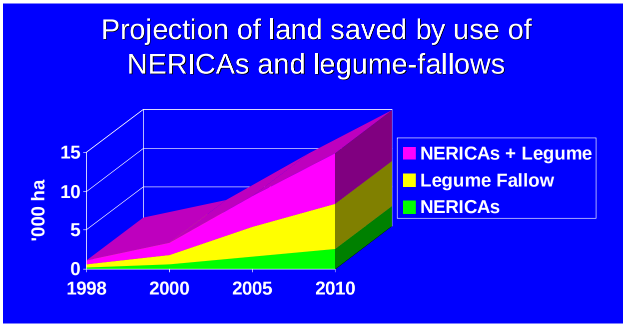
Each hectare of well-managed rice–legume rotation 'saves' 4 hectares from the machete. Projections on the spread of NERICAs and legume-fallows in the region, based



*Monty Jones examining NERICA lines with Dr Amir Yacouba Sido of Niger's National Agricultural Research Institute.*

on figures available in 1998, suggest that by 2010 the total area of land saved will be about 15,000 ha—that is, if NERICAs and legume-fallows were not used, then an extra 15,000 ha would have to be brought under rice cultivation to produce the same amount of rice (see graph).

The Japanese NGO Sasakawa Global 2000 is promoting the system of double-cropping NERICA rice and food legumes in Guinea and Nigeria.




*Drought tolerance.* Almost 80% of West Africa's rice land depends entirely on the fickle rains for water.

The rugged *O. glaberrimas*, which have survived in West Africa for millennia, have evolved a remarkable ability to resist and avoid drought.

"The plants go into a state of low metabolism when drought stress is severe," says Dr Alain Audebert, WARDA plant physiologist. "A field of *glaberrima* may *look* dead—but then it recovers quickly when the rains finally come."

Specific morphological traits help the *glaberrima*s avoid drought. Their leaves and roots, for example, are thinner than those of *sativa*.

"Put a *glaberrima* under drought stress, and its thin leaves 'roll' quickly, to retain water," Audebert explains.

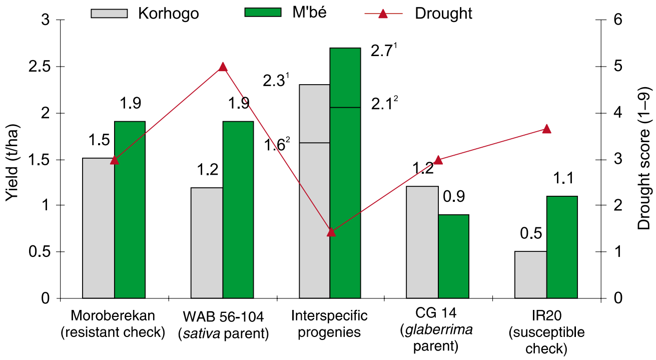
The thin roots make *glaberrima*s good 'soil explorers,' Audebert says. "One gram of *glaberrima* roots has a combined length of about 150 meters. A gram of *sativa* roots is about 100 meters long.

"The *glaberrima roots* come in closer contact with moisture that clings to soil particles, and can extract it for the plant's use."

When the rains come after drought, the *glaberrima*s can recover faster, because replacement of the thin leaves and roots requires less water and nutrients.

The NERICAs have inherited the thin leaves and roots of *O. glaberrima*.

Four new NERICA lines have shown good drought resistance, out-yielding their traditional *O. glaberrima* and *O. sativa* parents, as well as the resistant check variety, in drought screening at Korhogo, in the savanna zone, and M'bé, in the transition zone of Côte d'Ivoire. Plants were stressed




*Drought tolerance of four NERICAs compared with checks and parents. Drought score is a visual assessment of the effects of drought on the plants in the field.*

at the critical maximum tillering stage, when they need water to build new leaves, stems and roots, and at the reproductive stage, when grain production starts.

At Korhogo, where drought was more severe, the new rices averaged 1.6 t/ha, while their *glaberrima* and *sativa* parents averaged only 1.2 t/ha. The highest-yielding NERICA produced 2.3 t/ha (see graph).

*Acid-soil tolerance.* Most soils are acidic in the humid zones, where impoverished farmers grow 70% of West Africa's upland rice.

"Adding chemicals to make the soils suit the rice plant is not possible," says Dr Kanwar Sahrawat, WARDA soil chemist. "Instead, we're changing the plant to suit the soil."

WARDA is screening more than 8000 rice lines, including about 400 NERICAs, for tolerance to acidity in highly acid soils at Man, in western Côte d'Ivoire. Half a dozen NERICAs have been selected that grow normally, and give acceptable yields, in soils with a pH as low as 4 (7 is neutral).

*Use of indigenous rock-phosphate.* The humid forest soils are also severely deficient in phosphorus. Their high levels of aluminum and iron converts them into an insoluble form that the plant can't use.

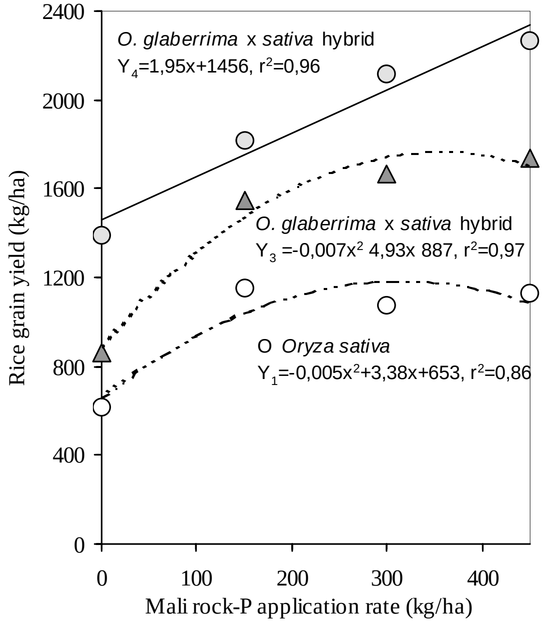
West Africa has vast rock-phosphate deposits. Millions of tonnes are mined, powdered, and shipped abroad.

Unfortunately, plants can't use the phosphorus in mined rock-phosphate, because it's not soluble. Rock phosphate is converted to phosphorus fertilizer through reaction with acids.

"The acidic soils, where most upland rice is grown, can trigger the same conversion," Sahrawat says.

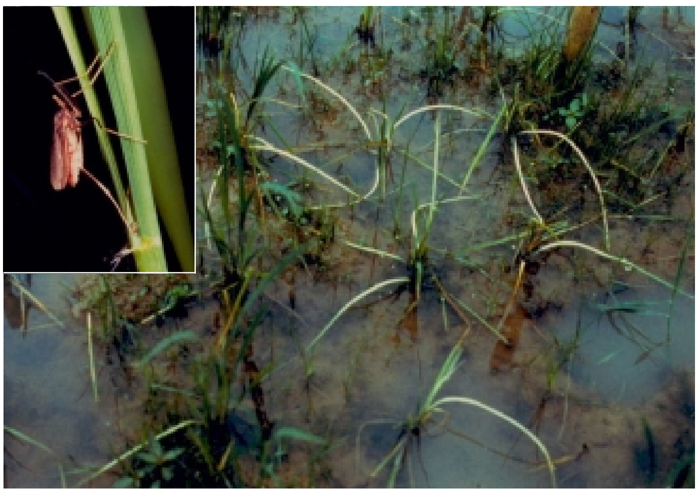
WARDA soil scientists are testing rock-phosphate from Mali as an alternative to expensive commercial phosphate fertilizers in trials in the humid forest soils of Man and Gagnoa, in Côte d'Ivoire. Rice varieties vary in response, but the new NERICAs react best to rock-phosphate application.

*Yield response of two NERICAs and a check* Oryza sativa *variety to rock-phosphate fertilization.*




Their adaptation to acid soils makes the new rices even more promising candidates for the utilization of rock-phosphate.

*Pests and diseases.* Africa's most serious rice insect pests are the stem borer and the African rice gall midge. Almost 300 rices with various genetic backgrounds were screened for gall midge resistance at IITA in Nigeria. One NERICA, WAB 450-I-B-P181-22-1-HB, had stronger gall midge resistance than the resistant check.



*African rice gall midge: galls produced by larvae on rice plants and (inset) adult midge.*

The most resistant variety, however, was Cisadane, a *sativa* from Indonesia. Its yields averaged 2.5 t/ha in farmer-managed trials across Nigeria. Cisadane was released in Nigeria as FARO 51 in 1998.

Root-knot nematodes are the most prevalent pests of tropical agriculture. Plants that produce *proteinase inhibitors*—natural proteins that the plant produces to interfere with the digestive enzymes, or proteinases, of feeding insects—are being developed in cooperation with the John Innes Centre and the UK's Department for International Development (DFID).

Although essential to the nematode digestive system, the proteinases are not found in mammals. In fact, millions of people have consumed the proteins for thousands of years through rice.

John Innes scientists are transferring the genes that control digestive disruption into NERICA lines, giving them a self-defence system against nematodes. Egg production is halved in nematodes that feed on such plants. Field trials of the new plants will begin soon.

Rice yellow mottle virus (RYMV) is the most serious rice disease in Africa. It is a major production constraint in irrigated and rainfed lowland systems. Most resistant varieties identified in the past have been upland rices, including *glaberrimas*, that yield poorly in irrigated conditions.

In irrigated trials where rices were deliberately infected with yellow mottle, 78% of the new rices were found to be resistant. Only 13% of the other rices resisted the virus.

A strategy similar in concept to human vaccination, called *homology-dependent resistance*, is being tested for non-chemical control of yellow mottle in cooperation with the John Innes Centre and DFID.

*Screening for resistance to rice yellow mottle virus.*

Fragments of the virus' genes, introduced into rice, render the plants resistant.

The resistant varieties must be field-tested and certified for biosafety before they are ready for farmers' fields. The resistant material will also enter into rice-breeding programs in order to 'pyramid' the transgenic resistance with natural resistance genes from *O. glaberrima* and *O. sativa* that will have been tagged with molecular markers (currently being developed). In this way, the basis of resistance would be broadened and thus more durable (that is, it will work longer in the field).

Blast, the region's other major disease, affects mostly upland rice. The NERICAs generally resist blast better than other varieties. Adaptation to acid soils seems associated with resistance to both blast and sheath rot.

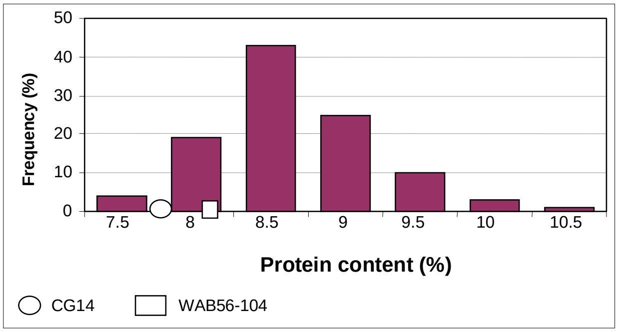
*Higher protein content.* Rice consumption is rising rapidly in West and Central Africa. High-protein rice will automatically improve daily diets in a region where the need for body-building protein is critical.

Most varieties of *O. sativa* have 7 to 8% protein. Some *sativa*s have 11 or 12% protein—but their yields are unacceptably low.

Protein content in the low-yielding *O. glaberrima* varies, but may reach as high as 15%.

For years, breeders have tried to increase the protein content of *O. sativa* by crossing high-protein and high-yielding varieties. But there has been a negative correlation between the two objectives. As protein content rises, yields decline. Get yields back up, and protein drops.

Protein content was measured in NERICA progeny of crosses of CG14, a traditional *glaberrima*, and WAB 56-14, a *sativa*. Both parent varieties average 8% protein. More than 70% of the progeny had more protein than either the African or Asian parent. Almost 40% had from 9 to 10.5% protein, and 43% had 8.5% protein.




That extra protein can vastly improve the nutrition of poor families that depend mostly on rice for their daily food.

Unlike the *sativa*s, the new rices do not lose significant protein with higher yields.

The protein content of *O. sativa*, *O. glaberrima*, and NERICA rices was compared at yields of 2.5 t/ha, about average for irrigated rice in West Africa, and at 5 t/ha by Dr Hideo Watanabe, WARDA grain quality specialist, and Dr Koichi Futakuchi, WARDA ecological physiologist.

The *sativa*s generally maintained 7 to 8% protein levels at both 2.5 and 5 tonnes.

The *glaberrimas* varied greatly at 2.5 t/ha, but generally had 10 to 14% protein. Only a few *glaberrimas* could produce 5 t/ha, but those that did had about 11% protein.

The NERICAs had 8 to 10% protein at 2.5 t/ha, and averaged 9% protein at 5 tons.

Grain quality of high-protein cereals is usually considered inferior. Fifty high-protein NERICA lines have been identified that have acceptable grain quality, and yields of 5 t/ha under rainfed lowland conditions.

"Overcoming hybrid sterility barriers and the successful introgression of adaptation and tolerance genes from African rices (*Oryza glaberrima*) into the high-yielding rices of Asia is a major scientific breakthrough in rice improvement. This achievement at WARDA will have a major impact on rice production not only in Africa, but also in Asia and Latin America."

*—Emil Q. Javier, Chairman of the CGIAR Technical Advisory Committee, in a letter to the CGIAR Chairman, Ismail Serageldin, 20 April 2000*

**NERICA Characteristics**

- Resistance to local stresses
- Rapid vegetative growth
- Weed suppression
- Grain quality
- Lodging resistance
- Non-shattering grains
- High yield

With such a suite of impressive characteristics (see box), WARDA has opened a gold-mine to the world of rice science.

## Molecular mapping

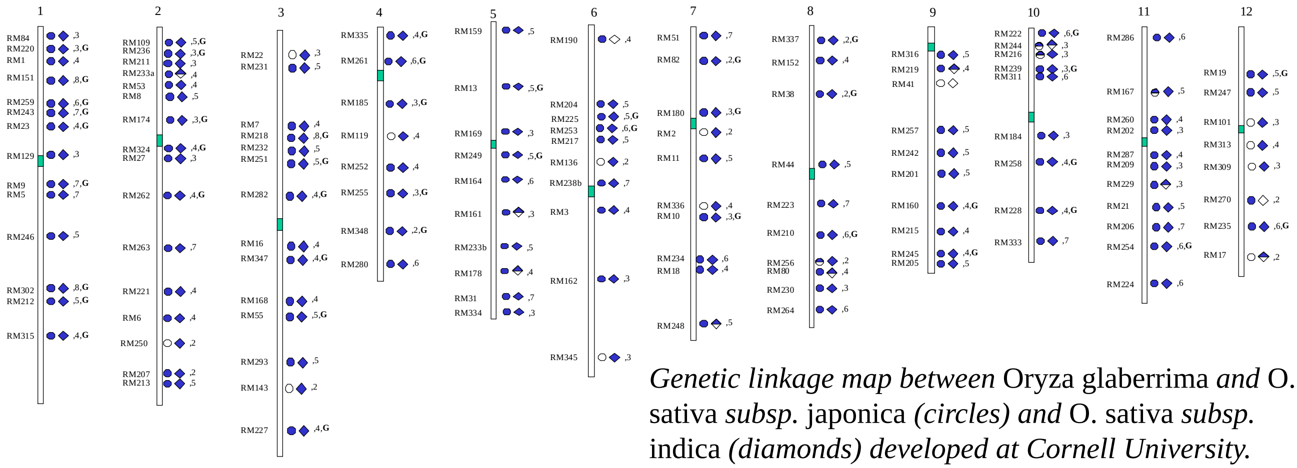
WARDA is using molecular biology to identify and localize rugged *glaberrima* genes, and follow their transfer into the higher-yielding *sativa* background of NERICA lines. NERICA lines selected for molecular study include those that perform well in farmers' fields because they have inherited *glaberrima* genes for wide, droopy leaves, drought tolerance, resistance to rice yellow mottle virus and blast diseases, grain quality, and tolerance of acid soils.

This molecular study will help us both *exploit* and *conserve* the genetic potential of *glaberrima*, says Dr Marie-Noëlle Ndjiondjop, WARDA postdoctoral fellow in molecular biology.

"It will help us understand the mechanism and the genes involved in the *reproductive barrier* that makes the two species difficult to cross," the Cameroonian says.

"It will also increase biodiversity by getting new genes onto farmers' fields, faster—and into the crosses that will produce varieties of the future."

Genome-mapping enables 'molecular screening' of progeny of *glaberrima* × *sativa* crosses. "We can select plants with those genome segments that carry the key genes. That will make selection faster, and more effective," Ndjiondjop says.




*Genetic linkage map between* Oryza glaberrima *and* O. sativa *subsp.* japonica *(circles) and* O. sativa *subsp.* indica *(diamonds) developed at Cornell University. Blue indicates polymorphic, and white monomorphic markers.*

She points out how gene-mapping is helping in the utilization of genes that convey resistance to rice yellow mottle virus, one of the most serious rice diseases in irrigated rice across Africa. WARDA identified Gigante, a traditional *sativa* that is grown in Mozambique, as highly resistant. The gene that conveys that resistance has now been mapped, in cooperation with France's *Institut de recheiche pour le développement*.

"We're now transferring that resistance gene into popular—but virus-susceptible—irrigated *sativa* varieties," Ndjiondjop says. "We're doing the same with resistant NERICAs."

WARDA is cooperating with Dr Susan McCouch of Cornell University, USA, in a study to characterize the genetic diversity of 200 *glaberrimas* from the WARDA germplasm collection, using microsatellite markers. The genetic markers will be used to guide breeders in a molecular breeding strategy. The accessions reflect the wide range of agroecologies where *glaberrima* is grown. Another goal is to identify duplicate accessions, to make a 'cleaner' core collection.

## Farmers *participate* in rice varietal selection

Farmers are partners with scientists in the tailoring of new varieties to suit their own needs. That's partly why the new rices for Africa are spreading so rapidly across the region. Technology spreads quicker, with more impact, if farmers have an input early in its development.

Scientists don't give farmers finished varieties to grow through the novel system of adaptive research. Instead, the farmer is asked to *participate* in the selection and refinement of varieties.

*Participatory varietal selection*, or PVS, puts subsistence farmers, especially women, 'upstream' in technology development.

The process reduces the time required to move varieties onto farmers' fields. It teaches scientists what traits farmers value in varieties—knowledge that can be used in planning strategies for future varieties. And it helps determine gender differences in desired traits—vital information, because women do most of the rice farming.

WARDA first tried participatory research on a small scale in an area where farmers still grew traditional varieties around Boundiali, northern Côte d'Ivoire in 1996.

The Boundiali experience encouraged WARDA to take the participatory approach to other countries. Guinea sent 10 specialists to WARDA for training in 1997. Back in Guinea, the 10 specialists trained 25 others. By 1998, more than 1300 Guinean farmers were involved in participatory research. The concept soon spread to Ghana and Togo.

In early 1998, WARDA decided to take the concept to all of its 17 member countries. An 8-day training workshop was held to teach the participatory approach to specialists from six more countries: Benin, Burkina Faso, The Gambia, Guinea Bissau, Nigeria, and Sierra Leone.

Thus, the 1996 Boundiali experiment led to the model that national programs now follow across West and Central Africa (see box, page 17).

## Farmers growing seed for farmers

The PVS trials *introduce* NERICAs and other improved rice varieties to pilot African communities. But supply can't meet demand as word spreads among farmers that the new rices yield higher with fewer inputs, and require less weeding.

Larger-scale seed multiplication and distribution is a serious bottleneck to the spread of any new crop variety in Africa. National seed systems simply lack the staff, equipment, and funding to assure farmers an adequate supply of quality seeds on a regular basis.

Yet 1 kilogram of seed, if properly managed, yields at least 20 kg of progeny seeds that other farmers can plant.

Farmers grow seeds for other farmers—and to make a profit from the 2000% increase—through the community-based seed production program.

"The community-based program is suited to the African culture, because farmers have grown and supplied seeds to other farmers for centuries," says Dr Amadou Moustapha Bèye, WARDA technology transfer agronomist.

## Participatory Varietal Selection

Participatory varietal research is a 3-year exercise. First, scientists put together a ‘rice garden’ of about 60 varieties to grow on an innovative farmer’s field.

NERICAs are included in the rice garden. So are traditional strains of *O. glaberrima*; the varieties that local farmers like best, whether *sativas* or *glaberrimas*; and the most popular varieties from across West and Central Africa.

Both men and women farmers from nearby villages are then encouraged to participate in the research by visiting the rice garden as often as possible.

Three ‘formal’ visits of the farmers as a group are organized.

The first visit is at *maximum tillering*, the most vigorous growth stage. The farmers compare traits like how fast the different rices grow, how well they shade and smother out weeds, and how they stand up to insects and diseases.

The farmers choose their favorite varieties—and more important, tell researchers *why* they like each rice. Men and women are interviewed separately. Women do most of the rice farming in West and Central Africa, as well as prepare the meals, so special care is taken to get women’s views. Often, women interviewers are used to get women’s views. That helps eliminate male bias.

The farmers return for a second formal visit at *maturity* stage, just before harvest. They evaluate such traits as plant height, panicle structure, rapid growth, and pest resistance. The farmers once again select their favorite varieties, and tell the surveyors why.

The third visit is for the *post-harvest* evaluation. At this stage, farmers compare traits such as grain yield, grain quality, broken grains, ease of dehulling, cooking time.

Women and men sometimes prefer the same varieties, but for different reasons. Women, who are responsible for feeding the family, often choose varieties on the basis of yield. They also like varieties that dehull easier. Men give higher value to taste. Also, partly because men usually

*Bintu, a real Ivorian rice farmer, selected the NERICA rices that she grows through a local PVS trial. Here, Bintu compares panicles of varieties during post-harvest evaluation.*

control money for farm inputs, the males like varieties that perform well with little fertilizer.

In the second year of participatory selection, farmers are given seeds of their five favorite varieties to grow on their own farms and compare with local varieties. Farmers are asked to pay for their favorite seeds in the third year. Willingness to pay for seeds of new varieties is indicative of a change in farmers' seed portfolio and adoption of new varieties.

WARDA and national programs compile the traits, or selection criteria, by which farmers value the varieties. Those become breeding objectives for future varieties.

*Women like Bintu dehull rice grains by pounding in a mortar. Thus, women prefer rice varieties that dehull easily.*

Bèye helped develop the program at Senegal's Institute for Agricultural Research (ISRA), and has improved on it in Côte d'Ivoire and Guinea.

Community seed production teaches farmers how to produce better seed for their own use, and to exchange or sell excess seed to other farmers. It shortens the time required for seed to reach farmers.

"Rather than bring in a new system, we build on the seed production practices that farmers have passed down, generation to generation, for centuries," Bèye explains.

First, the agencies identify farmers or farm organizations that want to multiply and sell seeds. They then organize farmers' field days on matters like removing 'off types' to purify seeds.

"Farmers learn how to select and harvest the best panicles for seed increase—before harvesting for food," Bèye says.

The farmers also learn to avoid seed mixtures during harvesting, threshing, winnowing, and storage; how to dry seed properly; and how to test for seed germination.

Community seed production is now spreading to the other WARDA member countries, with support from the United Nations Development Programme (UNDP) and the World Bank.

## Spread of NERICA seeds—and hope—in Africa

Community seed production is catalyzing the spread of NERICA rice varieties across West and Central Africa.

WARDA and the NERICAs have been instrumental in the revitalization of the rice sector in Guinea. *See separate story on progress in Guinea on page 21*.

*Nigeria*. To grow 150,000 hectares of NERICA rices by 2005 is the goal of Premier Seed Nigeria, a division of the US-based Pioneer Seed Company. Plans are underway to accelerate the release of three major varieties that farmers have selected. Training in community seed production began in 2000.

The Gatsby and Rockefeller Foundations, and USAID help fund the program for Nigeria.

*Côte d'Ivoire*. Projections of *Projet National Riz*, the national extension agency, are for 500 ha of NERICA coverage in 2000, and 7000 ha in 2001. Côte d'Ivoire will become the first country to *officially* release NERICA varieties, for planting in 2000.

*The WARDA Region.* The Gatsby Foundation is supporting PVS in Ghana, and the Rockefeller Foundation in Mali.

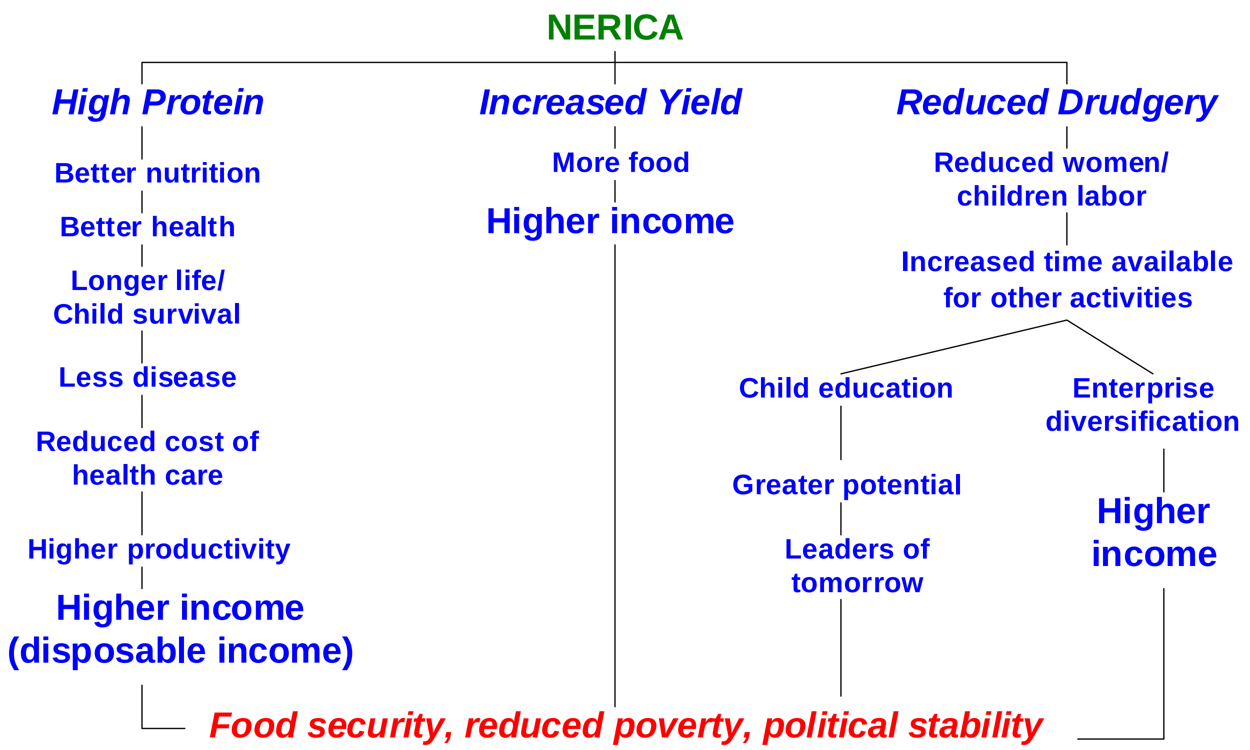
"I'm optimistic about the spread of the NERICAs," Bèye says. "We have a good start, with tonnes of seeds going to farmers through PVS trials in all 17 WARDA countries and through community-based seed production.

"At this pace, by 2005, the NERICAs may cover most of the rainfed upland rice land in West and Central Africa. A Green Revolution is already in the making in Africa."

Between 2000 and 2004, thirty-seven new varieties are expected to be released for the uplands, including low-management NERICAs. Many of these varieties have shown productivity gains of 24% over local varieties in widespread farmer-controlled evaluations. The financial value of such a gain in just Guinea, Côte d'Ivoire and Sierra Leone, assuming a 10% adoption rate, would amount to nearly US$ 8 million per year, and nearly US$ 20 million at 25% adoption rates.

"We at WARDA are looking at something much bigger than simply a new rice variety," explains Kanayo Nwanze. "The NERICA rices form a platform for agricultural development and economic growth. We have visualized this platform [see figure, page 20] and see three clear routes to our overall goal of reduced poverty, food security at household, national and regional levels, and socio-political stability. These routes start with the increased yields attributable to NERICA, their reduced requirement for labor, and their improved protein content. These advantages all lead directly, or indirectly, to increased income for the farmers' families, and thus to our overall goal. I for one am proud to be associated with this technology."

## A Platform for Development and Economic Growth



### *Programme pilote de transfert de nouveaux plants de riz pluvial dans les différents ecosystemes de la Guinée*

### (Pilot Program to Transfer New Rice Plants to Rainfed Ecosystems in Guinea)

**The Partners**

- *Service national de la promotion rurale et de la vulgarisation* (SNPRV)—the national extension service in Guinea
- *Institut de recherche agronomique de Guinée* (IRAG)—the national agricultural research institute in Guinea
- Guinean farmers
- West Africa Rice Development Association (WARDA/ADRAO)—international agricultural research center mandated to develop the rice-based systems in West and Central Africa
- Special Program for African Agricultural Research (SPAAR)—financial support
- World Bank—financial support
- Sasakawa Global 2000/Guinée—Japanese-funded NGO, providing in-kind and technical support

**Introduction**

Collaboration between WARDA and Guinea dates back to the mid-1970s, when research and development (R&D) activities were conducted in the mangrove-swamp rice-growing areas of Guinea in collaboration with WARDA's mangrove-swamp research station based in Rokupr, Sierra Leone. The pilot program was prompted by the visit of Moctar Touré of the World Bank's Special Program for African Agricultural Research (SPAAR) to WARDA's headquarters in mid-1996. World Bank funding was proposed to transfer rice technology to farmers in West Africa, with special emphasis on countries that had benefitted little from regional R&D up to that time. Thus, the *Programme pilote de transfert de nouveaux plants de riz pluvial dans les différents ecosystemes de la Guinée* was born. The Program Coordinator is Mamadou Billo Barry of IRAG.

Despite its small size, Guinea is one of the top five rice-producing countries in West Africa in terms of area cropped. About 70% of Guinea's rice area is upland, for which little new technology had been developed. The NERICAs were specifically developed for the low-input, rainfed upland farming systems of West Africa, and were thus an ideal candidate for participatory technology transfer to Guinean farmers.

**Mechanism of collaboration**

In order to get a new technology into farmers' fields at a much earlier stage in the R&D process than was ever considered by research organizations only a few years ago, it was essential for researchers and extension agents from IRAG and SNPRV to work with farmers to design, test and modify improved technologies to suit local conditions. The mechanism adopted was to run three types of trials concurrently: over an initial three-year period, conventional on-station and farm testing (*Unités expérimentales paysannes*) would be complemented with participatory varietal selection (PVS) trials, also conducted on farmers' fields.

Initially, 10 researchers and extension agents from IRAG and SNPRV attended WARDA headquarters in February 1997 to study varietal improvement and technology transfer, with special emphasis on PVS. At the end of the course, the participants selected some 25 varieties from WARDA's experimental plots, using their knowledge of Guinean farmers' preferences. These varieties—which included nine NERICAs— were taken back to Guinea.

Back in Guinea, SNPRV organized a second training course where the participants from the first course, along with WARDA's upland-rice breeder Monty Jones, trained 2–3 technicians and field assistants from each of the areas where the trials were to be conducted, plus the coordinators of the national research and extension teams—a total of 25 participants. Here the participants designed their plan of campaign for the first year of trials.

Farmer-managed on-farm trials were funded for two years (1997 and 1998) by SPAAR and the World Bank. Each of the on-farm trials consisted of five small plots: three new varieties from WARDA, one variety recommended by IRAG as 'regional control' and one a widely grown local variety (local control). Farmers grew the varieties following their usual practices, although each plot was divided into two parts, one of which received chemical fertilizer.

The three-year collaborative PVS program started in 1997 at Guéckédou and Faranah, following the scheme outlined in a separate box. The 25 NERICAs were compared with 5 varieties chosen by farmers, SNPRV and IRAG.

The traditional researcher-managed on-station trials were also started in 1997 in Bordo and Sérédou, with 15 varieties (5 NERICAs, 7 improved *sativas* and 3 local checks).

**Progress**

In 1997, some 116 farmers in eight prefectures completed the on-farm trials using three new varieties each. Throughout the country, Guinean farmers experimented with eight new varieties. In the same season, over 200 farmers in eight prefectures were exposed to 30 new varieties through the first year of PVS. The results from the PVS and on-farm trials were broadly similar to each other, and to the on-station trials involving 13 new varieties.

In early 1998, fourteen technicians made a second visit to WARDA headquarters, to review the 1997 results and plan the 1998 campaign. The visit also included extra training sessions, in particular in pest and disease identification, scoring plant resistance to pests and diseases, seed multiplication, and statistical analysis of trial results.

In the 1998 cropping season, farmer-managed trials were expanded to 16 prefectures and 240 farmers. Meanwhile, an additional 140 farmers were involved in the PVS, and some 200 NERICA lines were screened on-station to identify promising candidates for future farmer-managed trials. In a total of 356 on-farm trials, five NERICAs and one improved *sativa* proved particularly popular with farmers. These selections were confirmed by the PVS trials. On the basis of these results, the decision was taken to multiply seed and start an official release process; three NERICAs and the improved *sativa* were released by IRAG to farmers in Guinea in 1999. The NERICAs were credited for bringing increased productivity and protein content, while also reducing labor for weeding and slash-and-burn agriculture through their adaptation to low-input systems.

In 1999, ten new varieties underwent seed multiplication prior to the cropping season. These comprised two local and seven from WARDA, of which six were NERICAs—all extended to farmers through the pilot program. About 1750 kg of pre-basic seed were multiplied for the research program and for farmer use. More than 1000 farmers in 33 prefectures participated in the farmer-managed and PVS trials.

Sasakawa Global 2000/Guinée multiplied seed of three WARDA rice varieties under irrigation in the dry season of 1998, and was able to establish 15 ha of demonstration plots during the 1999 crop season.

In 1999, the partners looked into the problem of seed production, and then requested WARDA to conduct training in community-based seed multiplication at two sites, Kindia and Sérédou. At total of 62 farmers was trained in these courses.

In the dry season (off-season) of 2000, SNPRV produced about 10 tonnes of (foundation) seed of three NERICAs on its research stations at Kilissi and Yattiah. Meanwhile, community-based systems produced seeds at several lowland sites. One community— Fankama— expected to provide 40 tonnes of seed to its 150 rice-farmers for the main-season crop.

For the main season in 2000, SNPRV and Sasakawa Global 2000 have teamed up to demonstrate the new varieties in new areas, and for seed production. One thousand demonstration-cum-production plots (0.25 ha each) are being established in areas prone to food-shortages, and a further 1000 seed-production plots (0.5 ha each) are being established. Sasakawa-Global 2000 is providing fertilizer for these activities.

Particularly promising developments in Guinea in 2000 were the ongoing interest of key donors—World Bank, SPAAR, Japan and UNDP—, and interest sparked within a private production and trading company, SPCIA, which is now looking at complementing the work of IRAG, SNPRV and Sasakawa-Global 2000 in scaling-up NERICAs at farm level to improve farmers' profits. A new WARDA project in Guinea— *Participatory Adaptation and Diffusion of Technologies for Rice-based Systems*, PADS (which is funded by the International Fund for Agricultural Development, IFAD, and is also active in Côte d'Ivoire, The Gambia and Ghana)— is gearing-up farming communities to optimize their use of available technologies and financial facilities.

In 2000, NERICAs will cover about 8000 ha, of which 5000 ha on 20,000 farms will be fully supervised by SNPRV. The expected production is in the region of 15,000 tonnes, of which one-third is supposed to be kept as seed; the production in 2000 will generate a minimum gain of US$ 2.5 million over pre-NERICA production. The Guinean authorities project that 300,000 tonnes of NERICA will be produced in 2002, with surplus available for export to neighboring countries, where the demand for seed is also increasing rapidly. The production would be valued at US$ 69 million at today's prices.

"At this stage in Guinea we are looking at a network," explains Amadou Moustapha Bèye, WARDA technology transfer agronomist. "It is not simply the NERICAs, but the whole system from technology generation, through seed production, paddy production, rice processing and milling, to rice marketing. All these components are being used to upgrade the rice system in the country."

## Acknowledgements

"On behalf of the world's poorest farmers—those who, like Bintu, grow slash-and-burn upland rice in 17 WARDA countries—WARDA thanks the world community that supports the new rices for Africa through the Consultative Group on International Agricultural Research," Dr Kanayo Nwanze says.

"We also speak for those at the forefront of the movement to increase rice production in the area that needs it most—the national agricultural scientists and extension specialists across the continent," Nwanze adds.

WARDA and its member countries are grateful to their various partners (donors, collaborators and partners), and particularly to:

- Rockefeller Foundation, for support of the anther-culture program, which allowed production of fertile interspecifics;
- United Nations Development Programme (UNDP) and the Japan Ministry of Foreign Affairs, for supporting research on interspecific breeding, including molecular biology studies, and support of Participatory Rice Improvement and Gender/User Analysis (PRIGA);
- CGIAR Systemwide Program on Participatory Research and Gender Analysis, for support of the PRIGA;
- major collaborators in the Interspecific Hybridization Project:
  - Cornell University, USA (Dr Susan McCouch)
  - *Institut de recherche pour le développement* (formerly ORSTOM), France (Dr Alain Ghesquière)
  - International Rice Research Institute, Philippines (Dr Darshan Brar)
  - International Center for Tropical Agriculture, Colombia (Dr Cesar Martinez)
  - Japan International Research Center for Agricultural Sciences (Dr Satoshi Tobita)
  - University of Tokyo (Prof. R. Ishii)
  - Yunnan Academy of Agricultural Sciences, China (Dr Tao Dayun)
  - John Innes Centre, UK (Dr John Snape)
  - UK's Department for International Development (DFID) Plant Sciences Division (Dr Dave Harris)
  - national agricultural research and extension services, and farmers in the 17 WARDA member countries: Benin, Burkina Faso, Cameroon, Chad, Côte d'Ivoire, The Gambia, Ghana, Guinea, Guinea Bissau, Liberia, Mali, Mauritania, Niger, Nigeria, Senegal, Sierra Leone and Togo.

## Annex 1. Scientific Publications on the NERICAs, or Interspecific Hybrids

### Journal Articles


Albar, L., M. Lorieux, N. Ahmadi, I. Rimbailt, A. Pinel, A.A. Sy, D. Fargette and A. Ghesquière, 1998. Genetic basis and mapping of the resistance to rice yellow mottle virus. I. QTLs identification and relationship between resistance and plant morphology. *Theoretical and Applied Genetics* 97: 1145–1154.

Asch, F., M. Dingkuhn, C. Wittstock and K. Doerffling, 1999. Sodium and potassium uptake of rice panicles as affected by salinity and season in relation to yield and yield components. *Plant and Soil* 207: 133–145.

Asch, F., A. Sow and M. Dingkuhn, 1999. Reserve mobilization, dry matter partitioning and specific leaf area in seedlings of African rice cultivars different in early vigor. *Field Crops Research* 62: 191–202.

Audebert, A., M. Dingkuhn, M.P. Jones and D.E. Johnson, 1998. Physiological mechanisms for vegetative vigor of interspecific upland rices—Implications for weed competitiveness. *Japanese Journal of Crop Science* 67(2): 358–359.

Dingkuhn, M., 1996. Modelling concepts for the phenotypic plasticity of dry matter and nitrogen partitioning in rice. *Agricultural Systems* 52: 383–397.

Dingkuhn, M. and F. Asch, 1999. Phenological responses of *Oryza sativa*, *O. glaberrima* and inter-specific rice cultivars on a toposequence in West Africa. *Euphytica* 110: 109–129.

Dingkuhn, M., A. Audebert, M.P. Jones, K. Etienne and A. Sow, 1999. Control of stomatal conductance and leaf rolling in *O. sativa* and *O. glaberrima* upland rice. *Field Crops Research* 61: 223–236.

Dingkuhn, M., D.E. Johnson, A. Sow and A.Y. Audebert, 1999. Relationships between upland rice canopy characteristics and weed competitiveness. *Field Crops Research* 61: 79–95.

Dingkuhn, M., M.P. Jones, D.E. Johnson and A. Sow, 1998. Growth and yield potential of *Oryza sativa* and *O. glaberrima* upland rice cultivars and their interspecific progenies. *Field Crops Research* 57: 57–69.

Futakuchi, K., A. Audebert, M.P. Jones and M. Dingkuhn, 1998. Lowland adaptability of interspecific progenies from *Oryza sativa* and *O. glaberrima* crosses. 1. Screening for growth and yield performance of progenies in lowland conditions. *Japanese Journal of Crop Science* 67(2): 12–13.

Johnson, D.E., M. Dingkuhn, M.P. Jones and M.C. Mahamane, 1998. The influence of rice plant type on the effect of weed competition on *Oryza sativa* and *Oryza glaberrima*. *Weed Research* 38: 207–216.

Johnson, D.E., C.R. Riches, R. Diallo and M.P. Jones, 1997. *Striga* on rice in West Africa: Crop host range and the potential of host resistance. *Crop Protection* 16(2): 153–157.

Jones, M.P., 1997. Diversity and potential of *Oryza glaberrima* Steud in upland rice breeding. *Breeding Science* 47: 195–198.

Jones, M.P., 1999. Food security and major technological challenges: The case of rice in Sub-Saharan Africa. *Japanese Journal of Crop Science* 67 (extra issue 2): 57–64.

Jones, M.P., 1999. Basic breeding strategies for high yielding rice varieties at WARDA. *Japanese Journal of Crop Science* 67 (extra issue 2): 133–136.

Jones, M.P., M. Dingkuhn, G.K. Aluko and M. Semon, 1997. Interspecific *Oryza sativa* L. x *O. glaberrima* Steud. progenies in upland rice improvement. *Euphytica* 92: 237–246.

Jones, M.P., D.E. Johnson and T. Kouper, 1996. Selection for weed competitiveness in upland rice. *International Rice Research Notes* 21(1): 32–33.

Lorieux, M., M.-N. Ndjiondjop and A. Ghesquière, 1999. A first interspecific *Oryza sativa* × *O. glaberrima* microsatellite-based genetic linkage map. *Theoretical and Applied Genetics* 100: 593–601.

Ndjiondjop, M.-N., L. Albar, D. Fargette, C. Fauquet and A. Ghesquière, 1999. The genetic basis of high resistance to rice yellow mottle virus (RYMV) in cultivars of the two cultivated rice species. *Plant Disease* 83: 22–24.

Plowright, R.A., D.L. Coyne, P. Nash and M.P. Jones, 1999. Resistance of the rice nematodes *Heterodera sacchari*, *Meloidogyne graminicola* and *M. incognita* in *Oryza glaberrima* and *O. glaberrima* × *O. sativa* interspecific hybrids. *Nematology* 1(7-8): 745–751.

Sahrawat, K.L., M.P. Jones and S. Diatta, 1997. Extractable phosphorus and rice yield in an Ultisol of the humid forest zone in West Africa. *Communications in Soil Science and Plant Analysis* 28: 711–716.

Sahrawat, K.L., M.P. Jones and S. Diatta, 1997. Direct and residual phosphorus effects on yield and phosphorus efficiency of upland rice in an Ultisol. *Nutrient Cycling in Agroecosystems* 48: 209–215.

Sahrawat, K.L., M.P. Jones and S. Diatta, 1998. Plant phosphorus and rice yield in an ultisol of the humid forest zone in West Africa. *Communications in Soil Science and Plant Analysis* 29(7-8): 997–1005.

Sahrawat, K.L., M.P. Jones and S. Diatta, 1999. Phosphorus, calcium, and magnesium fertilization effects on upland rice in an Ultisol. *Communications in Soil Science and Plant Analysis* 30(7&8): 1201–1208.

## Articles in Proceedings

Dingkuhn, M. and T.F. Randolph, 1997. The potential role of low-management rice technologies during the agricultural transition in West Africa. In: M.P. Jones, M. Dingkuhn, D.E. Johnson and S.O. Fagade (ed.), *Interspecific Hybridization: Progress and Prospects*. WARDA, Bouaké, Côte d'Ivoire. Pp. 3–20.

Dingkuhn, M., D.E. Johnson, M.P. Jones and A. Sow, 1997. The physiological basis for developing low-management upland rice plant types. In: M.P. Jones, M. Dingkuhn, D.E. Johnson and S.O. Fagade (ed.) *Interspecific Hybridization: Progress and Prospects*. WARDA, Bouaké, Côte d'Ivoire. Pp. 81–102.

Dingkuhn, M., M.P. Jones, D.E. Johnson, B. Fofana and A. Sow, 1997. *Oryza sativa* and *O. glaberrima* genepools for high-yielding, weed-competitive rice plant types. In: S. Fukai, M. Cooper and J. Salisbury (ed.), *Breeding Strategies for Rainfed Lowland Rice in Drought-Prone Environments.* International Workshop of the Rainfed Lowland Rice Consortium, December 1996, Ubon, Thailand. *ACIAR Proceedings No. 77*, Australian Centre for International Agricultural Research (ACIAR), Canberra, Australia. Pp. 144–155.

Johnson, D.E., M.P. Jones, T. Dalton and M. Dingkuhn, 1999. Rice plant types for areas of low-input management in West Africa. In: *19th Session of International Rice Commission, 7–9 September 1998, Cairo*. FAO, Rome Italy, pp. 205–210.

Johnson, D.E., M.P. Jones, M. Dingkuhn and M.C. Mahamane, 1997. The effect of weed competition on *O. glaberrima*, *O sativa* and an interspecific hybrid rice. In: M.P. Jones, M. Dingkuhn, DE. Johnson and S.O. Fagade (ed.), *Interspecific Hybridization: Progress and Prospects*. WARDA, Bouaké, Côte d'Ivoire. pp. 197–206.

Johnson, D.E., M.P. Jones, M. Dingkuhn and M.C. Mahamane, 1997. The response of *O. glaberrima*, *O. sativa* and an interspecific hybrid rice to weed competition. In: *Proceeding of the Brighton Crop Protection Conference – Weeds*. British Crop Protection Council. Pp. 197–202.

Johnson, D.E., M.P. Jones, M. Dingkuhn and M.C. Mahamane, 1998. Weed competitive rice plants from the *O. sativa* and *O. glaberrima* genepools for improved weed management in the rainfed rice systems of West Africa. In: *Proceedings of the 17th COLUMA Conference, Dijon, December 1998*. ANPP, Paris, Vol. 1, pp. 71–78.

Johnson, D.E., M.P. Jones and M.C. Mahamane, *in press*. Screening for weed competitiveness among selections of rice in West Africa. In: *Proceeding of the Brighton Crop Protection Conference – Weeds*. British Crop Protection Council.

Jones, M.P., A. Audebert, S. Mande and K. Aluko, 1997. Characterization and utilization of *Oryza glaberrima* Steud. in upland rice breeding. In: M.P. Jones, M. Dingkuhn, D.E. Johnson and S.O. Fagade (ed.) *Interspecific Hybridization: Progress and Prospects*. WARDA, Bouaké, Côte d'Ivoire. Pp. 43–59.

Jones, M.P., M. Dingkuhn, G.K. Aluko and M. Semon, 1996. Progress in crossing Asian rice (*O. sativa* L.) with African rice (*O. glaberrima* Steud.). In: *Crop Productivity and Sustainability—Shaping the Future*. Abstracts of Poster Sessions, 2nd International Crop Science Congress. National Academy of Agricultural Sciences, New Delhi, India, p.10.

Jones, M.P., M. Dingkuhn, G.K. Aluko and M. Semon, 1997. Using backcrossing doubled haploid breeding to generate weed-competitive rices from *O. sativa* x *O. glaberrima* Steud. genepools. In: M.P. Jones, M. Dingkuhn, D.E. Johnson and S.O. Fagade (ed.), *Interspecific Hybridization: Progress and Prospects*. WARDA, Bouaké, Côte d'Ivoire. Pp. 60–79.

Jones, M.P., K.F. Nwanze, K.M. Miezan, B.N. Singh and R. G. Guei, 1999. Rice germplasm evaluation and enhancement at WARDA. In: *Proceedings of the International Symposium on Rice Germplasm*

*Evaluation and Enhancement*. J.N. Rutger, J.F. Robinson and R.H. Dilday (ed.). Arkansas Agricultural Experiment Station. Pp. 29–37.

Jones, M.P., M. Semon and G.K. Aluko, 1997. Characterization and utilization of Oryza glaberrima Steud. in upland rice breeding. In: M.P. Jones, M. Dingkuhn, D.E. Johnson and S.O. Fagade (ed.), *Interspecific Hybridization: Progress and Prospects*. WARDA, Bouaké, Côte d'Ivoire. Pp. 43–59.

Riches, C.R., D.E. Johnson and M.P. Jones, 1996. The selection of resistance ta Striga species in upland rice. In: M.T. Moreno, J.I. Cubero, D. Berner, D. Joel, L.J. Musselman and C. Parker (ed.) *Advances in Parasitic Plant Research. Sixth International Parasitic Weed Symposium. 16–18 April 1996, Cordoba. Spain*. Junta de Andalucia, Consejeria de Agricultura y Pesca, Sevilla. pp. 674–680.

## Book Chapters

Anon., 1997. Something new out of Africa. In: *WARDA Annual Report 1996*. WARDA, Bouaké, Côte d'Ivoire. Pp. 13–20.

Anon., 1998. Farmers in the driving seat. In: *WARDA Annual Report 1997*. WARDA, Bouaké, Côte d'Ivoire. Pp. 21–26.

Anon., 2000. New rice for Africa… with a little help from our friends. In: *WARDA Annual Report 1999*. WARDA, Bouaké, Côte d'Ivoire, *in prep.*

Anon., 2000. Molecular biology facilities at WARDA. In: *WARDA Annual Report 1999*. WARDA, Bouaké, Côte d'Ivoire, *in prep*.

Dingkuhn, M., M.P. Jones, B. Fofana and A. Sow, 1997. New high-yielding weed-competitive rice plant types drawing from *O. sativa* and *O. glaberrima* genepools. In: M.J. Kropff, P.S. Teng, P.K. Aggarwal, J. Bouma, B.A.M. Bouman, J.W. Jones and H.H. van Laar (ed.) *Application of Systems Approaches at the Field Level, vol. 2*. KluwerAcademic, Doordrecht, the Netherlands and International Rice Research Institute, Los Baños, the Philippines. pp. 37–52.

Dingkuhn, M., M.P. Jones, D.E. Johnson, B. Fofana and A. Sow, 1996. Towards new high yielding, weed-competitive rice plant types drawing from *Oryza sativa* and *O. glaberrima* genepools. In: *WARDA Annual Report for 1995*. WARDA, Bouaké, Côte d'Ivoire. Pp. 27–35.

## Complete Publications

*L'autoproduction améliorée—une nouvelle approche de production de semences communautaires de riz.* A.M. Bèye, 2000. ADRAO, Bouaké ; BAD-Ouest, Man ; et ANADER, Abidjan, Côte d'Ivoire, 49 p. ISBN 92 9113 198 9. *[Being translated into English.]*

*Bintou et la Biodiversité : Mise en valeur des riches potentialités génétiques des espèces africaines de riz*. 1996. ADRAO, Bouaké, Côte d'Ivoire, [8] p.

*Bintu and Biodiversity: Unlocking the genetic treasures of African rice species*. WARDA, Bouaké, Côte d'Ivoire, [8] p.

Crossing African and Asian rice species. *Advances in Rice Research*. [1996]. WARDA, Bouaké, Côte d'Ivoire, [9] p.

*De nouveaux riz pour l'Afrique*. 1998. ADRAO/WARDA, Bouaké, Côte d'Ivoire, 20 p.

*Focus: Interspecifics*. Africa–Asia Joint Research on Interspecific Hybridization between African and Asian Rice Varieties. Highlights of 1998 Activities. 1998. WARDA, Bouaké, Côte d'Ivoire, 24 p.

*Guide pratique de production de semences de riz par les paysans.* A.M. Bèye et R.G. Guei, 2000. ADRAO, Bouaké ; BAD-Ouest, Man ; et ANADER, Abidjan, Côte d'Ivoire, 14 p. ISBN 92 9113 199 7. *[Being translated into English.]*

*Interspecific Hybridization: Progress and Prospects / Hybriation interspecifique : Progrès et Perspectives. Proceedings of the Workshop: Africa/Asia Joint Research on Interspecific Hybridization between the African and Asian Rice Species (*O. glaberrima *and* O. sativa*), WARDA, M'bé, Bouaké, Côte d'Ivoire, December 16–18, 1996 / Actes de l'atelier Afrique / Asie : Activités conjointes de recherche sur l'hybridation interspecifique de riz d'Afrique et d'Asie (*O. glaberrima *et* O. sativa*), ADRAO, M'bé, Bouaké, Côte d'Ivoire, décembre 16-18, 1996*. M.P. Jones, M. Dingkuhn, D.E. Johnson and S.O. Fagade (Ed.), 1997. WARDA/ADRAO, Bouaké, Côte d'Ivoire. 231 p.

*Interspecific Hybridization Project / Projet d'Hybridation Interspecifique : Interspecific hybridization of African and Asian rice germplasm (*O. glaberrima × O. sativa*)*. [1997]. WARDA, Bouaké, Côte d'Ivoire. [8] p.

*New Rice for Africa*. 1998. WARDA, Bouaké, Côte d'Ivoire, 20 p.

*Participatory Varietal Selection: The Flame Spreads into 2000*. 2000. WARDA, Bouaké, Côte d'Ivoire, *in prep*.

*Participatory Varietal Selection: The Spark that Lit a Flame*. 1999. WARDA, Bouaké, Côte d'Ivoire, 32 p. ISBN 92 9113 201 2. *[Being translated into French.]*

*Rice Interspecific Hybridization Project: Research Highlights 1999*. 1999. WARDA, Bouaké, Côte d'Ivoire, 34 p. ISBN 92 9113 203 9. *[Being translated into French.]*

## Unpublished Annual and Progress Reports

*Africa/Asia Joint Research: Interspecific Hybridization between African and Asian Rice Species (*Oryza glaberrima *and* O. sativa*). 1997 Progress Report*, 27 p.

*Joint Research on Interspecific Hybridization between African and Asian Rice Species (*Oryza glaberrima *and* Oryza sativa*). Annual Report 1998*, 60 p.

*Joint Research on Interspecific Hybridization between African and Asian Rice Species (*Oryza glaberrima *and* Oryza sativa*). Project Mid-term Evaluation Report, WARDA, Yamoussoukro, Côte d'Ivoire, 30 November to 1 December 1998*, 24 p.

*Joint Research on Interspecific Hybridization between African and Asian Rice Species (*Oryza glaberrima *and* Oryza sativa*). Annual Report 1999*, 67 p.

## Major Conference and Seminar Presentations (unpublished)

Cadalen, T. and S. Tobita, 1999. Développement d'une capacité de marquage à l'ADRAO visant à l'identification de QTL et à leur utilisation en sélection pour des caractères tels que la compétition avec les adventices et la résistance à la sécheresse. Paper presented at Atelier CERAAS/CORAF sur le thème "Méthodes et Techniques de biochimie et de biologie moléculaire pour assister la sélection des espèces résistantes à la sécheresse". Thiès, Sénégal, 22-26 février 1999.

Dingkuhn, M., A. Audebert, D.E. Johnson and M.P. Jones. The physiological basis for seedling vigor in *O. glaberrima*, *O. sativa* and their interspecific progenies. Paper presented at 27th Rice Technical Working Group Meeting, 1–4 March1998, Reno, Nevada, USA.

Johnson, D.E., C.R. Riches, J. Kayake, S. Sarra and F A. Tuor. Wild rice in Sub-Saharan Africa: Its incidence and scope for improved management. Paper presented at FAO Global Workshop on Red Rice Control, 30 August to 3 September 1999, Cuba.

Johnson, D.E., C.R. Riches, M.P. Jones and R. Kent. The potential for host resistance to *Striga* on rice in West Africa. Paper presented at Workshop on Breeding for *Striga* Resistance in Cereals, IITA, Ibadan Nigeria, 16–20 August 1999.

Jones, M.P. and T. Dalton. Qualitative and quantitative data analysis of farmer participatory varietal selection results. Paper presented to the 1997 Annual Upland Rice Breeding Task Force, Bouaké, March 1997.

Jones, M.P., M. Dingkuhn and S. Mande. New breeding approaches to upland rice improved: The use of *O. sativa* and *O. glaberrima* crosses. Paper presented at Upland Rice Consortium/Breeders Workshop, Pandang, Indonesia, 4–13 January 1996.

Jones, M.P., S. Mande and K. Aluko. Upland rice situation in West Africa; prospects and priorities for the future. Paper presented at Upland Rice Consortium/Breeders Workshop, Padang, Indonesia, 4–13 January 1996.

Sreenivasaprasad, S., J. Chipili and Y. Séré. Genetic diversity of the blast pathogen populations at rice screening sites: West African experience. Paper presented at the NRI/IRRI/BRRI Workshop "Rice Crop Protection in Asia," Bangladesh Rice Research Institute, Dhaka, Bangladesh, 6–7 April 1999.

## Poster Presentations

Cadalen, T., P.-L. Amoussou, S. Tobita, S. Mande, M.P. Jones and S.R. McCouch. Assessment of polymorphism in rice cultivated species (*O. sativa* and *O. glaberrima*) through the utilization of microsatellites. Poster presented at the General Meeting of the International Program on Rice Biotechnology, 20–24 September 1999, Phuket, Thailand, [Abstracts, p. 265].

Chipili, J., Sreenivasaprasad, N.J. Talbot and Y. Séré. Genetic diversity of the rice blast pathogen populations in West Africa. Poster presented at the 2nd International Rice Blast Conference (2nd IRBC), Montpellier, France, 1998.

Dingkuhn, M., M.P. Jones and A. Sow. New low-management, weed-competitive rice plant types combining traits of *O. sativa* and African rice, *O. glaberrima*. In*: Crop Productivity and Sustainability—Shaping the future*. Abstracts of Poster Sessions, 2nd International Crop Science Congress. National Academy of Agricultural Sciences, New Delhi, India, 1996, p.10.

Lorieux, M., M.-N. Ndjiondjop, J. Séquier and A. Ghesquière. First studies on *O. sativa* × *O. glaberrima* crossability based on molecular markers and genetic mapping. Poster presented at Plant and Animal Genome VI, San Diego, USA, 18–22 January 1998. [Poster abstracts p. 112.]

Ndjiondjop, M.-N., C. Brugidou, M. Lorieux, D. Fargette, C. Fauquet and A. Ghesquière. Characterization and genetic basis of a new type of resistance to RYMV. Poster presented at Plant and Animal Genome VI, San Diego, USA, 18–22 January 1998. [Poster abstracts p. 115.]

## Web Publications and Stories

New Rice for Africa May Help Boost Economies. Future Harvest Backgrounder. *Http://www.futureharvest.org/growth/africanrice.shtml*

New Rice for Africa Offers Hope to Women Farmers and Millions More. *Http://www.cgiar.org/warda/research/nerica/nerica.htm*

## Video

WARDA and AGCOM International. 1998. *Bintu and Her New African Rice: A Genetic Bridge to Food Security and Biodiversity*. 28 min.