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West Africa Rice Development Association

Annual Report 1999

About the West Africa Rice Development Association (WARDA)

The West Africa Rice Development Association is an autonomous intergovernmental research association with a mission to contribute to food security and poverty eradication in poor rural and urban populations, particularly in West and Central Africa, through research, partnerships, capacity strengthening and policy support on rice-based systems, and in ways that promote sustainable agricultural development based on environmentally sound management of natural resources.

In collaboration with the national agricultural research systems of members states, academic institutions, international donors and other organizations, the work of WARDA ultimately benefits West and Central African farmers—mostly small-scale producers—who cultivate rice, as well as the millions of African families who eat rice as a staple food.

WARDA was formed in 1971 by 11 countries with the assistance of the United Nations Development Programme (UNDP), the Food and Agriculture Organization of the United Nations (FAO), and the Economic Commission for Africa (ECA). It now comprises 17 member states: Benin, Burkina Faso, Cameroon, Chad, Côte d'Ivoire, the Gambia, Ghana, Guinea, Guinea-Bissau, Liberia, Mali, Mauritania, Niger, Nigeria, Senegal, Sierra Leone and Togo.

WARDA is a member of the Consultative Group on International Agricultural Research (CGIAR), a network of 16 international research centers supported by more than 45 public- and private-sector donors.

Donors to WARDA in 1999 were: the African Development Bank, Canada, Common Fund for Commodities (CFC), Côte d'Ivoire, Denmark, France, the Gatsby Foundation, Germany, the International Development Research Centre (Canada), the International Fund for Agricultural Development, Japan, the Netherlands, Norway, the Rockefeller Foundation (USA), Sweden, the United Kingdom, UNDP, the United States of America, the World Bank and WARDA member states.

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Association pour le développement de la riziculture en Afrique de l'Ouest

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Cover: Farmer with harvest of variety Sahel 108, Ndiaye perimeter, Senegal River delta, Senegal. Sahel 108 was selected by WARDA and then released in Senegal in 1994.

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Message from the Director General and Chairman of the Board of Trustees

THE YEAR that closed the 'nineteen hundreds' was one of immense activity for all of us associated with WARDA. Several major projects were at or approaching the end of their first phase, and new projects and new directions were coming 'on line.' It was the start of an exciting, if busy, period in WARDA's history that will launch us into the new millennium with great prospects for the long-awaited Green Revolution in Rice in West and Central Africa.

To demonstrate the increasing activity at WARDA and among our partners, we are introducing a new annex to our Annual Report: *The Year in Review* (page 51). This annex chronicles the events as they happened, showing the breadth of research and development topics covered by the Association.

Perhaps the most important event from a management point of view was the Fourth External Program and Management Review (EPMR) of WARDA. The Review Panel consisted of six members and a consultant, and was chaired by Mandivamba Rukundi of Zimbabwe, Program Director of the W.K. Kellogg Foundation, with expertise in international agricultural research management, agricultural and food policy, and irrigation economics. The Panel brought a wealth of international experience to bear on the critical review of WARDA's program and management, with most members having served on CG external reviews of other centers. The review process involved a series of interactions with Center staff, Management and Board, and visits to selected national programs and WARDA's field stations in Senegal and Nigeria.

The Review Report itself attests to WARDA's progress in research and management over the past six years (since the Third External Review), and much praise is given to the interspecific hybridization work that has led to the development of the interspecific rices, or NERICAs. Two quotations from the Report are worthy of note.

> "WARDA is at the cross road where scientific breakthrough will yield large production increase in many developing countries where poor rice farmers now lag behind the technology curve. A fundamental difference is that WARDA is now developing technologies that are adapted to the African environment, without modifying the environment to fit the technology."
>
> "WARDA is best positioned to push hard for a rice-based green revolution in WCA [West and Central Africa]. The Panel urges WARDA to maintain focus on the impact of its work on people's lives—by putting more rice on the tables of poor and hungry people, and by putting more money into their pockets."

However, a major constraint that was identified in the overall impact of the products of our research was the lack of economic incentives for wide and massive adoption, due to (a) poor technology transfer and delivery systems, especially for seed, and (b) inadequate agricultural policies—policies are needed that encourage competitiveness of domestic rice production against heavily subsidized and cheap imports. This is particularly crucial in West Africa, where rice increasingly means food for over 240 million people and demand is growing at an annual rate of 6%, resulting in total annual imports of over 3.2 million tonnes at an alarming price of US$ 1 billion. Thus, WARDA is faced with a major challenge and a pivotal role in enhancing national capacities, both individual and institutional, in policy analysis and formulation for meeting the food security challenges of the 21st century.

The year saw a larger than average influx of new staff, especially when we consider the recently established middle-management positions established in 1998 and 1999. New faces in 1999 included: Frank Abamu (Agronomist/Crop Modeler), Mark Abekoe (Soil Agronomist, Visiting Scientist from Ghana), Antoinette Baroan (Personnel Officer), Olivier Briët (Medical Entomologist, DGIS), Mory Cissé (Purchasing and Supplies Manager), Gilbert Kato (Transport Officer), Mohamed Kebbeh (Agricultural Economist, Visiting Scientist from The Gambia), Rebecca Kent (Weed Scientist, DFID), Adrian Labor (Information and Communications Technology Manager, IDRC), Frédéric Lançon (Policy Economist), Marie-Noëlle Ndjiondjop (Molecular Biologist), Francis Nwilene (Entomologist), Takeshi Sakurai (Agricultural Economist, JIRCAS), Fassouma Sanogo (Translator), Olusegun Olubowale (Senior Accountant), Gaston Sangaré (Farm Manager), Nko Umoren (Internal Auditor), and Norberte Zézé (Public-Awareness Assistant).

As we like to remind everybody, partnership is the *modus operandi* of WARDA. In December, we hosted an International Workshop on 'Effective and Sustainable Partnerships in a Global Research System: Focus on Sub-Saharan Africa,' which we co-convened and coordinated with our fellow CG Center, the International Service for National Agricultural Research (ISNAR), in collaboration with the Organizational Change Program (OCP) and with significant support from other international agricultural research organizations. The Workshop significantly strengthened the mutual understanding of successes and failures in IARC–NARS partnerships in Sub-Saharan Africa, and noted transparency, trust, fair attribution of achievements and financial opportunities as important factors for success. Sharing of these lessons learnt from past research partnership experiences should help those involved to identify areas for establishment of new innovative global partnerships.

As indicated in last year's report, 1999 saw the merger of WARDA's Task Forces with the Rice Network of the West and Central African Council for Research and Development (WECARD/CORAF) to form the West and Central Africa Rice Research and Development Network (*Réseau Ouest et Centre Africain du Riz*, ROCARIZ). The role of ROCARIZ is to link rice stakeholders in the region to generate improved and relevant rice technologies and ensure their successful and widespread adoption. Its purpose is to strengthen the capacity and capability of the national agricultural research and extension services for coordinated research planning, and technology generation, evaluation and transfer to end-users. Ultimately, this work—like all of WARDA's activities—is aimed at reducing poverty and malnutrition through enhanced rice production and market development. A five-year strategy was developed and accepted by USAID for funding.

The first phase of our flagship Interspecific Hybridization Project (IHP) was drawing to a close in 1999 (it officially ended in early 2000). The principal donors to the project—the United Nations Development Programme Technical Cooperation among Developing Countries (UNDP/TCDC) and the Japanese Ministry of Foreign Affairs (MOFA)—reviewed the progress over the three years of phase 1, concluding:

> "The team highly **recommends** ... to consolidate funding and to identify 'champions' who will assist WARDA in moving this unfolding revolution beyond research and development to production, marketing, and the household consumer. Otherwise, the international community and friends of Africa will be missing a golden opportunity to finally change Africa from a 'food-aid' recipient to a rice-surplus producing continent."

The community-based seed production system (CBSS) has become a major component of the IHP since its introduction to WARDA in 1998 (*see* 'Farmers Producing Seed for Farmers,' *WARDA Annual Report 1998*, page 40). We introduced the system because the formal system for producing Certified Seed of cultivated varieties is poorly developed in most countries of the region. The CBSS enables farmers themselves to produce 'seeds of acceptable quality' to be grown by themselves and their neighbors, with a view to providing seed of the New Rice for Africa (NERICA) in this period of expanding demand; however, even this venture is not generating enough seed to meet demand, as the review team points out:

> "The team strongly believes that the direct participation of farmers from the initial stages of technology development [in] the IH project [in] such approaches as the 'village garden rice plots,' PVS [participatory varietal selection] trials, and CBSS has been both effective and instrumental in bringing about the positive outcomes of ***immediate and widespread acceptance of the NERICAs*** for the upland. In Côte d'Ivoire [two] varieties while in Guinea [three] varieties are not only already being grown by many farmers, the demand for seed far exceeds the supply. ... Access to adequate ***NERICA seed*** is a major constraint to greater widespread adoption of the new technology ... The request for seed by participants in the PVS, CBSS, their neighbors, or farmers that have simply attended field days was always top on the list of input needs during the team's field visits to Côte d'Ivoire, Guinea, and Nigeria. Although the current CBSS has been a good initiative and for which the team commends WARDA, it is not an adequate source of seed. WARDA and its partners [in] the CBSS [will need] to include contract seed growers and private seed companies."

Thus, not only the External Program and Management Review, but also the donor review of the IHP recognize the value of the NERICAs and associated technologies. Through their comments, many experienced research and development managers around the world are recognizing that we are truly on the verge of a Green Revolution in Rice in West and Central Africa. Funding for a second phase of the IHP is assured, and we call on the governments, policy-makers and private-sector investors in our Member States to put in place the components of a suitable environment (policy, socio-political, financial) that will enable it all to happen.

In the light of this threshold, we take the opportunity to look back over the ground-breaking development of NERICA, with special thanks to the donors who made Phase I such a success (page 9). The effects of the IHP have been far-reaching and have resulted in several spin-offs, one of which has been the establishment of molecular biology facilities at WARDA's Headquarters. The establishment of the laboratory and facilities is covered in our second feature story this year (page 16).

Soil degradation is a potentially major problem in many farming systems throughout the world. This year, we are highlighting the UK-funded research in irrigated systems in the Sahel (page 30) and the soil acidity problems in the humid forest zone (page 23).

Another project winding down towards completion in 2000 was the Human Health Consortium, hosted at WARDA. As an indication that research is not always the answer to the world's ills, we highlight the difficulties involved with indigenous perceptions of the potentially dangerous disease schistosomiasis (page 38). The Consortium is finalizing its research publications in 2000, but WARDA will be retaining an active interest in health matters as it starts to look at the nutritional benefits at community level of the NERICA varieties.

This year's *Donor Country Profile* highlights our complex relationships with colleagues and institutions in the United Kingdom. We particularly welcome the UK's stalwart support during this time of general decreases in unrestricted core contributions to CG Centers.

Foreword

Let us share with you our vision for WARDA as we move into the Third Millennium...

We see WARDA as fulfilling a triple role as a dynamic center of excellence, as a model regional institution, and as the hub or pivot of an efficient technology and knowledge delivery system. In the short term, our priority as a Center of Excellence will be in fostering and sustaining an enabling environment that supports all staff in contributing to excellent, effective and efficient research—research is our *raison d'être*. A central and leadership role for WARDA in the third millennium is one of a model and pivotal regional institution for science and technology-based systems. An institutional *system* will encompass broad partnership (WARDA's *modus operandi*) among all players and stakeholders, in contrast to an isolated *center*. The final element of our tripartite role is as the hub of an efficient technology and knowledge system. This will build on our successful Task Force, Open Center and participatory research approaches in the empowerment of farmers. It will constitute a sustainable framework to respond to current and future challenges, with the aim of providing a constant flow of new technologies (international public goods) to farmers. This triple role of WARDA represents a dynamic interlocked system with the ultimate objective of contributing toward poverty alleviation and food security in the subregion.

It comes as no surprise to us that this Vision, developed during 1999, fits in well with the recently developed CGIAR Strategy for Sub-Saharan Africa, which was developed in close collaboration with the CG Centers, subregional organizations, and all-inclusive NARS partners.

We hope that you will enjoy reading the various stories in this Report with as much pleasure as it gives us to present them to you.

Kanayo F. Nwanze
Director General

N. Lindsay Innes
Chairman, Board of Trustees

WARDA's Programs for the Next Millennium: Managing Continuity and Change

Amir Kassam
Deputy Director General for Programs

THE YEAR 1999 at WARDA will be remembered for its intense program review and planning activities. First, in early 1999, WARDA revisited its annual program review and planning process to assess the performance of annual work plans, and the continuing relevance of multi-year program priorities and strategies as presented in the three-year rolling Medium-Term Plan (MTP). Second, in June 1999, WARDA underwent a Center-Commissioned External Review (CCER) of its Program Strategy and Management. Third, in preparation for the Fourth External Program and Management Review (EPMR), with initial phase in November 1999 and main phase in February 2000, WARDA took a detailed stock of and documented its programmatic accomplishments since the Third EPMR. More information on this and the outcome of the Fourth EPMR, including WARDA's response, will be provided in the 2000 Annual Report.

The 1999 annual program review and planning exercise was used to critically assess WARDA's multi-year program proposals, as presented in its MTP 1998–2000, and to formulate a significantly revised MTP for the period 2000–2002. As elaborated below, the revised MTP resulted in a sharper operational mandate, and a dynamic and robust program framework that responds effectively to the regional challenges of: growing population and poverty, rapidly increasing demand for food (especially rice), risk of environmental degradation, weak national research and development capacity, and inadequate social capital base for development. The MTP 2000–2002 takes into account the region's agricultural potentials, and builds on WARDA's significant scientific achievements since 1991 and on the advantage of its special relationship with NARS and its concept of an 'open center.'

Overall, WARDA continues to strengthen its role as a pivotal regional center for rice-based systems, focusing its investments primarily on the unique problems of West and Central Africa. WARDA's programmatic vision is to create a regional research program to promote environmentally sound technical and economic change in the rice sector at national and local level, leading to an equitable improvement in food security for the poor, and sustainable reduction in rural poverty. WARDA's programmatic response reflects its operational mandate, which aims at ensuring the maintenance of its scientific excellence in: (i) rice genetic improvement; (ii) technology generation, evaluation and dissemination for rice-based systems; and (iii) providing leadership to inland valley ecoregional activities.

WARDA will continue to conduct strategic and applied research to generate urgently needed technologies for the region. During the 2000–2002 MTP period, WARDA's output-driven strategy will be implemented more effectively by strengthening its development-oriented rice research efforts through collaborative technology evaluation and transfer, supported by complementary information and training activities. In this regard, and consistent with initiatives already taken in 1998, WARDA will remain open to the participation of rice scientists from East, Central and southern Africa (ECSA) in its Task Forces, thereby responding to direct demand from the ECSA region and ensuring that the rest of Africa benefits from the high spill-over potential of WARDA's research. WARDA will also strengthen its ecoregional research on inland valleys through the Inland Valley Consortium (IVC). The IVC has developed into a tried-and-tested vehicle for the evaluation and delivery of technologies generated by WARDA and others for productivity improvement in inland valley land use systems. For the MTP 2000–2002, IVC will have a strong focus on integrated natural-resource management to underpin sustainable land use intensification and diversification.

Drawing from lessons learned in African agricultural research over several decades, WARDA's research programs represent a major departure from the agro-climatic program structure that characterized WARDA prior to 1997, and go beyond the program structure proposed in the 1998–2000 MTP. The revised program structure for the 2000–2002 period allows for consolidation of program activities and consists of two technology-generation programs, the *Rainfed Rice Program* (Program 1) and the *Irrigated Rice Program* (Program 2); a *Policy Support Program* (Program 3); and an expanded and strengthened Program 4, renamed *Systems Development and Technology Transfer Program* from the old *Information and Technology Transfer Program.* A full description of the programs, with goals, objectives, outputs and milestones, is contained in the MTP.

We believe that the new program framework lays a strong foundation for the next millennium, and allows WARDA to: (a) allocate research activities along the R-to-D Continuum in a logical way; (b) explicitly recognize the targeted production systems in technology generation and development, as well as in technology dissemination; (c) achieve a closer integration of the ecoregional research activities based in the IVC with WARDA's strategic research on technology and knowledge generation for inland valley systems; and (d) create strong cross-program linkages to ensure that the whole program agenda is of the highest relevance and scientific value, and cost-effective and efficient to manage.

This structure is in full accord with the four pillars of the CGIAR Strategy for Sub-Saharan Africa and provides a robust platform for responding to the challenges that face agricultural research and development in the region.

The Center-Commissioned External Review (CCER) on Program Strategy and Management panel was chaired by Dr Bernard Tinker of Oxford University. The panel concluded: "WARDA is now a highly active and respected member of the West African rice research community. Its applied research is producing new technologies, which are being applied at an increasing rate. Some of these are adaptations of well-known principles, as in the saline and alkaline soils in Senegal and Mali. Others are the continuation of its plant breeding for yield and against the pests, diseases and soil constraints of West Africa. The most important is the production of interspecific hybrids (the 'new rices for Africa'), that are showing great promise in some ecosystems. There seems little doubt that it is now generating impact at an increasing pace. ... WARDA has been treated relatively generously in proportion to the amount [of rice] produced in its region. The increase in rice demand, and this promise of truly important research developments shows that this is both deserved and well applied."

Beyond the accomplishments that are featured in this Annual Report, there were several others that deserve mention. The new interspecific rice plant type—dubbed 'New Rice for Africa' or NERICA—was released and actively disseminated. The establishment of WARDA's regional network on participatory rice improvement—a process begun in 1998, involving participants from all the 17 member countries—was completed. Decision tools for scaling up integrated management of nutrients, water and pests in irrigated rice agro-ecosystems in the Sahel were further developed. Policy research on competitiveness of rice production was strengthened, including the role of rural financial services in rice technology uptake and resource management. The second phase of the Inland Valley Consortium was launched, with an expanded membership and research agenda. The transfer of all responsibility from IITA to WARDA for rice germplasm management in Africa was finally completed, and a Rice Genetic Resources Unit was established at WARDA.

In the 1980s, WARDA succeeded in improving the productivity of mangrove rice with considerable impact. In the 1990s, WARDA made great strides in raising the productivity and output of irrigated rice in the Sahel, where yields of 4 to 6 t/ha are normal. The stage is now set for a green revolution in irrigated and rainfed rice across WARDA's mandate region in the first decade of the next millennium.

Management of continuity and change is at the heart of WARDA's program management processes, so that short-term efforts remain consistent with longer-term objectives. This spirit is well illustrated in the feature articles that follow. In the 1998 Annual Report, I said: "We remain confident that WARDA will continue to deliver a high level of performance next year and beyond." In 1999, WARDA's dedicated and qualified scientists and support staff, working alongside their national and international collaborators, certainly kept this promise. I am confident that WARDA will continue to remain a high-return investment in the CGIAR System.

New Rice for Africa... with a Little Help from Our Friends

AS OUR flagship Interspecific Hybridization Project comes to the end of its first phase, we look back at where we've come from and where we're going, and pay tribute to those who have 'paid the way' for us.

The Interspecific Hybridization Project (IHP) started in 1997 with support from the Japanese Government, the Rockefeller Foundation and the United Nations Development Programme (UNDP). It built on WARDA's major breakthrough—achieved in 1994—of producing fertile offspring of crosses between indigenous African rice (*Oryza glaberrima*) and Asian rice (*O. sativa*). Today, the new rice plant type—dubbed 'New Rice for Africa' or NERICA—is being grown on at least a few farms in every country in WARDA's mandate region, and the stage is set for a Green Revolution in rice in Sub-Saharan Africa.

Background: the breakthrough in rice breeding

The brains and driving force behind WARDA's interspecific hybridization research is Monty P. Jones, upland-rice breeder and program leader for rainfed rice at WARDA's Headquarters in Côte d'Ivoire.

"The whole concept goes back to the mid-1970s," explains Jones, "when I was working for my national program in Sierra Leone. WARDA had its Mangrove-swamp Rice Program based at Rokupr at that time, and I was seconded to the WARDA project." Jones's particular interest was in the short-season mangrove-swamp, where sea-water incursion gives a maximum three-month salt-free ecology. "Rice varieties for this ecology need to be either very short-cycled or else salt-tolerant," continues Jones. "The only varieties which were sufficiently tolerant of the salt to be able to grow there were *glaberrimas*." In the years leading up to his ground-breaking attempts to hybridize the two rice species, Jones also noted that in marginal upland environments it was again *glaberrimas* that were growing, rather than the Asian *sativas*. "Thus, it seemed that the *glaberrimas* had genes for resistance or tolerance to local stresses, such as soil acidity, iron toxicity, and blast disease, which were not available among the *sativas*."

Oryza glaberrima was domesticated in Africa over 4500 years ago. It is well adapted to the local environments, but yields poorly beause of lodging and grain-shattering

With a view to accessing and exploiting these useful genes, Jones brought all the available *glaberrima* material from the gene banks at the International Rice Research Institute (IRRI, The Philippines) and the International Institute of Tropical Agriculture (IITA, Nigeria) to WARDA in 1991 to evaluate it in the field. "We had 1500 accessions," Jones recalls. "We grew them first during the main season at M'bé [WARDA Headquarters], then we were so impressed with the results that we took them south to Gagnoa [south-central Côte d'Ivoire] for re-evaluation in the off-season." From these 1500 accessions, the team selected 48 promising varieties and tested their potential compatibility for the interspecific cross—only 8 survived this selection process!

Previous attempts to cross the two species had met with failure—the offspring were infertile, or else the few fertile seeds were not noticed among the infertile ones. Jones's determination to succeed led the team to unprecedented lengths: even the eight compatible varieties set very little seed in the first generation of the cross (known as F_1 generation)—in fact, they were looking at less than 5% seed-set. "We were collecting 5 seeds or less from apparently sterile plants," laughs Jones, "but what a goldmine we'd uncovered!"

These F_1 seeds were given extra-special care, and then the plants grown from them were used for 'back-crossing' with the *sativa* parent. After two or three backcrosses, the fertility of the plants increased to a 'reasonable' level, but the plants were still segregating—that is, not true-breeding—even after the fourth or fifth generation. So, in 1993 the team decided to adopt anther-culture to genetically fix the lines (*see* 'Molecular Biology Facilities at WARDA,' in this Report). In 1994, the first true-breeding interspecific lines were available at WARDA.

Partners in the Interspecific Hybridization Project

Donors
- United Nations Development Programme Technical Cooperation among Developing Countries (UNDP-TCDC)
- Japanese Ministry of Foreign Affairs (MOFA)
- Rockefeller Foundation
- CGIAR Systemwide Program for Participatory Research and Gender Analysis
- Donors who provide unrestricted financing to WARDA

Research Institutions
- West Africa Rice Development Association (WARDA/ADRAO)
- International Center for Tropical Agriculture (*Centro Internacional de Agricultura Tropical*, CIAT, Cali, Colombia)
- Cornell University (Ithaca, New York, USA)
- International Rice Research Institute (IRRI, Los Baños, The Philippines)
- *Institut de recherche pour le développement* (IRD, *formerly* ORSTOM, Montpellier, France)
- University of Tokyo (Japan)
- Yunnan Academy of Agricultural Sciences (YAAS, Kunming, China)

Research Institutions with staff based at WARDA
- *Centre de coopération internationale en recherche agronomique pour le développement* (CIRAD, France)
- Japan International Cooperation Agency (JICA)
- Japan International Research Center for Agricultural Sciences (JIRCAS)
- Ministry of Agriculture, Forestry and Fisheries (MAFF, Japan)
- Natural Resources Institute (NRI, UK)
- United Nations (UN Volunteers, *from 2000*)

Birth and development of the Interspecific Hybridization Project

"With this breakthrough, we clearly wanted to expand the work," Jones reflects, "but WARDA core funds at that time did not give us the scope to do so." In 1995, the team submitted a 'concept note' to UNDP and the Japanese Ministry of Foreign Affairs (MOFA). UNDP's immediate response was to fund a workshop on interspecific breeding, with special reference to rice, in December 1996. This meeting brought together all the institutions already involved in the interspecific hybridization research—*Centro Internacional de Agricultura Tropical* (CIAT, Colombia), Cornell University (USA), IRRI and *Institut français de recherche scientifique pour le développement en coopération* (ORSTOM, France)—together with seven national programs from West Africa to assess the state-of-the-art in interspecific rice breeding and identify the major problems still to be tackled. The workshop was immediately followed by a strategic planning meeting financed by MOFA. The upshot of these two meetings was that both the Japanese Government (through MOFA) and the UNDP's Technical Cooperation among Developing Countries (UNDP-TCDC) agreed to fund the ongoing research; thus, the 'Africa/Asia Joint Research on Interspecific Hybridization between African and Asian Rice Species (*Oryza glaberrima* and *O. sativa*)' was born.

The MOFA/UNDP-TCDC Project (known as IHP) was set for three years, 1997/98 to 1999/2000, with funding to the tune of US$ 450,000 per year, and an additional $ 474,000 from WARDA core over the three-year period.

Stringent reporting

Our friends in Japan and at UNDP were conscientious, and wanted to ensure that we are making the most of our new knowledge and resources. Thus, evaluation meetings were held both mid-term (November–December 1998) and toward the end of the first phase (November 1999). These were good for the scientists who can tend to be a bit sloppy in reporting, and the IHP's progress has been well documented, with informal annual reports prepared for each year (1997, 1998 and 1999) for the evaluation meetings, reports of the meetings themselves, and formal publication of annual research highlights in *Focus: Interspecifics* (1998 highlights) and *Rice Interspecific Hybridization Project Research Highlights 1999*.

The evaluation meetings brought together WARDA researchers and Board members, representatives of the collaborating institutions, and representatives from the principal donors; in addition, the World Bank and USAID showed a keen interest in the proceedings—the former sent a representative to both meetings, and the latter would have done so, but for logistical problems with travel. The meetings were 'earthed' by presentations from the national agricultural research and extension services in Côte d'Ivoire and Guinea, and farmers from Côte d'Ivoire. Madame Delphine Koudou received a standing ovation at the mid-term meeting—she is the original 'small-screen' Bintu (see below)!

Participatory varietal selection

A major feature of the IHP, and one strongly favored by the donors, was the use of participatory varietal selection, or PVS, as a dual mechanism for obtaining feedback on farmers' preferences in new rice varieties, and for technology transfer. Conventional varietal release mechanisms involve several years of on-station and on-farm testing before release, then it often takes several years to produce enough seed to disseminate to farmers. WARDA, and its partners, desperately wanted to get the new rices out to farmers as quickly as possible. So, WARDA organized a meeting of rice stakeholders—scientists from national research programs, extension workers, farmers and non-governmental organizations—in March–April 1996 to discuss strategies for getting the new rices to farmers. Aware that participatory research had catalyzed agricultural adoption in India and Nepal at a relatively low cost, and that it had also been adapted for farmers to select beans in Rwanda, the delegates opted to pursue the PVS approach.

The basic PVS adopted by WARDA is a three-year program. In the first year, WARDA and extension-agency staff establish a 'rice garden' in a target village, often in the field of a leading or innovative farmer. The rice garden comprises a demonstration plot of between 60 and 100 varieties, not just interspecifics, but also modern, improved *sativas*, popular local and regional varieties, and a few

The participatory varietal selection program was designed to reach as many farmers as possible. Men and women are usually kept separate so that researchers get important gender-differentiated data

glaberrimas. Farmers from the host and surrounding villages are encouraged to visit the garden as often as they wish to monitor progress, but three formal evaluation sessions are established. The first, at maximum tillering, enables farmers to select varieties on the basis of vegetative characteristics such as speed of growth, ability to compete with weeds, and performance in the face of diseases and insects. The second visit, at maturity just before harvest, enables the farmers to assess plant height and panicle structure, growth rate, pest resistance and plant type. At the third visit, after harvest, farmers look at yield and quality aspects such as percentage of broken grains, cooking ability and taste.

These three assessments give the farmers the information they need to select up to five varieties from the rice garden, which they will then grow on their own farms under their own management conditions in year 2. Here they can make direct comparison with their traditional varieties. In the third year, farmers are asked to pay for seed of their favorite varieties—this provides a test of how much they really prefer them over their traditional varieties.

Having started the approach in Côte d'Ivoire in 1996, and then taken it on to Ghana, Guinea and Togo in 1997, WARDA decided to 'spread the news' among its other member states. A training workshop was organized in May 1998, to which an additional six countries were invited—Benin, Burkina Faso, The Gambia, Guinea Bissau, Nigeria and Sierra Leone. With additional teams coming from the original four countries, 10 West African countries were now equipped to conduct the PVS on their own. In April 1999, WARDA held two consecutive meetings. The first was a reporting and planning workshop, at which the 10 teams from 1998 reported on how farmers had accepted the participatory approach in their countries. The second meeting was a training seminar, at which teams from the remaining seven WARDA member states—Cameroon, Chad, Liberia, Mali, Mauritania, Niger and Senegal—were taught the PVS methodology. WARDA received extra funding for these meetings from UNDP and the CGIAR Systemwide Program for Participatory Research and Gender Analysis. A full report of the 1998/99 activities as presented at the April 1999 meetings was published by WARDA in a book, *Participatory Varietal Selection: The Spark that Lit a Flame*, in the second half of 1999.

The trouble with seeds

Having achieved a certain level of acceptance of new varieties among farmers, the next step is to make sufficient quantities of seed available for wider distribution. In many countries of West and Central Africa the state-operated mechanisms for seed production and distribution are under-resourced, over-stretched and unable to meet demand. Regular readers of this Annual Report will be aware of community-based seed systems promoted by WARDA to enable farmers to produce seeds for their own communities (*see* 'Farmers Producing Seed for Farmers,' *WARDA Annual Report 1998*, pages 40–44). With the initial success in Côte d'Ivoire, the system was adapted and adopted in Guinea, and is expected to be used in Nigeria during 2000. Mainly owing to its 'self-help'

Farmers have gladly adopted the idea of using their own resources to multiply NERICA seed for their own communities

nature, the community-based seed system is another popular activity of the IHP among our donors.

What's in a name?

The interspecifics have gone through several 'incarnations' in terms of naming since the first lines were fixed in 1994. However, the decision to use 'New Rice for Africa,' first in 1998, then as the standard from early 1999 was crucial. "After all," explains Dr Tatsuo Fujimura of UNDP-TCDC, New York, "WAB 450-bla-bla really doesn't mean very much to a farmer, it's simply too long."

In late 1999, the decision was taken to standardize on 'NERICA.' This will serve not only as a general label for the *glaberrima–sativa* interspecifics, but also as a numbered series for the released varieties.

In early 2000, the first seven varieties will be released on a wide scale in Côte d'Ivoire and Guinea. For those who have an interest in details, here they are:

- NERICA 1 = WAB 450-I-B-P-38-HB
- NERICA 2 = WAB 450-11-1-P31-1-HB
- NERICA 3 = WAB 450-I-B-P-28-HB
- NERICA 4 = WAB 450-I-B-P-91-HB
- NERICA 5 = WAB 450-11-1-1-P31-HB
- NERICA 6 = WAB 450-I-B-P-160-HB
- NERICA 7 = WAB 450-I-B-P-20-HB

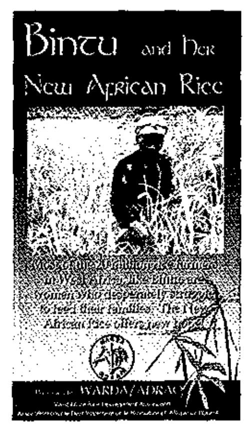
Telling the world about *'Bintu and Her New African Rice'*

Since the IHP has become very much our 'flagship' project at WARDA, our donors have provided resources for public awareness. Even before the official start of the IHP, we had released a brochure entitled *Unlocking the Treasures of African Rice Species: Bintu and Biodiversity* in 1996. Thus, the concept of Bintu as the typical West African woman rice farmer predates her later rise to 'small-screen' fame.

"I very much liked the concept of Bintu," says WARDA Director General Kanayo F. Nwanze. "So much so that she has become the focus of numerous seminar presentations that I have given on behalf of WARDA since coming here in 1996."

In 1998, our donors encouraged us to promote the 'new rice for Africa' both in print and in a video. The video, entitled *Bintu and Her New African Rice*, tells the story of Bintu, this time played by Ivorian farmer Delphine Koudou, participating in the PVS. It also includes interviews with many of the WARDA researchers involved in various aspects of the IHP, and expounding the virtues of the new rices.

Meanwhile, a general brochure on the IHP had been released in 1997, to be followed by *New Rice for Africa* in 1998. "The published PVS proceedings—both the 1999 *Spark That Lit a Flame* and the upcoming 2000 *The Flame Spreads*—are also very much in the public-awareness arena," explains WARDA Information Officer Guy Manners.



"In addition," comments Monty Jones, "our annual research highlight publications were designed to play a dual role of solid science written in an easy 'public-awareness style' language."

'Papa NERICA,' Monty Jones and 'Bintu' discuss the virtues of NERICA for the video *Bintu and Her New African Rice,* made in 1998

Where are we now?

By the end of 1999, two interspecific varieties were well advanced along the varietal-release process in Côte d'Ivoire. At the same time, four interspecifics were doing well in PVS and other variety adoption trials in Guinea. These important milestones had already been predicted by the early part of the year, and brought to a head a need that had been expressed by the donors at the mid-term evaluation in late 1998. That was, the need for a specific name for the new rices so that they could be recognized wherever they may be. "Having standardized on 'new rice for Africa'," explains Director General Nwanze, "it was a simple step to come up with the name NERICA."

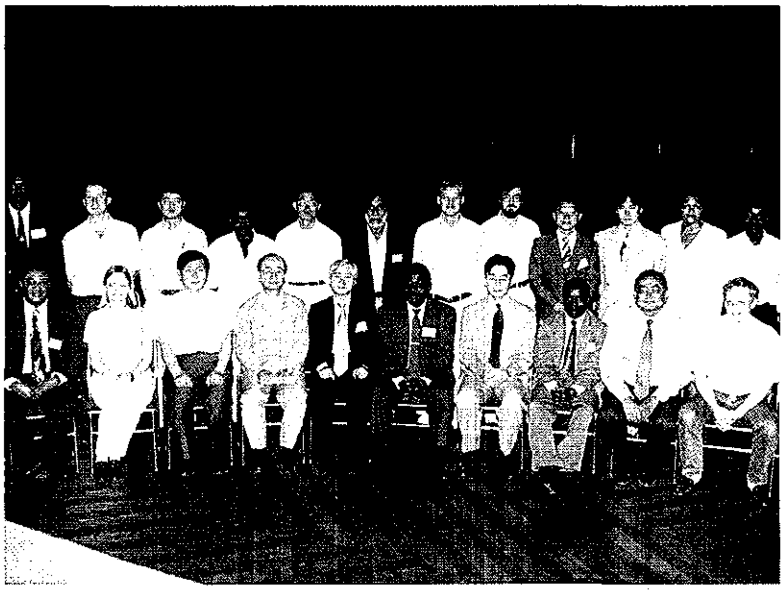
Where next?

"The November 1999 evaluation meeting was dubbed 'final,' but we are expecting a delegation from UNDP to visit and prepare a final evaluation report in June and July 2000," explains Jones. "This will not be formal seminars like in the Project-wide evaluations with all parties, but rather one-on-one and round-table discussions with individuals and groups of scientists." The evaluation team will also be discussing the financial management of the project with WARDA's finance division. This will be the official end of phase 1 of the IHP, but the main donors—MOFA and UNDP-TCDC—have already committed themselves to a second phase. Phase two is also attracting other donors. "The PVS seems to be a particular attraction to other donors," explains Jones. The Rockefeller Foundation first showed interest in PVS in 1998 with a small cash injection, and is now planning to fund activities in Mali and Nigeria for three years from 2001. Meanwhile, the Gatsby Foundation is supporting PVS in Ghana and Nigeria from 2000 to 2002, and USAID is supporting the work in Nigeria in 2001.

"The future is opening up before us," enthuses Jones. "We really are on the verge of a green revolution in rice in West and Central Africa, if not throughout Sub-Saharan Africa! NERICA 1 and NERICA 2 will be released in Côte d'Ivoire by the middle of 2000, and some 500 hectares will be planted with them." Meanwhile, NERICAs 3 through 7 are spreading from sites where they proved initially popular in Guinea. Amadou Moustapha Bèye, technology transfer agronomist, is spearheading the community-based seed system work and is intimately involved 'on the ground' in Guinea. "Despite the lack of official varietal release mechanism," he expounds, "the national agricultural research program has already 'released' NERICAs 3, 4 and 5 to farmers. In 2000, we expect Guinean farmers to be growing some 5000 ha of five NERICA varieties." Projections for Guinea run to 400,000 ha of NERICAs in 2002.

"The first decade of the new millennium promises to be really exciting," says Nwanze. "With the early success of the upland NERICAs, we started to target rainfed lowland and irrigated systems with interspecific crosses of their own." For the irrigated ecology, the first targeted NERICAs are just beginning to be fixed—the point at which the upland material was 5–6 years ago. "WARDA is moving into the new millennium," explains Nwanze, "looking at a three-pronged strategy: stabilization of upland rice production, in which the NERICAs and associated technologies are playing a vital role; intensification and diversification of the rainfed lowlands, especially inland valley bottoms; and, maximizing resource use efficiency in the irrigated systems. We now have plant material—especially the NERICAs—that can resist or tolerate most of the region's stresses, that survive *and produce* with minimal inputs, and yet respond bountifully once inputs become available. What we are looking at is an *upward* spiral, with productivity gains generating income, income being invested in inputs, and inputs producing even greater productivity gains. We truly will see subsistence rice farmers being drawn up out of the poverty trap."

With that sort of prospect, it is no wonder that the IHP phase 2 is attracting more donors than any other project in the Association.



Just part of the wide network that makes up the IHP team: WARDA and collaborating researchers, donor representatives and support staff, who attended the Mid-term Evaluation of the project in 1998

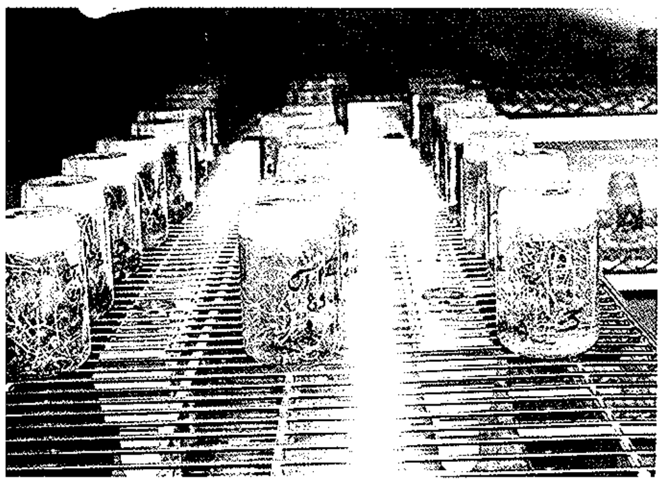
Molecular Biology Facilities at WARDA

MOLECULAR BIOLOGY is generally considered an advanced science, and maybe not something most people would immediately associate with an institution based in West Africa. So, why has WARDA built its own facilities, and what is it doing with them?

Historical perspective

By the early 1990s, rice breeders at WARDA realized that conventional breeding efforts over the previous three to four decades had not achieved any remarkable impact, especially in the rainfed ecologies. At this time, the idea of creating interspecific hybrids between African (*Oryza glaberrima*) and Asian (*O. sativa*) rices was put forward, with a view to utilizing the genes for local adaptation in the African species (*see* 'New Rice for Africa... with a Little Help from Our Friends,' in this Report). However, it quickly became apparent that there were problems with 'fixing' (stabilizing) the progeny of these crosses and that something extra was going to be required.

"In the early 1990s, we gave no thought to adopting molecular biology at WARDA," explains Upland Rice Breeder and Rainfed Rice Program Leader Monty Jones. "But we soon realized that an answer to our problem of fixing the interspecifics was to adopt anther-culture." Anther-culture is a molecular technique whereby the genetic complement of pollen grains is doubled. Pollen is the plant equivalent of sperm and therefore contains only half the gene complement of the parent in preparation for combination with an egg-equivalent to produce a new individual. By doubling the chromosomes of pollen, we immediately obtain a fixed line, as the two sets of genetic material are identical.



Anther-culture: where it all began for WARDA

"Anther-culture had several advantages over conventional breeding," explains Jones. "First, it allowed us to fix lines in two years, rather than in the normal five to six. Second, the process helped reduce the problem of sterility among the first-generation progeny of the interspecific hybrids; and, third, it enabled us to recover 'recombinant' lines, that is lines combining features of both parents—in itself, the first goal of the project." WARDA was fortunate to gain full support from the Rockefeller Foundation to set up its anther-culture facility in 1992/93, and by 1996 several pure-breeding interspecific progenies had been obtained by this technique.

"The new materials appeared to combine characteristics of the two parents, as we'd hoped," continues Jones, "including the early growth vigor that gives *glaberrima* its weed-suppressive abilities, along with other *glaberrima* traits of resistance or tolerance to drought, blast disease, rice yellow mottle virus and acid soils. However, we really needed to know exactly what had been transferred from *Oryza glaberrima* into the new progenies, where the genes were located and how we could utilize them." These questions could be answered by molecular biology; to be precise, by genetic markers.

Within the Interspecific Hybridization Project (IHP), molecular biology activities had been assigned to Cornell University in the USA and the *Institut de recherche pour le développement* (IRD, formerly ORSTOM) in France, but now the decision was taken to establish facilities at WARDA, with help from its partners.


The WARDA molecular biology team in late 1999: from left, Irène Dopeu, Jeanette A. Kouakou, Thierry Cadalen, Kouamé Ipou, Marie-Noëlle Ndjiondjop and Félix B. Guela

Establishing the molecular biology laboratory

Thierry Cadalen was appointed WARDA's first molecular biologist in October 1997. "My first objective was to set up WARDA's molecular biology lab," Cadalen recalls. "Monty Jones had already established the link with Susan McCouch at Cornell before I arrived, and the advice was that WARDA should work with microsatellite markers. Although I was a molecular biologist, I was not specifically trained in microsatellites." Cadalen would be trained in the appropriate techniques at Cornell, in Susan McCouch's laboratory. "But before I could go there, we had to equip the lab." Thus, the essential equipment for general molecular biology and for microsatellite work was ordered in early 1998, freeing Cadalen to travel to Cornell for three months training.

Cadalen returned to WARDA in April 1998, and a laboratory assistant was recruited. The laboratory staff increased by the addition of a research assistant in May 1998 and a part-time technician in June 1998. "The training at Cornell was not solely for my benefit," explains Cadalen. "It was my job to train the new staff and get the lab up and running." Enforced absence after a road accident showed that Cadalen had been doing his job—Research Assistant Pierre-Louis Amoussou continued the microsatellite work for four months with only e-mail and telephone contact to the outside world!

The material necessary for the methodology of choice (silver staining and polyacrylamide gel electrophoresis, or PAGE, and other equipment) did not arrive until late 1998, and it was not until the end of February 1999 that the microsatellite procedures were functioning as planned.

Even after the arrival of the silver-staining and PAGE materials, all was not plain sailing. Technical problems continued to beset the work through August/September 1999. Principal among these was that of water quality (the silver staining requires exceptionally pure water): a new cartridge for the water-purifier ordered in February 1999 did not arrive until the end of August. Using impure water gave results that were often unpredictable and unexpected, rendering such results effectively useless. Another problem has been the difficulty of obtaining required chemicals (especially enzymes) at short notice. Such problems have caused inevitable delays in the research.

Research results

Despite the various setbacks, research is underway in the WARDA molecular biology laboratory, and some headway has been made in achieving its objectives.

As noted earlier, there was an early decision to work with microsatellite markers. This was because a certain amount of work had already been done using other markers, in particular restriction fragment length polymorphisms (RFLPs), and microsatellites had several advantages over these. Perhaps most importantly, RFLP analysis is technically complex, slow and costly. In addition, RFLP and other marker systems had revealed very little diversity (polymorphism) within *Oryza glaberrima*. Conversely, microsatellites were cheaper to analyze and showed good polymorphism within *O. glaberrima*. The early microsatellite work within the IHP had been conducted at Cornell, where 94 new markers were mapped in 1997 alone.

Since its inception, the molecular biology laboratory has concentrated on two main themes: genetic mapping using microsatellites (for identifying quantitative trait loci) on interspecific progeny, and diversity studies of *Oryza glaberrima* using microsatellite markers.

Being genes, microsatellites may occur in a single form or in two or more forms known as alleles. As the genes occur on both members of a chromosome pair, each 'normal' individual organism has either one or two alleles of a particular gene. If an individual is pure-breeding for a particular gene, it carries the same allele of the gene on each member of the chromosome pair, and is termed *homozygous*. For example, there may be a gene for resistance to a disease, say rice yellow mottle virus (RYMV); in a non-resistant individual the allele of the gene that confers the resistance is replaced by an allele that does not confer resistance. To avoid confusion of terms, the position of a gene is referred to as its locus, so we talk about number of alleles per locus, rather than per gene.

To exploit the potential of the *O. glaberrima* genome (that is, the full gene complement), especially its adaptation to the stresses prevalent in Africa, we need to identify and locate 'informative' markers on the genome. Informative markers occur where the microsatellite alleles at a locus are different in *O. sativa* and *O. glaberrima*. We used 132 markers in our comparison of the chosen parent plants, and found a high level polymorphism between the species in markers throughout the genome (*see* Figure 1).

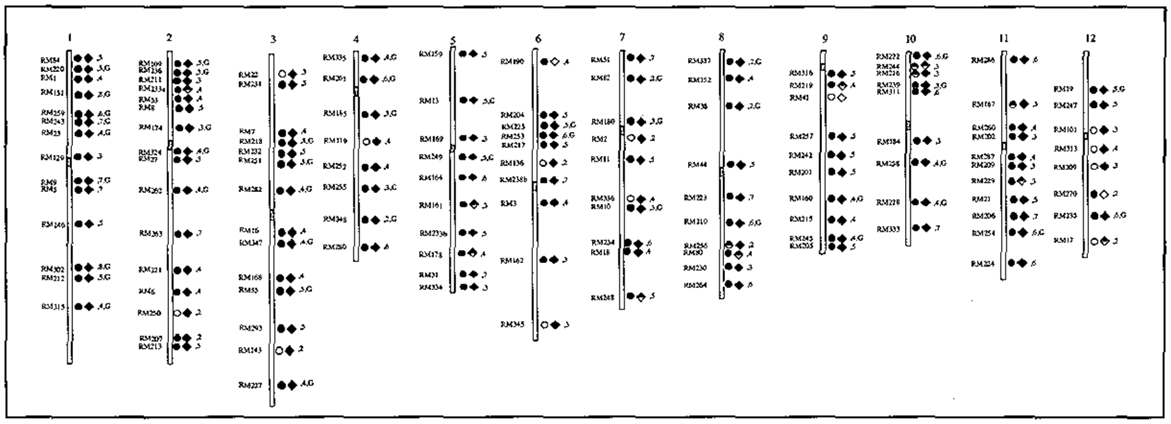


Figure 1. Genetic linkage map between *Oryza glaberrima* and *O. sativa* subsp. *japonica* (circles) and *O. sativa* subsp. *indica* (diamonds) developed at Cornell University. Blue indicates polymorphic, and white monomorphic markers.

This is good news: it opens the opportunity of finding informative markers associated with the traits of interest on the *glaberrima* genome (for example, weed-suppressive traits, RYMV resistance, drought tolerance). This in turn opens up the possibility of using microsatellites in marker-assisted selection. In marker-assisted selection, a simple procedure can determine the presence or absence of the desired gene in a small quantity of DNA material extracted from young or early-generation plant material, without the need for extensive and expensive large-scale field screening to see which plants have inherited the required trait. This early testing also minimizes any undesirable environmental effect which may result from full field screening.

The first study on allelic diversity of *O. glaberrima* was conducted on crosses among four varieties. Pair-wise combinations revealed low levels of polymorphism (between 15 and 28%), but comparison across the four varieties showed that 46% of the 77 microsatellites studied were in fact polymorphic (with at least one 'parent' showing a different allele from the other three). This confirmed that microsatellites were a good choice of markers for the diversity study in *O. glaberrima*.

Detailed work on allelic diversity within *O. glaberrima* is the subject of PhD research by Sémon Mandé (formerly a staff member at WARDA) at Cornell University. Meanwhile, preliminary studies were conducted by Cadalen on a subset of 83 of Mandé's 200 *O. glaberrimas*, while at Cornell for a second visit in March–May 1999. Cadalen identified 155 alleles among 30 microsatellite markers, giving a mean number of alleles per locus of 6.13—very similar to the figure for a set of 13 *O. sativas* (6.63 alleles per locus). However, the *glaberrimas* showed a much wider variation among loci for the number of alleles, as illustrated by six markers having 11–25 alleles, while at the other extreme 11 markers had between 1 and 3 alleles. Again, microsatellites are showing much more polymorphism within *O. glaberrima* than any previous marker-studies had shown.

Partnerships

As with so many of WARDA's activities, a key to the success of the molecular biology work is the partnerships built up and maintained with other institutions. We have already highlighted the vital role of Susan McCouch's laboratory at Cornell University in training WARDA staff, providing technical expertise in the form of advice for initially setting up the facility at WARDA, and in hosting the allelic diversity study on *O. glaberrima* (Sémon Mandé's thesis research).

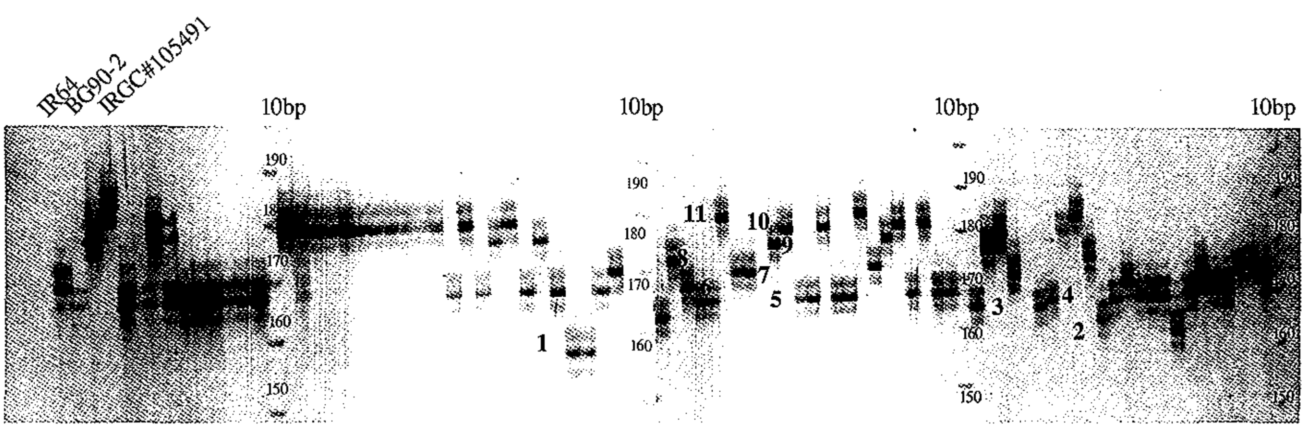


Figure 2. Allelic diversity profile of microsatellite RM333: 11 alleles detected on 83 accessions of *Oryza glaberrima*

The Japan International Research Center for Agricultural Sciences (JIRCAS) seconded Physiologist Satoshi Tobita to work in the WARDA molecular biology laboratory as part of the IHP in January 1998. Tobita's job is to look into the physiological aspects of gene-mapping. "We need a team to gear-up the laboratory for marker-assisted selection," he explains: "the molecular biologist, the breeder, and a physiologist. When we start to identify markers for disease resistance, we also need a pathologist on board." In marker-assisted selection, markers are identified that are closely associated with the gene for the trait we are interested in; this is what is called 'gene tagging.' In the IHP, microsatellites will be used to tag genes for traits such as drought tolerance, rice yellow mottle virus resistance, and plant growth characteristics. Each of these target traits is believed to be governed by several genes that have an additive effect within the plant. Thus, the alleles concerned are quantitative—that is, each provides some level of the trait—and are known as quantitative trait loci (QTLs). The microsatellites associated with the QTLs then form the basis of the selection tool.

Our other principal partner in molecular biology research for the IHP has been the *Institut de recherche pour le développement* (IRD), France. Marie-Noëlle Ndjiondjop did her PhD research at IRD focusing on resistance to rice yellow mottle virus (RYMV). Strong resistance to RYMV conferred by a single gene has been found in both *O. glaberrima* and *O. sativa*. Molecular markers associated with this resistance have been identified, located on chromosome no. 4. These markers will now be used in a marker-assisted breeding program to transfer the resistance into popular lowland rice varieties from West Africa. Other work at IRD produced a genetic linkage map of an interspecific cross in 1999, showing excellent compatibility with existing maps based on *O. sativa*. An important contribution of the new map was the location of a major sterility gene from *O. glaberrima* on chromosome 6, which was known to exist but not previously localized.

The work at IRD is giving direct benefits to the WARDA laboratory, as Marie-Noëlle Ndjiondjop is the new Molecular Biologist at WARDA.

The future

So, what of the future? Ndjiondjop takes up the story: "The genetic-mapping work is continuing with the generation of a 'mapping population' derived from an interspecific cross. This is essential for identifying markers associated with quantitative trait loci (QTLs). A major problem is the sterility of the first-generation hybrids—with very few seeds being set for us to work with. Several back-crosses are needed to raise the fertility to a useful level. Thus, we are still working on a program of basic interspecific crosses (of course, using the same parent varieties) and back-crossing, as we need to generate about 300 progeny from first back-cross generation by the end of 2000." Anther-culture will be applied to fix the lines after the second back-cross. It is these plants to be generated by anther-culture that will be used in the mapping work.

"Concurrently," continues Ndjiondjop, "we are using the best NERICA lines, as selected and characterized by WARDA scientists, for 'graphical genotyping'." Microsatellites are used to determine the frequency of *glaberrima* alleles in NERICA lines. "In particular, colleagues at IRD have asked us to do a rapid 'graphical genotyping' of one particular NERICA line that is resistant to nematodes." Knowing that the nematode resistance comes from the *glaberrima* parent, IRD scientists are seeking to narrow the search for the resistance gene—they need only search those parts of the NERICA genome derived from the *glaberrima* parent.

WARDA Phytopathologist Yacouba Séré is keen to see progress in the genetic control of RYMV. "With the molecular marker identified at IRD, we are well on our way to generating 'bridging materials'," he explains. 'Bridging materials' are interspecific progenies that carry the RYMV-resistance gene from the *glaberrima* parent. They are used simply because the fertility of crosses between them and target varieties is going to be much greater than that of direct crosses between the *glaberrima* donor and the target variety. "Once the 'bridging materials' are available," continues Séré, "we will start crossing them with popular lowland varieties from the region, especially Bouaké 189." Many varieties that are popular with farmers in West and Central Africa, are limited by their susceptibility to RYMV—"we believe that by introducing that single resistance gene, we can increase the value of these varieties many fold." In addition, the breeding team is looking at transferring the 'IRD gene' into NERICAs that already have QTL-based resistance to RYMV—this 'pyramiding' of resistance genes should ensure that the resistance does not break down in the near future. The newly developed lines will then be tested against the full spectrum of available RYMV isolates under isolated (screenhouse) conditions, before testing in the field at WARDA against the local Ivorian isolate.

Comparison of RYMV-resistant *glaberrima* (left) and RYMV-susceptible *sativa* (right), and NERICA line (middle)

Thus, despite various hiccups along the way, the WARDA molecular biology lab is up and running, and providing valuable input into WARDA's breeding program. "We often talk with some pride about our partnerships," says WARDA Director General Kanayo F. Nwanze. "And 10 years ago, many people might have told us to rely solely on our partners for molecular biology work. But we saw the value in having a level of in-house capacity and facilities, and are now reaping the benefits from that decision. We could not have done this alone, however, and are truly indebted to the partners and colleagues who have helped make this possible."

On the Road to Overcoming Soil Acidity in Upland Rice

SOIL ACIDITY is a major problem in most of the uplands in the humid forest zone, resulting in phosphorus deficiency in growing crops. WARDA is looking at the possibility of using a combination of tolerant rice varieties, rock-phosphate and nitrogen-fertilizer application to enable farmers to improve their rice production in the uplands.

Nearly 70% of the upland rice in West and Central Africa is grown in the humid forest zone. However, the productivity of rice in the uplands of the humid forest is probably the lowest among all the ecosystems in which rice is grown throughout West and Central Africa, averaging about one tonne per hectare. These upland soils are acidic and acid-soil-related infertility is the principal cause of the problem. The acidic components in the soil (aluminum and iron oxides) react with phosphorus and render it unavailable to plants. Since phosphorus is a vital element in plant growth, this effective deficiency in the soil has a direct impact on crop yield.

WARDA Soil Chemist, Kanwar Sahrawat, takes up the story: "if we look at a cross-section of soils in West Africa on a north–south axis, we find that the further south we travel, the higher the rainfall and the stronger the soil acidity. At the same time, we find a decrease in phosphorus in the soil, to the extent that phosphorus-deficiency becomes the most serious soil nutrient problem for growing crops in the humid forest zone." Acidity is a problem in its own right, in that rice varieties that are not tolerant of soil acidity give no yield at all. Farmers' varieties (commonly known as 'landraces') are acid-tolerant because they have been selected over many generations in acid soils. Improved upland varieties are also tolerant of soil acidity, since the breeders have built on the work the farmers started, and the plants are then specifically selected in acidic uplands. It is well known among agricultural researchers and many farmers that nitrogen is almost always a limiting factor in crop production, but in the humid forest of West and Central Africa the soil phosphorus level is so low that the crops cannot respond to the addition of nitrogen fertilizer alone. However, once the phosphorus deficiency is overcome, the crop will respond well to nitrogen fertilizer, which should never be far away from the crop-manager's armory.

"Phosphorus deficiency was known to be a problem in tropical acid soils by the early 1970s," explains Sahrawat. "However, acid soils are also often deficient in other nutrients—calcium and magnesium." In one early experiment, therefore, WARDA investigated the effects of applying these nutrients (along with nitrogen) in various combinations to see what role they play in alleviating the acidity-related infertility of the soil. The results were conclusive: the addition of phosphorus alone or in combination with calcium, magnesium, or both, increased both grain and straw yields of upland rice; however, application of calcium, magnesium, or both, without phosphorus did not increase yields (Table 1). In fact, the addition of the calcium and magnesium to the suite of fertilizers had no greater effect on yields than the application of phosphorus alone.

Other nutrient problems may arise, however, in the longer term. WARDA Soil Physicist Sitapha Diatta explains: "since 1997, we have been studying the effects of long-term rice cropping on soil nutrient reserves. This has confirmed that nitrogen and phosphorus are deficient in the acidic uplands of the humid forest zone. In addition, latest results indicate that potassium may also become deficient in the third season of cropping. In traditional slash-and-burn farming, this wouldn't be a problem, but as farmers are forced to crop the same land for more seasons, and to return to land after shorter and shorter fallow periods, potassium may become a serious limiting factor."

Compare same rice variety receiving Mali rock-phosphate (left) with control receiving no P fertilizer (right) on acidic upland soil. Note reduced tillering (more soil is visible between plants) and fewer panicles of unfertilized plants

It is important for subsistence-oriented farmers to know if they need to add fertilizer to their soils and, if so, how much. A next step was, therefore, to assess the relationship between the availability of phosphorus in the soil and the yield of the rice crop. The experiment was conducted on a soil that had received phosphorus fertilization (in the form of commercially available triple superphosphate) in the preceding season. For each experimental plot, available phosphorus was determined in the laboratory. Owing to the vagaries of acid soils, plots fertilized in the previous season had widely differing levels of phosphorus that was available to growing plants (known

Table 1. Effects of calcium, magnesium and phosphorus fertilization on yield (t/ha) of rice variety WAB 56-50, Ultisol, Man, Côte d'Ivoire, 1994.

Treatment†	Grain yield	Straw yield
Control‡	2.02	2.14
P	3.14	2.99
Ca	2.11	2.43
Mg	2.28	2.86
P + Mg	2.87	2.72
P + Ca	2.79	2.79
Ca + Mg	2.12	2.28
P + Ca + Mg	2.98	2.81
LSD (0.05)	0.364	0.712

† All treatments received 100 kg N and 80 kg K per hectare.
‡ No P, Ca or Mg added.

as 'available phosphorus'). This, however, was a positive aspect and enabled us to calibrate grain yield (in the form of relative grain yield—a percentage of maximum yield achieved) against available phosphorus. The results established a 'critical limit' of available phosphorus (for the varieties tested) at 12.5 to 15 mg of phosphorus per kilogram of soil. If a soil test gives a reading for available phosphorus below this critical limit, the farmer needs to apply phosphorus fertilizer.

"Another indicator for grain yield—and a potentially more accurate one—is the amount of phosphorus actually accumulated by the rice plants," explains Sahrawat. "Therefore, we conducted a series of experiments to relate plant phosphorus content to final grain yield and to measure available phosphorus in the soil." For the plant test, whole plant tops (that is, all of the plant above the ground) were collected at maximum tillering stage, that is when the plants have maximum vegetative growth just before they put out spikes to bear flowers and grains. Like the soil, plants were tested for phosphorus content in the laboratory. Again, results were positive, demonstrating a linear relationship between phosphorus taken up by the crop (as measured at maximum tillering) and final grain yield, and also between plant phosphorus uptake and available phosphorus in the soil (Figure 3). Thus, a relationship was established from available phosphorus in the soil, not just to relative yield, but (through plant uptake) to actual grain yield. This means that the soil test can act as a direct indicator of likely crop yield, and phosphorus-fertilizer requirement.

Towards affordable phosphorus

A serious problem with all this need for phosphorus, however, is the cost of commercial phosphorus fertilizer (triple superphosphate, TSP). The experiment that confirmed phosphorus as the limiting nutrient used some 50 kg of phosphorus per hectare, and other experiments gave even better response with higher rates of fertilization (e.g. 90 kg P/ha). Fertilizer is sold by the sack, each sack containing 50 kg of fertilizer, in this case TSP, but TSP is only 20% phosphorus, so 50 kg of phosphorus would be five sacks of TSP! Each sack of TSP may cost about 10,500 FCFA—that is simply too much investment for subsistence farmers!

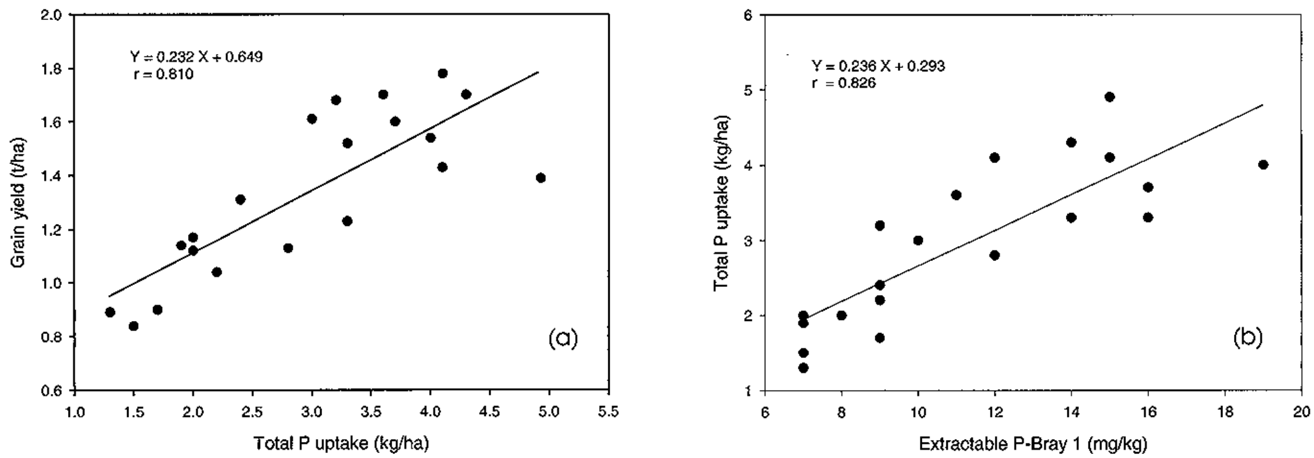


Figure 3. Relationship between grain yield and plant total P uptake (a), and plant total P uptake and extractable P in the soil (b) of four upland rice varieties

"To compound the problem of cost," explains Sahrawat, "there is the fact that TSP is only really effective in the soil for one or two seasons. Our experiments on the soil test for phosphorus availability demonstrated a significant yield response to TSP applied in the first year by the second-year crop, but only as a fraction of the 'immediate' response." By the fourth year, residual effect of applied TSP is negligible, except for plots that received very high doses of TSP (Figure 4). "With these facts in mind," Sahrawat continues, "we started looking for alternative, and potentially affordable, sources of phosphate for use on this rice crop."

Diatta takes up the story again: "we were aware of work on phosphorus-demanding crops in the humid forest, savanna and Sahel zones—groundnut, maize, millet and sorghum—involving the use of local rock-phosphate. These crops give a good response to rock-phosphate applied as a fertilizer." Much of this ground-breaking work had been conducted by the International Fertilizer Development Corporation (IFDC), which is headquartered in Alabama, USA, with an Africa Division based in Lomé, Togo. Rock-phosphate occurs naturally throughout the dry savanna and Sahel zones of West Africa, and IFDC had characterized many of these for their reactivity and solubility in acid soils. In 1997, WARDA established trials to compare the effects on rice yield of rock-phosphate from six sources—Burkina Faso, Mali, Niger, Senegal (two sources) and Togo—with that of TSP. "Plots receiving TSP significantly out-yielded those receiving rock-phosphate," explains Sahrawat. "However, among the rock-phosphate sources, that from Mali gave good results and showed potential as a substitute for expensive TSP." The following year (1998), a trial was established at Man, Côte d'Ivoire, to compare residual effects of a single application of rock-phosphate with that of annual application of TSP. That year, the Mali rock-phosphate treatment performed as well as the TSP treatment (Figure 5). In the second year of the experiment (1999), all rock-phosphate treatments gave significantly higher rice yield responses than in the first year—a clearly demonstrated 'residual effect.'

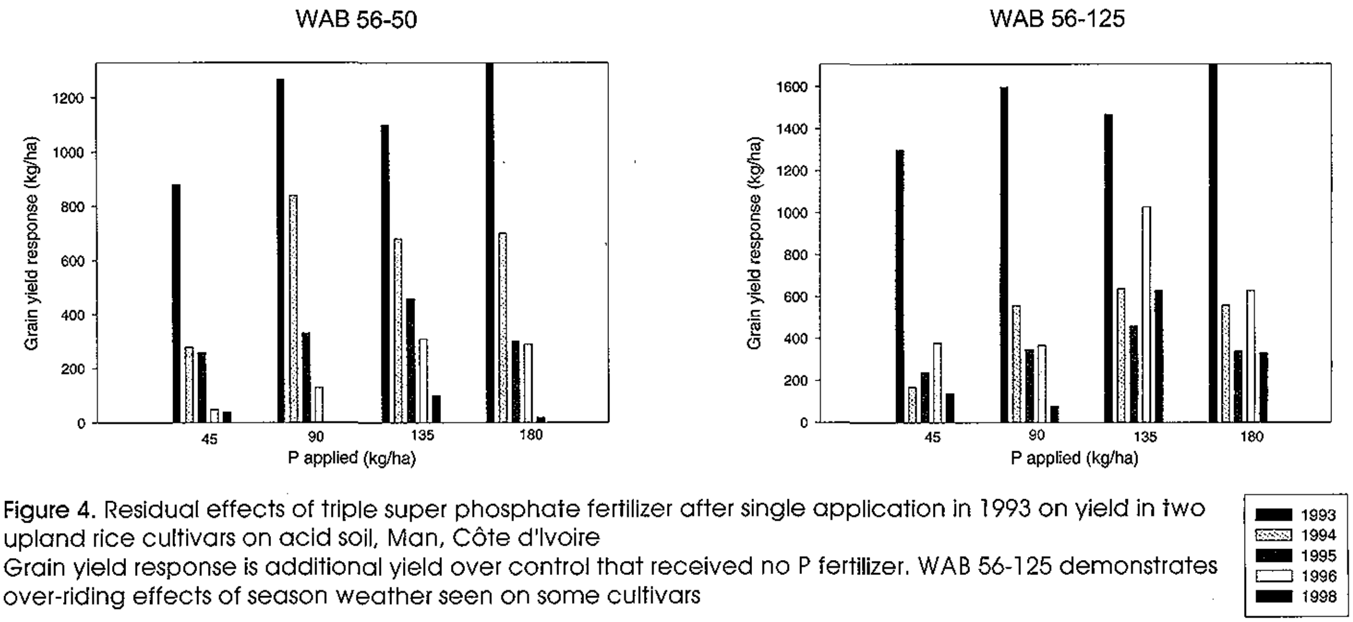


Figure 4. Residual effects of triple super phosphate fertilizer after single application in 1993 on yield in two upland rice cultivars on acid soil, Man, Côte d'Ivoire
Grain yield response is additional yield over control that received no P fertilizer. WAB 56-125 demonstrates over-riding effects of season weather seen on some cultivars

What we are building on—the work of IFDC

The International Fertilizer Development Corporation (IFDC) has a mandate for detailed research and development in soil fertility management. Its headquarters are in Alabama, USA, and there is an Africa Division based in Lomé, Togo.

IFDC has a database containing characteristics of rock-phosphate sources throughout the world, including many from West and Central Africa. Particularly important qualities of rock-phosphate are how easily it reacts with acidic soils, and how soluble it is in such soils. These are used as measures of the appropriateness of rock-phosphate from a particular source being used as a direct-application fertilizer. These data were used earlier in IFDC tests on the use of rock-phosphate fertilizer in drier-zone crops of West Africa, such as groundnut, millet and sorghum. The Mali rock-phosphate that appears promising in WARDA trials has an IFDC designation of 'medium reactive' and, as such, was potentially the most useful source of those tested. "The IFDC ground-work enabled us to target our own research and resources," explains Sahrawat, "but we are working on a crop and environment combination [upland rice in the humid forest zone] that had not been researched by IFDC. Rice reacts very differently to soils and phosphate fertilization than dry-area crops. Compared to the dry-area crops tested by IFDC, rice is acid-soil tolerant and less demanding of fertilizer phosphate; however, it is still responsive to applied phosphate, especially in acid soils."

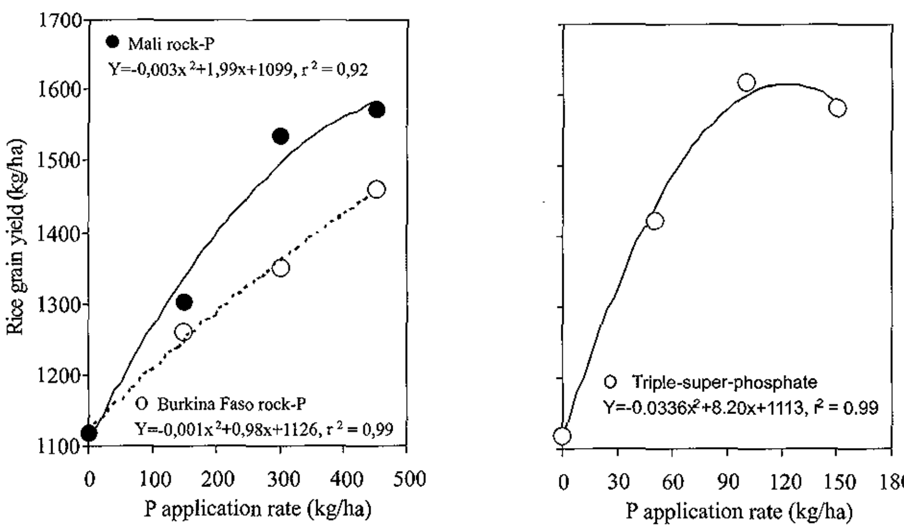


Figure 5. Rice response to rock-P from Mali and Burkina Faso (left) and to triple super phosphate (right) in an acid Ultisol

Sitapha Diatta explains: "rock-phosphate is relatively insoluble, so we are not surprised that, generally, in the first year yields from rock-phosphate fertilized plots fail to match those from plots fertilized with soluble TSP. However, the solubility of TSP works against its potential residual effect, as it can be progressively immobilized by the aluminum and iron oxides that are so common in the acidic soils."

"Chemical reactions are not one-way events," explains Sahrawat, "but rather reactions occur until a state of equilibrium is reached." Thus, in the absence of soluble phosphorus, the acid elements are free to react with the rock-phosphate, slowly but continuously releasing phosphorus. Some phosphorus therefore becomes available for plant nutrition in the seasons following rock-phosphate application. Thus, rock-phosphate looks increasingly like a viable alternative to TSP for rice fertilization in the humid uplands.

Improving acidity tolerance in rice varieties

Alongside the fertilizer management trials, breeders are trying to improve the acidity tolerance of available varieties. Three of the four varieties used in the soil- and plant-test diagnostic trials were WARDA-bred materials, which are more acid-tolerant than the local traditional variety IDSA 6. These improved rices have formed the basis for assessing the performance of WARDA interspecific hybrid progenies (recently dubbed NERICA for *NE*w *RI*Ce for *A*frica). "The interspecific hybridization project was initially established to develop new plant types for the uplands," explains upland-rice breeder and Rainfed Rice Program Leader Monty Jones, "so we should not be surprised to find the

NERICAs doing well on acidic, phosphorus-deficient soils in the humid forest zone." At the acidic Man site in Côte d'Ivoire, 15 NERICAs gave an average yield of 1.16 tonnes per hectare without phosphorus fertilizer, compared to 0.89 t/ha for the best *Oryza sativa* variety. In fact, the best NERICA gave a staggering 2.9 t/ha *without application of phosphorus*! In 1999, two NERICAs gave grain yields in excess of 3 t/ha in unfertilized soil at Man. One of these is scheduled to be one of the first NERICAs to be officially released in the region—NERICA 1 [= WAB 450-I-B-P38-HB] in Côte d'Ivoire in 2000.

"What we really want is to encourage farmers down the road of development," explains Monty Jones. "First, we need an acidity- and low-phosphorus-tolerant variety that will increase farmers' yields, and therefore their incomes. But then we want to encourage them to take the next step—applying fertilizer. Thus, we want varieties that perform well under no inputs, but then respond positively to inputs when the financial status of the farmer allows their use." Accordingly, WARDA is also testing the response of the acidity-tolerant NERICAs to applied phosphorus. In 1999, again at Man, four NERICAs were tested for their response to phosphorus application in the form of both TSP and Mali rock-phosphate. And the good news—all four NERICAs responded positively to rock-phosphate application, one of them even giving a linear response to application of up to 450 kg P/ha (Figure 6). What's more, the yields of these NERICAs were higher than those of the traditional check at all levels from 0 to 450 kg P/ha.

Outstanding questions

So, it can be seen that we are developing a three-pronged approach to the soil-acidity related infertility problem in upland rice in the humid forest zone. We are developing varieties that are tolerant to both soil acidity and phosphorus deficiency, but that are also responsive to the addition of phosphorus once farmers can afford to buy it. Then we are working towards a long-term phosphorus-fertilizer strategy involving local rock-phosphate, possibly with the use of TSP in the first year of rice cropping. After that, we may be in a position to refine nitrogen-fertilizer recommendations to improve the benefit–cost ratio of upland rice farming further.

"We are well along the road," Sahrawat cheerfully explains, "but we still have a long way to go. So far all this research has been an academic exercise to examine the possibilities, but we are still a few years off from making concrete recommendations to farmers." Results from on-going trials—which may be available as soon as the end of 2000—should determine once and for all the agronomic viability of rock-phosphate as a fertilizer for upland rice, then we will have to seriously look into the socio-economic aspects. Rock-phosphate is available in large quantities in the northern Sahel and dry savanna zones of the region, but it is needed in the southern humid forest. To date, Mali rock-phosphate has not been commercially exploited as a fertilizer, so there are outstanding questions of logistics. Can the rock-phosphate be formulated where it is mined into a product that is both easily transportable and immediately usable on the farm?

The only rock-phosphate available commercially in Côte d'Ivoire comes from Senegal, and is distributed by a company in Abidjan—a fortunately suitable center for distribution to the humid forest zone. The other rock-phosphates used in the WARDA experiments were carried in from their sources. "In our experiments," explains Diatta, "we used powdered rock-phosphate. However, this has several disadvantages. First, it is bulky and difficult to transport. Second, and perhaps more importantly, it is labor-intensive to apply—application by hand results in the farmer being covered with white dust, so it is better if the powder is first mixed with humid soil and then applied. It can take a whole day to fertilize one hectare, but then again, we are not talking about an annual event! We believe that it should be possible to formulate the rock-phosphate as granules." These would be both easier to transport and easier to apply.

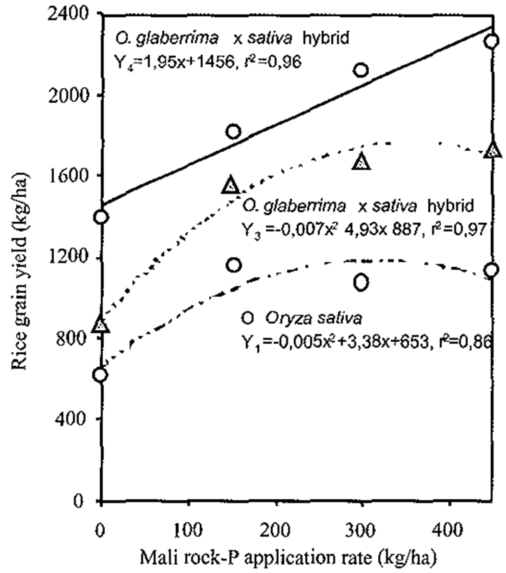


Figure 6. Response of two NERICA rice varieties and control to Mali rock-phosphate in humid forest acid soil

Once we have a suitable formulation, transport costs will then determine the viability of using the product as proposed. If transport costs are too high, farmers in the humid forest will not be able to afford the rock-phosphate, and therefore will not use it. We believe that rock-phosphate fertilizer made and distributed within the region will be much cheaper than imported fertilizers like TSP. But TSP is so expensive, that it remains to be seen whether a mechanism can be found to make the rock-phosphate product available at a cost affordable to resource-poor farmers.

Future avenues

"Our studies are far from complete," says Diatta. "One thing we need to do is to study plant uptake of phosphorus from fertilizer rock-phosphate in much the same way as we calibrated yield to plant uptake with TSP. A further avenue is the possibility of P-32 isotope analysis to determine the rate of immobilization of soil phosphorus fixation by the action of aluminum and iron oxides." WARDA does not have the facilities for this work, but Diatta has contacts in France with whom he hopes to collaborate on this work.

The first on-farm trials with rock-phosphate will take place at three sites in Côte d'Ivoire (humid forest and savanna zones) in 2000. These will be an addition to the ongoing participatory varietal selection program (*see* 'New Rice for Africa... with a Little Help from our Friends' in this Report) and will involve 25 farmers at each site.

Another potential avenue for the future is to combine our agronomic work on fallow-replacement legumes into the 'package.' Using legumes in place of natural (weed) fallow has the double benefit of reducing the weed population and not depleting the nitrogen reserves of the soil. In fact, if a cover-crop legume is used and the whole crop plowed back into the soil, the legumes actually replenish the soil's nitrogen, reducing the need for nitrogen fertilizers (*see WARDA Annual Report 1998*, pages 36–37). "Even what nitrogen is held in the leaves can improve soil nitrogen status," explains Diatta. So, he is looking into the possibility of starting rotation trials with cowpea—the seeds of which can be harvested for food—in the 2001 season.

A Holistic Approach to Irrigated Rice Farming Problems Uncovers More Than Just Soil Degradation

AT FIRST sight, Foum Gleita in southern Mauritania is an ideal place for irrigated rice farming. But less than ten years after the construction of a dam to provide the necessary quantity of water, farmers were complaining of salinity problems and abandoning fields. A WARDA scientist came across the site in 1996, and decided it would make an ideal field-laboratory for soil-degradation studies, but first they had to gain the farmers' confidence by looking at the problem as they perceived it.

Background

The dam across the Gorgol River, constructed with funding from a variety of donors (including the World Bank) in 1984, created a large artificial lake with a normal retention capacity of about 500 million cubic-meters of water. This enables gravity irrigation of the land downstream, and the gentle land slope (1–2%) equally allows for gravity drainage back into the river. By 1989, the infrastructure was in place to irrigate some 1950 hectares of land for rice cropping. Initially, yields were reasonable (4.6–5.2 tonnes per hectare), but declined rapidly to 2.7–4.6 t/ha in 1992–1996. By 1993, some 237 ha had already been abandoned by farmers.

In 1996, a joint WARDA/ORSTOM (*Institut français de recherche scientifique pour le développement en coopération*, now *Institut de recherche pour le développement*, IRD) mission looking at salinity and alkalinity problems in the Senegal River valley arrived at the site to find the local extension service (*Societé nationale pour le développement rural*, SONADER) eager for partners to help them resolve the problems that the local farmers were facing. "Foum Gleita irrigation water contained positive calcite residual alkalinity—a sign that soil degradation may occur upon concentration in the root zone," explains Marco Wopereis, WARDA agronomist and member of the 1996 mission. "We decided that the site may be a useful field-laboratory for studying the processes of soil degradation in general, and alkalinization in particular." The hypothesis was that the concentration of alkaline water may lead to faster degradation of the soils of Foum Gleita than at other sites along the Senegal River valley, and that the site may act as an early-warning system of what might occur elsewhere in the longer term.

With this in mind, the UK Department for International Development (DFID) is funding a three-year project to determine the extent of the degradation problem, and the principal degradation processes, to establish and provide training to the extension service on a system for monitoring soil and water quality, and to develop low-cost alternative land and water management options tailored to the farming context (*see* Box).

The DFID Soil Degradation Project

International organizations

- West Africa Rice Development Association (WARDA/ADRAO)
- International Water Management Institute (IWMI)

National research institutes

- *Centre national de recherche agronomique et de développement agricole* (CNRADA, Mauritania)
- *Institut de l'environnement et des recherches agricoles* (INERA, Burkina Faso)

Extension services

- *Société nationale pour le développement rural* (SONADER, Mauritania)
- *Autorité de Mise en Valeur de Vallée de Sourou* (AMVS, Burkina Faso)

What the farmers said and what the researchers thought

At a workshop in June 1998, farmers complained that the areas north of the Gorgol River were degraded (most of the abandoned fields were north of the river), and that soil salinity was a major constraint to rice production. They felt a strong need for immediate solutions to this problem from the researchers. However, at the same time, they were highly skeptical of researchers in general—previous research into the soil degradation problem at the site had neither involved them personally nor yielded any concrete results that either extension or farmers could understand.

Researchers and extension workers from WARDA and Mauritania took a more holistic view, however. Although salt patches were observed on the soil surface, it was not at all clear that salinity was actually the principal constraint facing rice production, but it could easily become so in the future. In either case, soil degradation by alkalinization is a long-term process, and researchers would need more time to achieve practical results than it appeared the farmers were prepared to give them. Thus, WARDA decided to look at the farming practices at the same time, with a view to making recommendations for improving production in the short term.

Work elsewhere showed that the alkalinization process is practically irreversible, and can severely affect yields. Alkalinity occurs as a result of the build-up of carbonate salts in solution, especially in relation to relatively low concentrations of calcium and magnesium (*see* Box).

Researchers follow clues along the way

Thus, the research became broad based, looking at two themes at the same time: soil degradation and farming practices.

A first step was to map salinity throughout the scheme by means of a tool (known as EM38) that does not require soil sampling and extensive laboratory studies—this mapping was conducted in collaboration with the *Centre national de recherche agronomique et de développement agricole* (CNRADA) and SONADER. The study revealed that soil salinity was in fact very low at Foum Gleita, and that abandoned soils were not necessarily those with the highest salinity. A surprisingly poor relationship was found between EM38 and laboratory salinity tests of the same soils. The reason for this was discovered by our partners at IRD: precipitated minerals, such as calcite, did not affect the EM38 readings since they were not in solution in the soil, but the laboratory process redissolved much of these minerals, giving higher salinity readings. The lab tests revealed alkalinity in the Foum Gleita soil, but not to the same extent as that found in the Office du Niger scheme in Mali, where good rice production is still achieved. Thus, we were a little skeptical of the farmers' assertion that salinity was their major production problem.

Next, WARDA Sahel staff applied their standard suite of farming-practice tools to the situation in Foum Gleita. They monitored farming practices 'on the ground'; conducted nutrient-omission trials on both 'good' and 'problem' soils, in which nitrogen, phosphate or potassium are deliberately not applied to individual experimental plots to

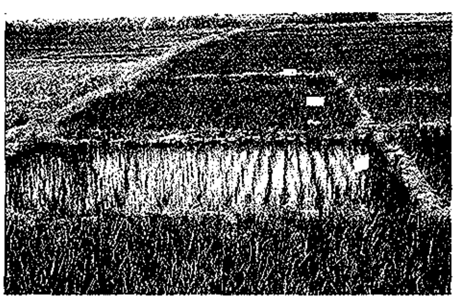
What is alkalinization?

Although both are associated with what we term salts, the processes of 'salinization' and 'alkalinization' are qualitatively different: salinization occurs in the presence of sodium chloride and calcium sulfate with minimal carbonate ions, while alkalinization is a result of high concentration of carbonate ions in relation to calcium and magnesium.

All the main Sahelian rivers have a positive calcite residual alkalinity. Soils that are relatively rich in calcium can buffer irrigation-water alkalinity. However, if soil leaching (that is, flushing out of salts by the irrigation water) is insufficient, and no preventive measures are taken, this buffering capacity will eventually run out. Eventually, the soil solution will consist mainly of carbonate and sodium ions, leading to an increase in 'exchangeable sodium percentage' (sodication), and a rise in pH (alkalinization). Sodication eventually destroys the soil's structure, resulting in an impermeable mass, like concrete. Although rice can still cope to some extent with such unfavorable soil properties, other non-flooded crops cannot. The complexity of alkalinization and sodication makes them difficult to recognize. In addition, the processes are rather irreversible in practical terms, because of the costs involved in adding acid and gypsum in combination with heavy machinery needed to plow these products into the soil. For this reason it is essential to monitor alkalinization (and sodication), so that we can intervene before sodication destroys the soil structure. The advantage of the Foum Gleita site is that the initial alkalinity readings were three times the average of the Senegal River valley, so alkalinization will occur here much earlier than it will in the larger valley. Thus, we can use Foum Gleita as a field-laboratory for what might happen on a wider scale in the future.

To make matters worse, increasing alkalinity reduces the solubility of phosphate, and this too is lost from soil solution. This is the major cause of poor rice performance in Foum Gleita, where no phosphate fertilizer is normally added to the crop.

In the nutrient-omission trials, a no-phosphate treatment (center) stands out clearly among the others



determine their relative importance; and conducted trials to determine the efficiency of farmers' fertilizer regimes, by leaving small plots within farmers' fields unfertilized (known as T0 plots—see *WARDA Annual Report 1998*, pages 18–19). In addition, variety trials were conducted to see if there were varieties available that would perform better under farmers' management than their existing varieties. At various times during the season, the SONADER extension agents gathered groups of farmers to assess the trials.

As expected from our initial skepticism, the potential for rice production in Foum Gleita is a lot higher than one would assume from the farmers' performance, and a whole series of management practices contributed to the low yields achieved there. Farmers used poor-quality seed, and took little care of the seedbed. Land preparation (or soil tillage) prior to transplanting was either minimal or completely absent. Phosphate fertilizer was never applied, and nitrogen fertilizer poorly managed. Both sowing and transplanting were carried out rather later than at the optimal time. Transplanting itself was poor, both in terms of depth and spacing between plants. The rice fields were not drained when the grains matured, and harvesting was delayed and took a long time (up to one month)—resulting in loss of grain and quality. However, when comparing soil

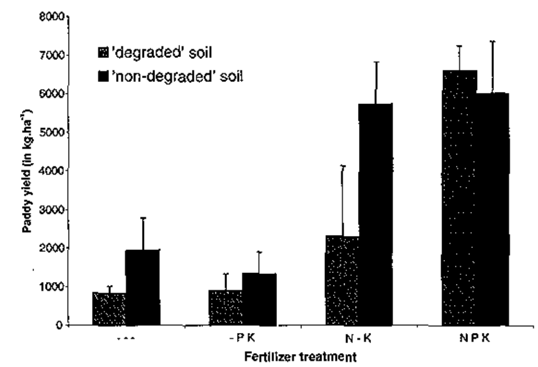


Figure 7. Nutrient-omission trials, dry season 1999: Not applying phosphate to 'problem' soils renders other management practices effectively useless—farmers normally achieve in excess of 2 t/ha with their current practices

Rice seedlings are often transplanted by young children, who are paid on an area basis (about US$ 15 per hectare)—this leads to sloppy work, with plants being placed too far apart and not properly imbedded in the soil. Note also that there was no prior land preparation

and lab tests with rice performance in the fields, there was a clear relationship between the level of soil alkalinity and rice grain yield: the higher the alkalinity, the lower the yield. But the experience in the Office du Niger scheme suggested that the levels of alkalinity in Foum Gleita could not account directly for this yield loss, so what is going on?

The answer lay in the results from the nutrient-omission trials, where even with optimal management of other fertilizers, experimental plots on 'problem' soils without phosphate fertilizer gave yields close to what the farmers achieved (Figure 7). It was already known from elsewhere that phosphate and zinc can become deficient—that is, inadequate to support plant growth—in alkaline soils. Moreover, during one field-visit meeting of researchers, extension agents and farmers' cooperative leaders, the farmers were asked to indicate the location of the 'problem' soils on a map. When this was compared with an earlier soil map prepared for SONADER, there was a clear link between farmer-perceived 'problem' soils and research-determined shallow (less than about 80 cm deep) soils. Graphical representation of these fields in terms of topography (that is, position on the valley slope and depth of soil) showed a clear relationship with yield in unfertilized (T0) plots and that in farmers' fields (Figure 8).

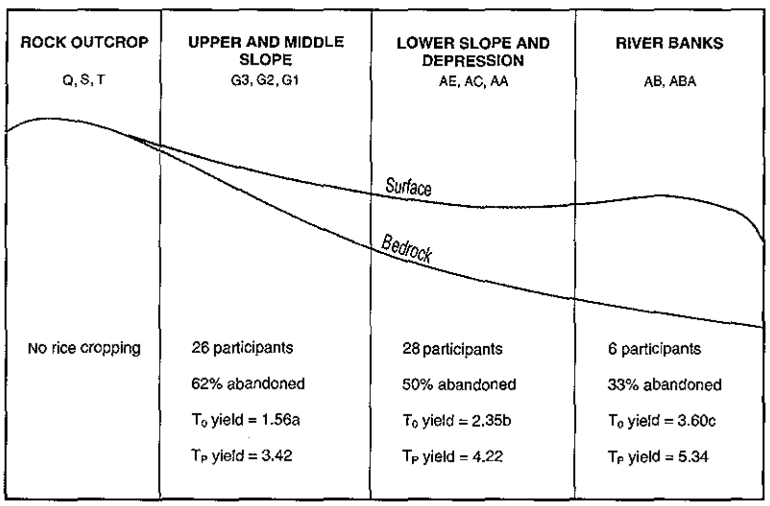


Figure 8. Toposequence diagram showing farmers' performance (% farmers abandoned, Tp and T0 yields) as a function of topographic position and soil depth.

Subsequent detailed soil analysis revealed that alkalinity increases within the soil as one approaches the bedrock. It is this schist bedrock (or parent rock) that is the source of the carbonate, which is released by water action into the adjacent soil. In the shallower soils, the alkalinity is clearly much closer to the plant roots, and results in the phosphate-deficiency problems that depress rice yields.

Despite all this, however, very few of the soils at Foum Gleita would warrant classification as 'degraded' according to internationally recognized scales. At an end-of-season workshop for sharing the research results with farmers, WARDA researchers emphasized the importance of improving farming practices as the route to improved rice production (*see* Box).

Changing perceptions and their scientific and socio-economic bases

In the dry season of 1999, SONADER agents again monitored farmers' practices and additionally asked them to rank constraints to production in order of importance. Overall, farmers no longer consider salinity as a very important problem, although the average across the various soil-types masks the views of those farming on 'problem' soils, who continue to see salinity as a problem. After bird damage, the availability of fertilizers is the major production constraint. This is well known to WARDA, as phosphate fertilizer is rarely available to farmers in Mauritania—perhaps because it was never part of the old 'blanket' fertilizer recommendations, and therefore farmers could never obtain credit from the bank to buy it.

Farmers claim to be sufficiently aware that their farming practices are not optimal, but blame external forces such as the availability of credit (to buy inputs—seed, fertilizer), phosphate fertilizer, and labor for their inability to improve the timing of various activities (sowing, transplanting, fertilizing).

Researchers also blame the majority of the problem on suboptimal management practices and acknowledge the importance of external factors, such as the availability and

Recommendations for improving rice production at Foum Gleita

In a way, WARDA has now 'done its job' for the extension services and farmers at Foum Gleita. All they now have to do to improve their farming system is to implement the following practical recommendations—but they still face numerous constraints, some of which are not under their control.

- Seedlings should not be left in the nursery too long, but rather transplanted while young and vigorous.
- Fields should be tilled in advance of transplanting.
- Transplanting requires better management, particularly in terms of plant spacing and secureness within the soil.
- Fertilizers need careful management, in particular phosphate needs to be applied and the timing and dosage of nitrogen needs better control—minimal improvement in production is possible on the 'problem' soils without the addition of phosphate (see text for problems with phosphate availability); once that is resolved, proper management of nitrogen can increase yields still further, as it already will on the 'good' soils.
- Fields should be drained before harvest, and then should be harvested soon after maturity and quickly.
- The adoption of new varieties could increase yields by a further 10–25%.

Comparison of farmer's practice (foreground) with trials demonstrating improved management—farmers were clearly falling far short of potential price of inputs. However, they also attribute low yields to lack of knowledge on the part of the farmers themselves, in addition to poorly organized farmers' cooperatives. Researchers do, however, recognize the potential of the alkalinization problem getting worse—therefore, strategic research is needed to monitor soil degradation. Equipment has been placed in various fields to monitor water movement and properties as part of the long-term research.

Moctar Ould Isselmou, formerly *Chef Service de Vulgarisation* (that is, in-charge of the extension activities) at Foum Gleita, and now *Chef Service Vulgarisation et Recherche en Milieu Paysan* (Head of Extension Services) for SONADER as a whole, sees the current problem mainly as one of finances. "Initially, we had a World Food Programme 'Food for Work' program in place, whereby farmers of the various cooperatives maintained the irrigation canals, for which they were given food and also earned a reduction in their contribution to SONADER for scheme upkeep." Primary and secondary canals are shared among cooperatives, but are managed by SONADER—a service for which the cooperatives have to pay, if they want SONADER to release water from the secondary canals into their fields. With the abrupt removal of the 'Food for Work' program (in 1992), farmers are no longer motivated to do their bit in canal maintenance.

Moctar again: "When we had external funds, SONADER bought the seed and fertilizer for the whole scheme, and farmers paid us back out of their profits. Now they have to buy these inputs commercially and pay for them at the time of receipt, as well as paying their contribution to SONADER for scheme upkeep." The cooperatives have major problems coordinating the payments: many farmers pay their contributions late, so the season starts late, with subsequent loss of yield. Some farmers also delay paying back their bank credit, so cannot draw further credit for buying inputs. The compounded effects of lack of credit and unavailability of fertilizers conspire to delay the onset of the cropping season still further. So, "SONADER created a Union among the farmers' cooperatives to manage the scheme as a whole, including the finances," explains Moctar. "The money paid to SONADER (*redevance*) for scheme maintenance is kept in a bank account, to which the regional director of SONADER and the president of the farmers' union have equal access." It remains to be seen how effective the union will be in helping to manage these funds.

What of the future?

Thanks to the careful inclusion of farming-practices research into the project, WARDA and its partners have been able to give short-term advice (recommendations) to the rice farmers at Foum Gleita, and have thereby gained the good reputation of being the first researchers to visit the site and to have come back with some useful information—remember how skeptical the farmers were in 1998? This now gives us the opportunity to use the site for longer-term strategic research on soil-degradation processes associated with alkalinization—an opportunity we would otherwise not have had. Salt and water monitoring equip-

SONADER no longer has financial resources for automatic mechanical weeding. The use of herbicides or emptying (drying) the canals is not possible as the water is also used for domestic purposes. The few farmers who can swim are paid to manually weed the canals. The *tipha* is cut just below the water line—vigorous regrowth means that the measures normally only last for a short period (few weeks/months).

The Sourou Valley—The other half of the DFID project

Foum Gleita comprises only half of the WARDA–DFID soil-degradation project. The other half is based in the Sourou Valley in Burkina Faso. Soma Etienne Barro is a soil scientist based at the Farako-Bâ station of the *Institut de l'environnement et des recherches agricoles* (INERA), and is principal contact for the project in Burkina. "The first rice scheme was established in the Sourou Valley in 1985," explains Barro, "when an area of 50 ha was brought 'on line'." INERA became involved in 1995/96, when the local extension service (*Authorité de Mise en Valeur de Vallée de Sourou*, AMVS) contacted them and WARDA because farmers were complaining of salinity problems, and abandoning fields—sounds familiar? By that time, some 3000 ha were under irrigation, and the majority of the abandoned fields were in the oldest blocks. Here in the Sourou, however, low productivity was associated with patchiness of rice performance in the field, and there were calcareous (calcite) nodules in the soil. "Even before the DFID project," Barro continues, "we were in contact with Marco Wopereis at WARDA." Together, they decided to monitor farmers' practices, with INERA taking the lead—the Sourou Valley is a long way from WARDA's Sahel Station, even after a flight into Burkina. "We identified a great diversity among farmers' practices," says Barro, "with very few adhering to local recommendations, and all short of optimal. We believed that this was sufficient to explain part of the yield loss we saw in the field, but the farmers disagreed with us both on the classification of their practices as 'sub-optimal' and on our belief that they contributed to the yield loss."

At the start of the project, the researchers looked at the pockets of low productivity in the farmers' fields. They found that some were highly calcareous (that is, rich in calcite) and some had drainage problems. "During a field visit, farmers asked us to find a solution," continues Barro, "but first we wanted to know their own experience." Farmers said that they achieved partial relief from the problem by applying organic matter to the fields, but this only lasted for one season; they also obtained short-term relief by removing the calcareous nodules. The objectives of the project at Sourou were effectively the same as those at Foum Gleita. "However, on the basis of the farmers' reports, we decided to conduct a series of organic-matter trials," says Barro. "We tested the effects of manure, compost and straw on both rice performance (yield) and soil chemistry." Both manure and compost improved crop yields, but straw had virtually no effect. "There are two possible explanations for the effect of manure and compost. First, they may be altering soil chemistry, and enabling the binding of carbonates, so that they no longer create an alkalinity problem. Or second, they are simply providing nutrients that the plants can take up." Plant and soil samples are being analyzed, but "we suspect that there may be some nutrient-deficiency problem, possibly either zinc or phosphate." Piet van Asten favors the former option, "it seems very unlikely that phosphate is a problem," he says, "as all rice farmers in Burkina already apply adequate amounts of phosphate fertilizer to their crops, so I guess we will find that zinc is limiting here."

Unproductive patches are common in farmers' fields in the Sourou Valley. They may be associated with calcareous deposits and/or drainage problems. The higher productivity near the field bunds is an indication of a possible nutrient-deficiency problem—plants near bunds suffer less competition for nutrients

Other preliminary work included finding and interpreting old soil maps of the valley for possible clues; sampling of water from irrigation and drainage canals and wells for analysis; sampling of soils from productive and unproductive pockets in farmers' fields; and rapid EM38 salinity testing. So far, there is no clear salinity problem. Both water and soil are slightly alkaline, however, suggesting a similar problem to that in Foum Gleita, and the possibility of longer-term soil degradation. "If this is a nutrient-deficiency problem," says Barro, "is it that there are not enough nutrients in the soil, or are such nutrients being blocked by, for example, alkalinity?"

Samples from soil profiles (to monitor changes in soils with depth) have revealed increasing concentrations of calcareous nodules below 30 cm. These nodules have hard centers, and are soft on the outside—but whether they are dissolving in the soil to release carbonates and increase alkalinity, or whether they are being deposited by precipitation of calcite from the soil is as yet unclear.

Other problems are abundant in the Sourou Valley soils—for example, nematodes—but these do not seem to be related to the unproductive pockets. Farmers complain about the abundance of earthworms, which pile soil up at the base of the rice plants and reduce tillering. A pathological survey found a lot of plant disease, but again nothing specifically associated with the pockets.

Nutrient-omission trials are being started in 2000 to run for at least two seasons, especially to look at the role of phosphate and zinc fertilizers, but also including a treatment with nematicide. Monitoring of farmers' practices will continue, and the earthworm situation will be monitored and assessed. "Maybe in the next year, we will start to test the water and salt balances, and install piezometers to monitor the changes in groundwater depth," concludes Barro.

Moctar Ould Isselmou (second from left) and Soma Etienne Barro (third from left) look at screened trials at WARDA's Sahel Station with Marco Wopereis (left) and Piet van Asten (right)

ment is now in place in various fields (on both 'good' and 'problem' soils) and water quality is monitored throughout the scheme by SONADER, which has installed a small laboratory there, paid for by project funds. "We need about one more year to gather data on groundwater quality and water and salt movements," explains Piet van Asten, Dutch associate soil scientist handling most of the WARDA end of the DFID project, "and then we will move into modeling to determine just how important the alkalinization process is likely to be at Foum Gleita in the long term." Thus, with continued good-will from both farmers and SONADER, there is still the possibility of using Foum Gleita as a field laboratory for what might happen elsewhere.

The original plan was for the scheme to cover a total of 3600 hectares. The knowledge gained to date through the DFID project—that shallow soils are most affected by degradation—will serve as an important guideline for the positioning of further irrigation infrastructure once any such expansion goes ahead.

"This year (2000), SONADER will help the Foum Gleita farmers' union to work together with the Kaédi and Boghé unions to buy inputs (certified seed, phosphate and urea fertilizers) in bulk," says a positive-looking Moctar. "This should enable the farmers to have their inputs both cheaply and well before the start of the wet-season campaign."

Perception is Reality

PERCEPTION molds people's reactions to the world around them. In West Africa, the perceptions that communities have of the potentially deadly disease of schistosomiasis make it particularly challenging for prevention programs to be implemented successfully.

Wetland water management and irrigation schemes are thought to make vector-borne disease endemicity worse in West and Central Africa. The development and promotion of wetland, or irrigated, rice cultivation has been restrained because of such health concerns. However, with the rapidly growing consumer demand for rice in the region and the limited options for intensification of upland areas, wetland rice development becomes a major focus for agricultural policy-makers and farmers. Inland valley bottoms in West and Central Africa represent approximately 50% of the agriculturally available wetland area (375,000 to 842,910 km^2).

The Human Health Consortium brings together six multidisciplinary West African research institutions (*see* Box) to evaluate the health and social impacts of various degrees of wetland water management and irrigation in the humid rain-forest, savanna and Sahel zones. This work is conducted with a view to providing relevant information to planners and policy-makers. The Consortium focuses on two major vector-borne diseases—malaria and schistosomiasis. Results are to be used to develop environmental management strategies that will minimize the health risks related to land use. We have previously looked at malaria ('Rice Cultivation: Kill or Cure?' *WARDA Annual Report 1996*, pages 27–31); this year we turn to schistosomiasis.

The Human Health Consortium

National Institutions

Côte d'Ivoire

- *Centre universitaire de formation en entomologie médicale et vétérinaire* (CEMV), Bouaké
- *Institut Pierre Richet* (IPR)/OCCGE, Bouaké
- International Development Research Centre (IDRC, Ottawa)

Mali

- *Faculté de médecine, de pharmacie et d'odonto-stomatologie*, Malaria Research Training Centre, DEAP, Bamako
- *Institut d'economie rurale*, Niono/Bamako
- *Institut national de recherche en santé publique*, Bamako

International Institutions

- West Africa Rice Development Association (WARDA/ADRAO)
- World Health Organization Panel of Experts on Environmental Management for Vector Control (WHO-PEEM)

Donors

- Denmark (DANIDA)
- IDRC
- Norway

Targeted funds for the Health Consortium were provided from May 1994 to June 2000, during which period the objectives were accomplished. Health-related research continues at WARDA on the nutritional impact of NERICA varieties on farm families, especially children.

The disease

Schistosomiasis, also known as bilharziasis, is the second most common parasitic disease in the world after malaria. It is estimated that some 200 million people in 76 developing countries are infected world-wide. Of these, about two-thirds show symptoms, and about 10% (that is, about 20 million people) will suffer serious, debilitating disease—80% of all cases occur in Africa.

The disease-causing organisms develop alternately in humans and aquatic snails. Snail-infective parasites are excreted in human feces and urine, and human-infective parasites are released in millions from infected snails. Thus, the disease is prevalent where people are in frequent contact with snail-infested water. The snails require vegetated banks of lakes and slow-moving rivers to live in. It is not surprising, therefore, that there has long been concern over the role of agriculture in general, and irrigated rice farming in particular, in increasing the incidence of schistosomiasis.

The alternate hosts of schistosomiasis are tiny aquatic snails (left), which favor still or slow-moving water with plenty of vegetation (below)

Impact of human activity

People depend on water to live; they also alter their environment to meet their needs—rather than adapting to their environment, which is what most other forms of life do. People use water sources for drinking, cooking, washing and recreation, and how they manage their water resources can have a major effect on the incidence and spread of schistosomiasis. For example, we have stated that snail-infective schistosomes are excreted in urine and feces, so if a community allows its members to urinate or defecate near snail-infested water, the disease cycle is going to be continually refueled. Conversely, if these activities are kept away from the water source, the supply of snail-infective organisms should be significantly reduced.

Conditions 'on the ground'

Although schistosomiasis has the potential to be a problem in most rice-growing areas of West and Central Africa, we find that the situation in each ecology is primarily influenced by how people behave in the vicinity of water. The prevalence of schistosomiasis is high in both the Sahel and the forest zone. In the Sahel, the disease is (probably correctly) seen as a direct result of irrigation practices introduced in the 1970s. This has particularly been the case in the *Office du Niger* scheme of Mali, where development agencies were blamed for schistosomiasis 'epidemics' when they developed and rehabilitated the irrigation infrastructure. As a semi-desert habitat, the Sahel has very little standing water, except for irrigation schemes, so these are the very areas where snail populations build up and people congregate to collect essential water supplies.

In the forest zone, there is plenty of slow-moving and standing water. Here schistosomiasis is associated with sites where commonly used pathways traverse streams and slow-moving rivers. It is here that human–water contact is at its greatest in this zone. Overall, about 70% of the population is affected, with very high worm-loads in infected individuals, but it is difficult to show any effect of wetland rice farming in increasing disease prevalence. Rice fields themselves have no floating vegetation for the snails to live in, but irrigation infrastructure may provide suitable snail habitat. We found large differences in prevalence rates in school children between villages, both within and across rice-cropping systems—for example, 0–51% for *Schistosoma haematobium*, and 4–77% for *S. mansoni* (*see* Table 2)—but these could not be linked to the size of rice cultivations in village perimeters in inland valleys nor to the cropping system (single or double cropping) used.

In strong contrast to the situation in these habitats is the situation in the savanna. Here, communities are far more conservative in their toilet habits. So, despite the existence of more water than in the Sahel, the only major risk group are the children who swim. Again, we observed large differences in disease prevalence rates between villages in similar habitats, indicating no simple link between rice cultivation system and disease prevalence (*see* Table 2). Irrigation schemes established in the early 1970s seem to have had no effect on the disease burden of the communities using them—in both single- and double-cropped areas, schistosomiasis-infection prevalences are low, with low parasite counts in infected individuals. Conversely, populations with access to dammed lakes tend to be

Recreational use of water makes for high risk of schistosomiasis infection, especially in children

Table 2. Prevalence of schistosomiasis in school children in the forest and savanna zones of Côte d'Ivoire.

Zone	Rice system†	No. villages	*S. haematobium* prevalence (%)		*S. mansoni* prevalence (%)	
			Mean	Range	Mean	Range
Forest	R0	7	1.7	0.4–4.9	17.5	3.7–50
	R1	7	4.4	0–51.2	46.6	16.7–65.1
	R2	7	0.9	0–2.6	61.3	20.3–77.2
Savanna	R0	8	0.7	0–2.2	2.1	0–6.3
	R1	8	2.3	0.5–6.2	11.9	1.5–26.9
	R2	8	4.8	0–30.8	16.1	4.9–38.3

† R0 = villages without rice cultivation; R1 = villages with one rice crop per year, in inland valleys with no or partial water control; R2 = villages in inland valleys with partial or complete water control that permits two or more rice crops per year.
Data from individual villages were subjected to angular transformation, one-way ANOVA and then Scheffé's posthoc test for multiple comparisons. (1) In both zones, there was no significant difference between cropping systems for *S. haematobium*. (2) For both zones, *S. mansoni* prevalence in R0 was significantly (α= 0.05) lower than that in R1 and R2.

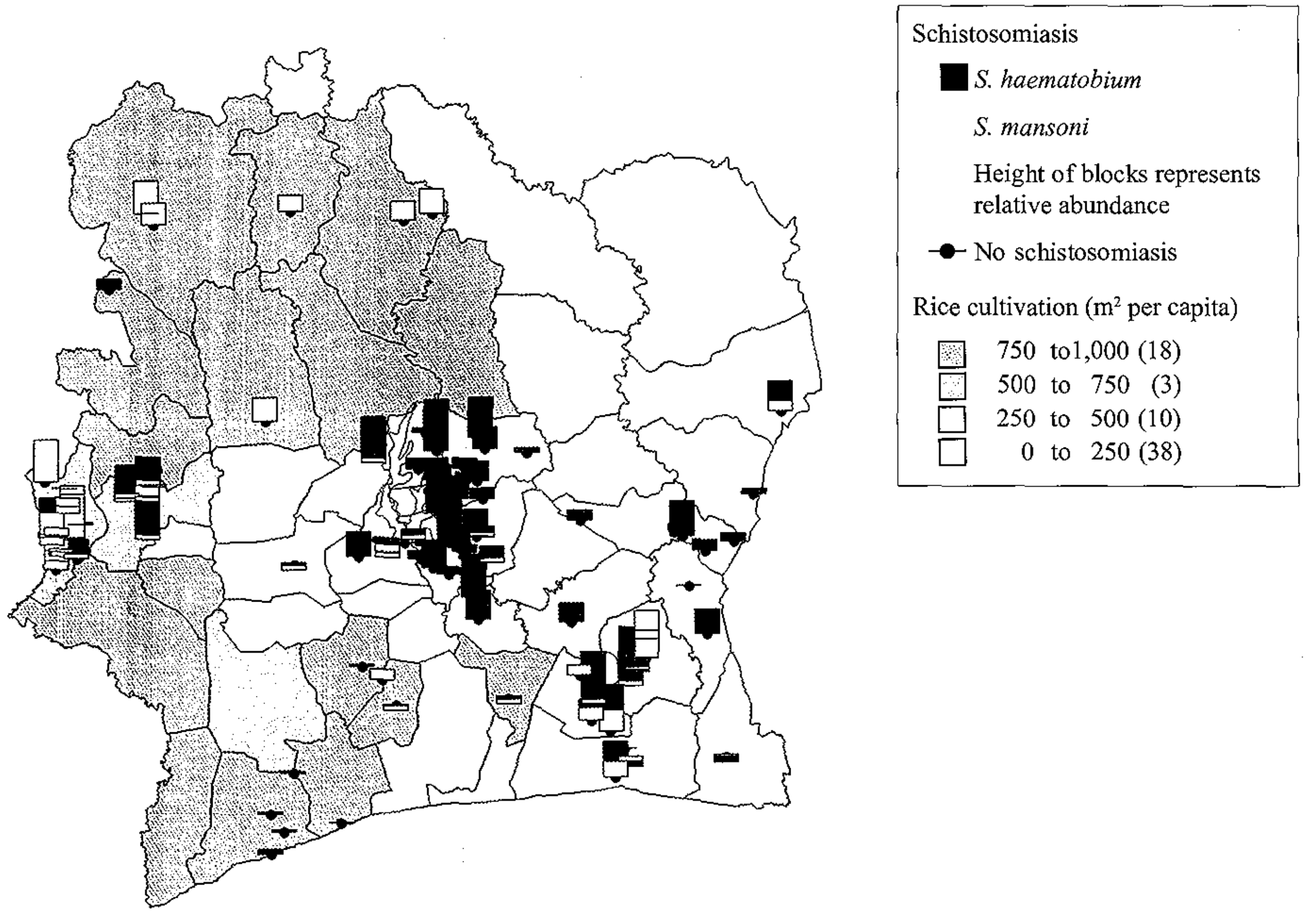


Figure 9. Distribution of schistosomiasis in Côte d'Ivoire

heavily infested—for example, some 80% of the children living by the lake that supplies drinking water to the Ivorian town of Katiola suffers from disease caused by *S. haematobium*.

Efforts to control the disease

In the past, disease-control efforts have concentrated on reducing the contact between people and infested water, mostly through improved sanitation and health education. Chemical control of snails is difficult and expensive. In East Africa, a plant was discovered that liberates a snail-toxic chemical when crushed or pounded; however, the chemical is also toxic to fish, and when attempts were made to introduce it as a means of snail control, it was instead adopted for fishing!

Schistosomiasis itself has proved easy to control with modern drugs, which are highly effective in a single-dose formulation and have minimal side-effects. Thus, it seems simplest to manage the disease through a health-service based program of diagnosis and treatment, although reinfection is common in high-risk groups. In particular, school-based control campaigns have been successful—where they have been maintained.

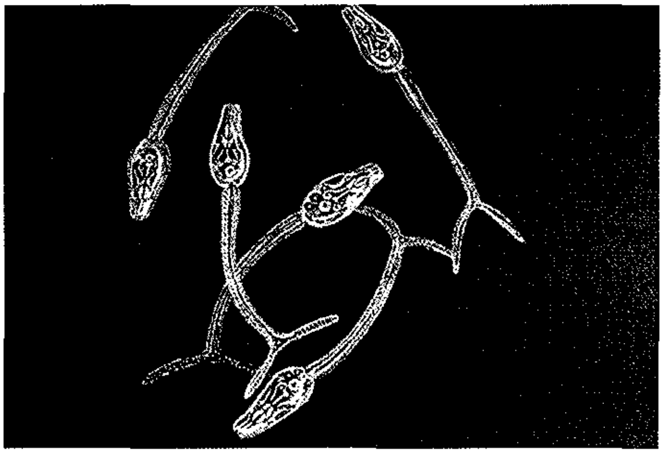
Another potentially useful avoidance practice is the simple wearing of boots. Schistosomes are not the only nuisance in wetlands. Farmers (and others) are also plagued by leaches, large snails, and an animal known as the 'double-headed snake.' Boots protect the wearer from all of these. Migrant workers who opt for wearing boots do so to avoid these nuisances. However, in resource-poor farming communities, boots are considered a work tool, and one that is expensive; thus, with expenditure controlled by the head of household, it is only he (or exceptionally she) who is likely to possess them, leaving the rest of the household still at risk. In both the savanna and the forest, while men are usually the ones owning and wearing boots, most of the work in lowlands is done by women who do not have access to boots (a notable exception is migrant groups from Sahelian countries, where men are largely involved in lowland agriculture).

In addition to surveying for baseline data, the Human Health Consortium also looked for ways to control the spread of the disease. It hypothesized that, in large irrigation areas such as the *Office du Niger* with 70,000 ha of irrigated land, it should be possible to identify the vegetation types responsible for maintaining snails in contact zones, and therefore control the vector by vegetation clearance. Once such vegetation blocks could be identified, a series of removal experiments would be necessary to test the hypothesis; however, the work never got that far...

Native perceptions of disease

A major stumbling block made such intervention theories falter to the point that continuation of the work would have been a complete waste of effort. The problem is the perception that the native communities have of diseases.

There is a perception among rice-based rural farming communities in the humid forest and savanna of West and Central Africa that all diseases are already present in the body. It is perceived that 'risky behavior' causes diseases to become manifest, rather than such behavior increasing the likelihood of infection by an external germ (the scientific understanding). Furthermore, it is only in areas with high parasite infection rates that people actually identify schistosomiasis as a specific disease. Intestinal schistosomiasis is often associated with dysentery, and urinary schistosomiasis associated with sexually transmitted diseases among teenagers and adults. Even in areas where the disease is identified as such and is known to be associated with lowlands (in areas where large education campaigns have been undertaken), people usually associate the disease with the drinking of dirty water rather than with standing or working in the water. Thus, the 'risky behavior' may be coming into contact with water, but little or no value is attached to prophylactic measures, such as wearing boots or using latrines, even in areas where the disease is well known.



Schistosomes under the microscope

In addition, schistosomiasis is simply not perceived as life-threatening, or even as debilitating. This is due to the fact that many infected people do not suffer to any great extent. Urinary schistosomiasis is seen rather as a disease of adolescence—a sign that a child (particularly a boy) is growing into an adult. In 90% of infected individuals, 'red urine' is the only symptom of schistosome infection (*see* Box), and that occurs during late childhood (school age) and early adolescence.

Both intestinal and urinary schistosomiasis are easy to cure. The intestinal form requires laboratory analysis to differentiate it from either amoebic or bacterial dysentery, but then is treated by administration of a single dose of the appropriate anthelminthic drug. However, reinfection is very common, as exposure is usually continuous.

The fact that the disease is chronic and untreated 'red urine' in adolescence could lead to kidney failure at the age of 45–55 years is simply not known or acknowledged. For some reason, untreated intestinal schistosomiasis results in severe liver disease much less frequently in many parts of Africa than it does in some other continents.

Red urine (left, compared with normal urine, right)—often the only symptom of schistosomiasis

Schistosomiasis in West Africans

Schistosomiasis is a parasitic disease brought about by worms, known as schistosomes. There are two types of schistosomiasis which infect humans in West and Central Africa: urinogenital, caused by *Schistosoma haematobium*, and intestinal, caused by *Schistosoma mansoni*. In both cases, the disease is brought about by the body's immune reaction to worm eggs deposited in target-organ tissues, rather than by the schistosomes themselves. The immune system seeks to encase the deposited eggs, and it is the body's inflammatory response to the eggs that causes the disease symptoms.

Urinogenital schistosomiasis
Adult worms migrate through the venous blood system and eggs are deposited in the bladder wall. The inflammatory response to the worm eggs causes bladder-wall bleeding. This results in what is often the disease's only symptom, 'red urine.' As the worm eggs are encased close to the base of the urethras (urine-tubes), the urethras become blocked. With time, this blockage of urine outflow can extend back to the kidney and result in kidney failure, which is inevitably fatal if both kidneys are involved; however, this is unlikely to occur before the patient is 45 years old. In other cases, chronic bladder infection may eventually lead to cancer of the bladder. In populations where life-expectency is short, the chronic (long-term) effects of schistosomiasis infection are simply not apparent.

Intestinal schistosomiasis
Intestinal schistosomiasis is initially manifest as painful bloody dysentery, which usually leads to the patient (or their family) seeking medical advice and prompt curative treatment. The worm migrates through the venous blood system to the liver, where the ensuing worm-egg inflammation results in granuloma, which over time will destroy the normal liver tissue, leaving scar tissue and resulting in cirrhosis. Liver cirrhosis is again fatal; however, in most cases, either the disease is treated with the onset of diarrhea and dysentery, or else people die from other causes before the effects of liver failure or cirrhosis become manifest.

Lessons learned

The Health Consortium's work on schistosomiasis showed very clearly that community perceptions can have a marked effect on the success of scientific interventions. In theory, it should have been possible to identify vegetation types associated with schistosome-vector snails, but the lack of understanding of how the disease works would have meant that the suggestion of clearing appropriate vegetation to decrease the snail habitat would have gone unheeded. It is proving almost as difficult to persuade the farming communities involved in this research to adopt bed-nets as a means of preventing malaria, and that disease is a well-known killer! Thus, agricultural (and other development-oriented) research needs to look beyond its own sphere and take such fields as sociology into consideration when developing technology to improve the livelihoods of its clientele.

In contrast to the 'failure' of snail-control technology, the sociological surveys conducted by the Consortium, and others, have shown ways of improving the health status of farming communities. Where women achieve increased independence through income-diversification (that is, they have several sources of income, rather than just one agricultural crop), they are better empowered to take control of their families' health. While traditionally it is men who are in charge of all health-related expenses and decisions, in practice it is women who most often identify the medical needs of their family members, and when they have the financial resources to do so, they play an increasing role in the decision and choice of the medical treatment to seek. It has been shown that the families of women with diversified income sources have up to 40% fewer malaria episodes compared with those of women with undiversified income sources. Clearly, the more independent the woman concerned, the more financial decision-making freedom she has to obtain that help quickly. Thus, a simple prescription to improved farmer health is development projects that target the diversification of women's farming practices, and helping them to achieve greater financial autonomy.

Linking research with community development

Community-focused research represents a substantial time investment by participants and, consequently, there is a need for some sort of 'pay-off' or 'pay-back' that directly benefits the communities concerned. Many bio-medical research projects provide this in the form of short-term health care, with the medical personnel providing treatment for ailments when they visit the project site (or else making specific visits to provide such treatment). The Health Consortium decided to provide sustainable assistance to villages participating in its research activities in the savanna zone through support to the Ivorian Government's 'village revolving drug fund' strategy. The strategy aims at facilitating access to essential drugs in villages that have no formal health services (the majority of villages in Côte d'Ivoire). The Health Consortium provided the initial investment funds in the form of a complete drug kit for each participating village. The Consortium also helped establish appropriate management tools for the revolving fund at the community level. Once the kit is available, the villagers purchase from it and so a revolving fund is established to replenish supplies. One of the 12 villages involved with the Health Consortium won the Ministry of Public Health Prize for having successfully implemented the strategy, setting an example for other rural communities to follow.

Research activities also provide a suitable framework for training junior scientists. The Consortium's activities included postgraduate training (Masters and Doctoral levels) for 12 young scientists in Côte d'Ivoire and Mali. Three of these students received prizes from their universities for best thesis—a clear indication of the quality of the research conducted and support given to these young scientists.

Donor Country Profile: United Kingdom

THE RELATIONSHIP between WARDA and the United Kingdom goes back to at least 1975. The UK has provided direct grant support to core and restricted projects, 'in-kind' grants, and seconded staff. In recent years, WARDA has teamed up with several UK 'high-tech' institutions in research partnership.

Since the earliest days, the United Kingdom has maintained strong development-aid links with members of the British Commonwealth; it has also expanded those links to non-Commonwealth countries throughout Sub-Saharan Africa and to multilateral agencies such as WARDA.

Seconded experts

In 1993, DFID (then the Overseas Development Administration, ODA) posted scientists from UK institutions to WARDA to work on jointly implemented projects. Charles Williams, entomologist with the Centre for Agriculture and Biosciences International (CABI), was posted to WARDA's Nigeria Station, based at the International Institute of Tropical Agriculture (IITA), Ibadan. The ODA-funded project on African rice gall midge brought together expertise from CABI's Institute of Biological Control and Institute of Entomology with WARDA staff, members of the WARDA–NARS Task Forces on Integrated Pest Management and Lowland Breeding, and other West and Central African NARS scientists, while IITA provided facilities and administrative support. The work sought to assess the distribution and economic importance of African rice gall midge in West Africa; to assess the role of pest ecology, alternative hosts and farm cultural practices in gall-midge population dynamics; to identify natural enemies (predators, parasites) of gall midge and their importance in the natural regulation of pest populations; and, to develop resistant rice varieties with good agronomic characteristics and grain quality. The project mapped the distribution of gall midge in at least six countries in the region, and also devised equations to predict yield loss from a knowledge of the midge infestation level. Through field surveys and insectarium tests, project staff determined that African rice gall midge is restricted to plants of the genus *Oryza*, with the weed *O. longistaminata* and volunteer and

On a susceptible rice variety, African rice gall midge can cause complete yield loss

Cisadane shown here at grain filling, is tolerant to gall-midge attack, producing panicles despite infestation

ratoon rice as the principal alternative hosts that enable populations to survive through the non-growing season. Two parasitoids were identified that constitute the pest's most important natural enemies—one of these also parasitizes a related gall midge of a regionally common weed, thus suitable management of the weed could yield more parasitoids to attack rice gall midge. Gall-midge resistance proved surprisingly elusive in rice, despite thousands of lines being screened. The best find was of an Indonesian variety, Cisadane, which was subsequently released for cultivation in the gall-midge endemic region of southeast Nigeria. Meanwhile, the project's activities did serve to develop a suitable screening methodology for gall-midge resistance. Research on African rice gall midge at WARDA continues today under core funding.

At about the same time, David Johnson, weed scientist with the Natural Resources Institute (NRI), was posted to WARDA Headquarters. Since 1994, DFID has funded several weed projects in West and Central Africa—some specific to WARDA, and others where the NRI/WARDA weed scientist has given input into non-WARDA projects. Much of the NRI/WARDA weed work was reported last year (*see* 'Allies in the War on Weeds,' *WARDA Annual Report 1998*, pages 33–39). In 1999, the weed team was boosted by the arrival of Rebecca Kent under DFID's Associate Professional Officer Scheme.

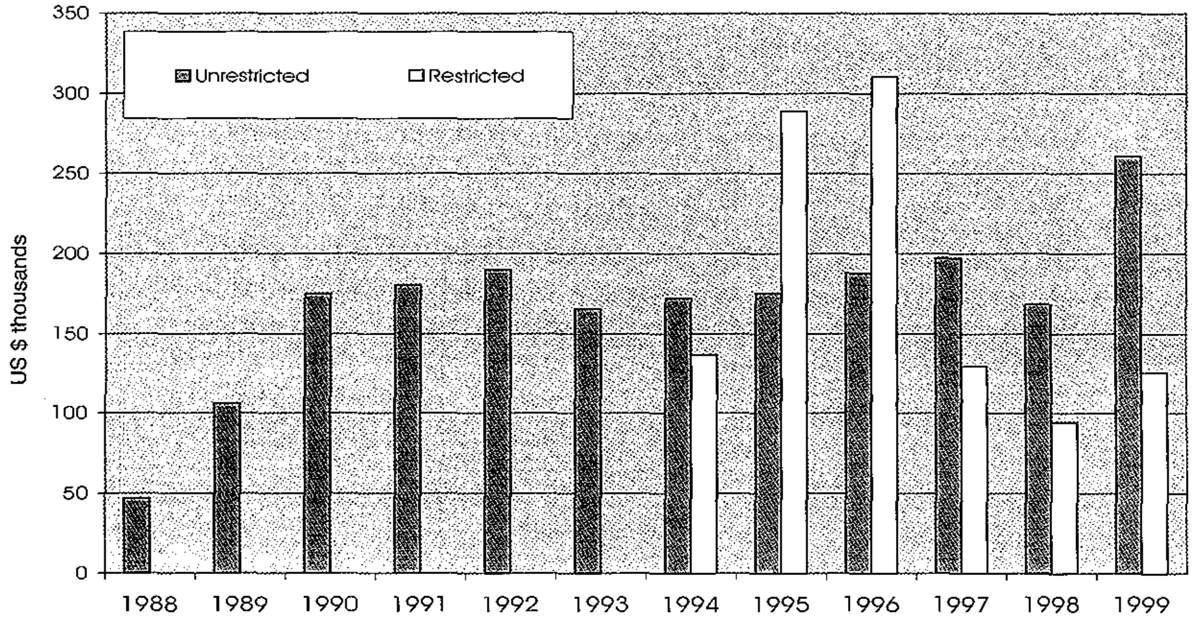
In 1994, Daniel Coyne, nematologist also with NRI, was posted to Headquarters. The NRI/WARDA nematology project also brought in expertise from CABI's Institute of Parasitology. The project highlighted the insidious nature of nematode infestation in rice—a problem almost unknown to West and Central African rice farmers, although almost every field is infested to some extent, with nematodes accounting for an estimated 10% of all crop losses. Some eight genera of nematodes are responsible for root and foliar damage to rice in the region, and a brochure is in preparation (with NRI/CABI and the International Rice Research Institute, IRRI) to raise the awareness of these important pests among research, extension and development agents working on rice world-wide.

More pests... but also genetic resources, soils and drought

The UK's expertise and keen interest in pest management is clearly seen in the specializations of the four secondees. British funds have also been geared toward addressing

David E. Johnson, NRI/WARDA weed scientist, 1992–2000

Figure 10. UK funding to WARDA, 1988–1999



the problems caused by the major rice diseases in West and Central Africa. Since 1996, the WARDA phytopathology team has been helping CABI and Horticulture Research International (HRI) with the characterization of sites in Côte d'Ivoire, Ghana and Nigeria for screening for blast and scald resistance. Then in 1997, DFID started to provide funds for us to screen varieties for their resistance to rice yellow mottle virus (RYMV) in Mali and Niger. Most recently, DFID has attributed funds (from 1999) for research on integrated management of RYMV and the study of the genetic diversity of the blast fungus pathogen.

In 1994–1996, DFID "picked up the tab" for the relocation of the International Network for the Genetic Evaluation of Rice for Africa (INGER-Africa) from IITA to WARDA. Formerly operated under the direct auspices of IRRI, INGER-Africa is now fully imbedded in the WARDA program; it tailors nurseries to the precise needs and resources of its partners in national programs throughout Sub-Saharan Africa. The first INGER-Africa meeting since the relocation was scheduled for early 2000, and the Network receives on-going valuable support from DFID.

In 1997, DFID agreed to support a special project on soil degradation in irrigated rice systems in the Sahel, which is conducted by WARDA and its national partners in Burkina Faso and Mauritania. A detailed account of some of that work in given in 'A Holistic Approach to Irrigated Rice Farming Problems Uncovers More Than Just Soil Degradation,' in this Report.

Also in 1997, WARDA scientists became involved in DFID's work on testing drought-tolerant varieties of upland rice in Ghana, in collaboration with the University of Reading.

In 1998, a project was launched on seed priming, as a component of integrated weed management. This project also involves another UK institution—the Centre for Arid Zone Studies of the University of Wales. It is planned to incorporate seed priming with some of the participatory varietal selection trials being conducted throughout WARDA's mandate region.

In 1999, a three-year project was initiated on 'weedy rice,' based at WARDA, with field trials in Ghana and Mali. Two species of wild rice cause problems to farmers in many parts of Africa—*Oryza longistaminata* (a perennial) and *O. berthii* (an annual). One of the main problems is that during early growth stages, the wild species look similar to the cultivated species. The project seeks to develop a range of control measures for an integrated approach—there are both biological and social scientists on the project team. The project also has field activities in Tanzania, and glasshouse studies are being conducted at Long Ashton Research Station in the UK.

Networking

Increasingly, WARDA sees itself as a linkage between so-called advanced institutions and the region's national research and extension services. Our goal is to ensure that the resources of each partner are utilized in the most efficient way, then bring everything together for the benefit of all parties, and our ultimate clientele—the resource-poor farming households of West and Central Africa.

The UK expertise in pests and diseases continues to be of benefit to the WARDA team. On-going collaboration in blast research involves NRI, CABI and the Commonwealth Mycological Institute, with molecular analysis and pathotyping being conducted by HRI. NRI also continues to be involved with RYMV work, looking at virus transmission by insects. An initial project on developing transgenic resistance to RYMV in rice was a collaborative effort between the Sainsbury Laboratory (part of the University of East Anglia) and WARDA. The latest such project, however, is being conducted in collaboration with the John Innes Centre, where colleagues are conducting molecular characterization of the virus with a view to developing transgenic resistance to RYMV. The John Innes Centre is also using NERICAs to map natural resistance genes to nematodes and RYMV, and genes for weed competitiveness. With the early success of transgenic research for RYMV resistance, we are looking into the possibility of linking up with Leeds University to investigate the possibility of transgenic nematode resistance.

Gatsby Foundation

"Work with the British is not all about direct government aid funding," says WARDA Director General Kanayo Nwanze. "One exciting development is our growing relationship with the Gatsby Foundation." As a philanthropic institution, the Gatsby Foundation is an ideal supporter for agricultural research and development. In 1997, Gatsby made a contribution to WARDA's efforts to build a containment facility at its M'bé headquarters, as part of its biosafety mandate in the region. This support is expected to be reinforced in 2000.

Gatsby have also shown an interest in the participatory varietal selection (PVS) research aspect of the interspecific hybridization project, and have agreed to fund PVS activities in Ghana and Nigeria for three years from 2000 (*see* 'New Rice for Africa... with a Little Help from Our Friends,' in this Report).

Training

A mix of training opportunities has been provided through WARDA–UK collaboration. Between 1977 and 1987, four regional scientists were sponsored by ODA to carry out MSc work at Reading University in collaboration with Rokupr Rice Research Station (then part of WARDA).

DFID is currently sponsoring three postgraduate scholars at WARDA: Tien Hoang (Dutch) taking an MSc in salinity tolerance in irrigated rice at Wageningen UR; Daba Ndour (Senegalese) researching for a PhD in irrigated-rice breeding at Cheikh Anta Diop University, Dakar; and, Jill Cairns (Scottish) researching for a PhD in rice genetics at Aberdeen University.

In addition, two WARDA staff are scheduled to leave WARDA in 2000 to take up PhD studies at the University of East Anglia, as part of the WARDA/John Innes Centre RYMV research program.

An unusual recent development is the work of Cary Clark (US citizen), who is funding her own way through PhD research with Reading University, in community resource management and credit systems.

The British influence: Board chair and other staff

In 1997, Lindsay Innes of the Scottish Crop Research Institute was elected to the WARDA Board of Trustees. His clear insights and leadership qualities have led to his being elected Chairman of the Board from 2000.

Between 1996 and 1997, 'Brit' Andrew Urquhart served WARDA as acting Head of Finance and Personnel Services. Then in 1998, two more 'Brits' were hired by WARDA as core senior staff: Amir Kassam joined as Deputy Director General for Programs, and Guy Manners as Information Officer.

From strength to strength

At a time when so many donor nations seem to be 'shying away' from international agricultural research, it is pleasing to see the faith and trust placed in WARDA by the United Kingdom. DFID in particular has recognized the value of entrusting WARDA with rice research activities for Africa, and has encouraged us by increasing its support to our activities during this difficult time. For this they receive our grateful thanks, and we look forward to continued fruitful collaboration well into the next millennium.

Just what is the UK? A lesson in political geography

"One thing that really confuses everyone," says Guy Manners, WARDA's 'very English' information officer, "is the relationship between (Great) Britain, the United Kingdom and their component entities."

Here is a simple guide to the political and geographical complexities of those islands off the northwest coast of continental Europe:

- Great Britain = England, Scotland and Wales (political)
- United Kingdom = Great Britain and Northern Ireland (political)
- British Isles = United Kingdom, Irish Republic and all associated islands, or (originally) Great Britain and Ireland (geographical)

"What makes for the greatest confusion," continues Guy, "is the fact that those of us from the UK are usually expected to state our nationality as 'British'! I've never understood that one! I am English, British and a citizen of the United Kingdom. Personally, I prefer to say that I'm English."

The Year in Review: 1999

THE YEAR 1999 was a busy one for WARDA and its many partners. With several major projects at or approaching the end of their first phase, and new projects and new directions coming 'on line,' it was a time for review and planning. It marked the start of an exciting, if busy, period in WARDA's history.

In January, the National Coordination Unit of the Inland Valley Consortium (IVC) in Côte d'Ivoire held its ***Atelier national sur les bas-fonds en Côte d'Ivoire*** in Gagnoa. The meeting was attended by representatives from IVC and the Human Health Consortium (HHC), the Ivorian national program (CNRA), the University of Bouaké, various development agencies and NGOs. The meeting revived the Ivorian National Coordination Unit and prepared an action plan for the coming years, including activities to strengthen the linkages between research and development.

A major public-awareness event was held in Abidjan, Côte d'Ivoire—***Journée ADRAO*, or WARDA Day**, on 16 February at the Hotel Ivoire. This was a one-day event where WARDA presented itself to the region's diplomatic community and others; an event sponsored by AfDB, FAO, UNDP and the World Bank. The day was a great success, with speeches from the sponsors, WARDA's Council of Ministers, the Ivorian Minister of Agriculture and Animal Resources, farmers and national partners. The Ivorian Prime Minister was guest of honor. Other guests included diplomats representing the donor community, WARDA member states and other African nations from missions based in Abidjan and elsewhere in the region. In the afternoon the exhibition was opened to the public, and we estimate that some 600–1000 people saw the displays.

During 17–20 February, 16 participants representing GTZ, WARDA, the University of Hohenheim, the NARS of Nigeria and Benin, the agricultural extension system of Benin and farmers' organizations from both Nigeria and Benin, took part in a **Planning Workshop on Farmer Participatory Improvement and Adaptation of Production Technologies for Rainfed Rice-based Systems in West Africa with Emphasis on Nigeria and Benin**, at WARDA Headquarters. As a result of the workshop and subsequent project proposal, BMZ is funding a project on this subject, implemented by WARDA in collaboration with the University of Hohenheim.

March saw the final meetings of the **WARDA/NARS Task Forces** at which they began to be remodeled into **ROCARIZ**, with a Task Forces Stakeholders' Meeting on 15–17 and full Task Forces Meeting on 18–19. Over 100 delegates attended, comprising NARS Task Force members, WARDA researchers, and WECARD/CORAF representatives. It was at this meeting that an Interim Steering Committee was established for ROCARIZ, which was mandated to draw up rules and regulations for the new network for approval at the First Regional Rice Research Review in early 2000.

A training course on **Systems Analysis and Simulation of Rice Production and Rice–Weed Interactions** was held at WARDA Headquarters between 22 and 30 March, conducted by the Department of Theoretical Production Ecology, Wageningen Agricultural University, The Netherlands. It was primarily aimed at WARDA research staff, although 5 NARS personnel also took part.

Another public-awareness event took place from 25 March to 4 April—***Carnaval de Bouaké*** **(Bouaké Carnival)**. An estimated 2–3 thousand people visited the WARDA stand on one of the main streets of WARDA's host city.

The **Inland Valley Consortium (IVC)** was also in transition in 1999, as the year marked the end of phase I and the establishment of a new status in preparation for phase II. The IVC Heads of Member Institutions met on 13–14 April, immediately followed by the Annual Planning Workshop through 16 April. A collaborative agreement was signed by the heads of institutions and a Consortium Management Committee was established. The ground was set for the wrapping up of phase I activities (principally some unfinished agro-ecological characterization work in several countries) in 1999–2000, and for the start of phase II in 2000 with new emphases and activities, building on the lessons learned in phase I and other inland-valley and technology-transfer initiatives. The IVC is now an integral component of WARDA's research program structure, being housed in a project in the Systems Development and Technology Transfer Program—*Inland Valley Systems Development and Technology Transfer*—, rather than being a separate entity with no overlap (and little interaction) with WARDA's mainstream program.

Building on the success of participatory varietal selection (PVS) in several countries up to 1998, WARDA organized two workshops from 19 to 28 April 1999. The first—**Participatory Rice Improvement and Gender/User Analysis Reporting and Planning Workshop**—brought together the PVS teams from 10 countries (many of whom had been trained in 1998) to report on their experiences, share ideas and plan activities for the 1999 campaign. The follow-on **Participatory Rice Improvement Training Workshop** offered PVS skills to teams from the remaining seven WARDA member countries, so that all 17 member states have now received PVS training. The reporting and planning workshop is set to become an annual event, as more donors are giving backing to this technology-transfer research initiative.

In May, our financial team were put 'under the microscope' by the **Center-Commissioned External Review on Financial Management and Control**. The review panel made 23 recommendations and concluded that the mechanisms were in place to significantly improve financial reporting.

The year was also set to be crucial for the **Human Health Consortium**, as the project was coming to an end and had met its objectives (or, in the case of schistosomiasis, showed that some avenues of research are doomed to be unproductive—*see* 'Perception is Reality' in this Report). The Consortium is a joint undertaking between research and extension agencies in Côte d'Ivoire and Mali, WARDA and the World Health Organization's Joint Panel of Experts on Environmental Management for Vector Control (WHO/PEEM). The Consortium Scientific Advisory Committee—chaired by WHO/PEEM—met with IDRC (representing the donors) in Bouaké, on 24–26 May for their annual meeting to discuss results and plan activities through the end of the project in 2000. Unfortunately, with a lack of donor funding for a second phase, the end of the project will see the end of Consortium activities hosted by WARDA.

June saw the WARDA research staff taking a good hard look at themselves as they were evaluated by a **Center-commissioned External Review of Program Strategy and Management**. The Review, chaired by Dr Bernard Tinker, was generally positive, but gave valuable feedback on issues such as the balance between adaptive and strategic research. The Review was timed to provide valuable feedback and input into the External Program and Management Review, which started towards the end of the year.

'Summer' is always a quiet time at the international centers, as many senior staff take their annual holidays to spend time relaxing with their families. However, 'Fall' kicked in with the **Twenty-second Ordinary Session of the Council of Ministers** Meeting, on 16–17 September, where member-state ministers of agriculture met to discuss WARDA's progress and make recommendations for the future. This year, the meeting made history as the first international forum to meet in Liberia since the onset of the civil war there. Eight member states were represented at the meeting, five of those at ministerial level. Despite the lack of quorum, nine resolutions and two votes of thanks were drafted for submission to the full Council for approval.

The **Crop Science Society of America** (CSSA) offered the CGIAR the opportunity to present seminars and an exhibit-stand at its **Annual Meetings**, starting with IRRI and WARDA in October–November 1999, in Salt Lake City, Utah, USA. We, of course, jumped at the opportunity to 'spread the word' of our work among the elite of America's crop scientists. Three presentations were made by WARDA staff, and they and the exhibits were well received.

Another important event for the Human Health Consortium was the **Ecosystem Health Analytical Workshop** from 6 to 24 November. The meeting, split between Abidjan and WARDA Headquarters, focused on **Mapping malaria Risk in Africa (MARA) in West Africa: The role of humid zones and open water bodies**. The combined results of several research groups were brought together to develop the first map of malaria risk in Africa, now available on the Internet.

The biennial ***Salon international de l'agriculture et des ressources animales*** (SARA)—a regional forum for promotion of all things agricultural, both commercial and not-for-profit—was held in Abidjan between 12 and 19 November. WARDA again had a booth, and senior staff took turns discussing our work with members of the public, commercial farmers, and dignitaries from all over the region—an estimated 8000 visitors.

The Initial Phase of WARDA's **Fourth External Program and Management Review** (EPMR) ran from 20 to 30 November, with general presentations to the Panel (chaired by Dr Mandi Rukundi of Zimbabwe) and preliminary discussions on matters of interest to Panel members. This was to pave the way for the Main Phase in early 2000. The report of the EPMR was presented to the CGIAR Mid-Term Meeting in Dresden in May 2000. Issues facing WARDA as it enters the next millennium, and the overall assessment of the Review Panel are presented in the Message from the Director General and Chairman of the Board of Trustees (page 1).

At the November meeting of the **Board of Trustees**, the new Information and Documentation Center (IDC) and research extension buildings were inaugurated. Building costs of US$1,677,084 were provided by the WARDA member states—attesting to both their political support and ownership of the Association. The meeting also marked the last meeting of Chairman Dr Just Faaland of Norway. Dr Faaland served as Chairman for six years, extending his term to seven years in order to provide continuity and smooth transition during the EPMR year. Prof. Lindsay Innes of Scotland (UK) was elected as the incoming Chairman, to be effective June 2000 at the next Board meeting.

The **Final Evaluation of the Interspecific Hybridization Project Phase I** took place on 29 and 30 November, with representatives from UNDP/TCDC, the World Bank, the Japanese Ministry of Foreign Affairs, the Japanese Embassy in Abidjan and JIRCAS, along with research partners from IRRI, IRD, Cornell University, Yunnan Academy of Agricultural Sciences (China) and Guinea. (*See* 'New Rice for Africa... with a Little Help from Our Friends' in this Report.)

In December, WARDA hosted an **International Workshop on Effective and Sustainable Partnerships in a Global Research System: Focus on Sub-Saharan Africa**. The workshop was convened and coordinated by WARDA and ISNAR, in collaboration with the Organizational Change Program (OCP) and with significant support from other CG Centers, the Global Forum for Agricultural Research (GFAR) and the Technical Centre for Agricultural and Rural Cooperation (CTA). Thirty-nine participants represented 27 organizations and 18 countries.

The activity in 1999 set the stage for WARDA to launch a full and exciting agenda into 2000 and beyond. The events listed here were only the first signs of WARDA's renewed energy and enthusiasm for the work ahead, and provided a platform on which upcoming meetings in 2000—the first Regional Rice Research Review (ROCARIZ), the first INGER-Africa workshop under the auspices of WARDA, the third series of PRIGA/PVS workshops, the second biennial meeting of the National Experts Committee, and the Universities Collaborative Platform—would build.

Financial Statement

1. Position for the year ended 31 December 1999 (in US$)

ASSETS	1999	1998
Current Assets		
Cash and Bank Balances	2 637 527	1 669 204
Accounts Receivable:		
Donors	1 044 533	1 662 227
Employees	177 948	201 862
Others	902 768	864 039
Inventories	683 361	832 388
Prepaid Expenses	30 670	57 925
Total Current Assets	5 476 807	5 287 645
Fixed Assets		
Property, Plant and Equipment	19 768 974	18 936 253
Less: Accumulated Depreciation	(5 415 464)	(4 941 190)
Total Fixed Assets (Net)	14 353 510	13 995 063
TOTAL ASSETS	**19 830 317**	**19 282 708**
LIABILITIES AND FUND BALANCES		
Current Liabilities		
Cash and Bank Balances (Overdraft)	71 067	808 166
Accounts Payable:		
Donors	3 875 936	2 581 774
Employees	129 818	187 039
Others	1 288 254	1 234 384
Provisions and Accruals	1 024 696	1 053 154
Total Current Liabilities	**6 389 771**	**5 864 517**
Total Liabilities	**6 389 771**	**5 864 517**
Net Assets		
Capital Invested in Fixed Assets		
Center-owned	14 353 510	13 995 063
Capital Fund	12 301	281 933
Operating Fund	(925 265)	(858 805)
Total Net Assets	**13 440 546**	**13 418 191**
TOTAL LIABILITIES AND NET ASSETS	**19 830 317**	**19 282 708**

2. Statement of activities by funding for the years ended 31 December 1998 and 1999 (in US$)

	Unrestricted	Restricted	Total 1999	Total 1998
REVENUE				
Grants	6 511 825	2 557 817	9 069 642	8 077 201
Member States' Contributions	83 924		83 924	762 497
Other Income	399 778		399 778	305 974
TOTAL REVENUE	**6 995 527**	**2 557 817**	**9 553 344**	**9 145 672**
OPERATING EXPENSES				
Research Programs	3 048 070	2 482 766	5 530 836	5 901 627
Administration and General Operations	3 298 922		3 298 922	2 931 510
Depreciation	735 660		735 660	625 600
Gross Operating Expenses	7 082 652	2 482 766	9 565 418	9 458 737
Recovery of Indirect Costs	(258 498)		(258 498)	(291 459)
OPERATING EXPENSES (NET)	6 824 154	2 482 766	9 306 920	9 167 278
EXCESS/(DEFICIT) OF REVENUE OVER EXPENSES	**171 373**	**75 051**	**246 424**	**(21 606)**
Allocated as Follows:				
Operating Funds	(171 373)		(171 373)	135 643
Capital Funds		(75 051)	(75 051)	(114 037)

MEMO ITEM

Operating Expenses by Natural Classification

	Unrestricted	Restricted	Total 1999	Total 1998
Personnel Costs	*3 569 585*	*624 306*	*4 193 891*	*4 707 373*
Supplies and Services	*2 406 769*	*1 533 464*	*3 940 233*	*3 460 476*
Operational Travel	*370 638*	*324 996*	*695 634*	*665 288*
Depreciation	*735 660*		*735 660*	*625 600*
Gross Operating Expenses	*7 082 652*	*2 482 766*	*9 565 418*	*9 458 737*

3. Grants for the year ended 31 December 1999 (in US$)

Unrestricted research agenda

	1999	1998
Belgium	115 796	
Canada	468 133	478 077
Côte d'Ivoire		109 176
Denmark	294 737	342 773
France	89 455	121 296
Germany	328 940	349 627
Japan	1 584 382	1 367 018
Netherlands	247 083	260 824
Norway	279 641	293 403
Sweden	442 938	473 100
United Kingdom*	260 720	168 574
United States of America (USAID)	250 000	200 000
World Bank	2 150 000	1 100 000
Total unrestricted grants	**6 511 825**	**5 263 868**

Restricted research agenda

	1999	1998
African Development Bank (Institutional Support)	155 787	
Canada (Laval University)	45 134	48 579
Canada (Health—Vector-borne Diseases Project)		365 631
Canada (FDCIC Project)	11 342	11 111
Denmark (Phytosanitary and Seed Health Project)	24 107	22 671
France (Agrophysiology Project)		74 488
France (Inland Valley Consortium Project)	87 337	100 248
Gatsby Foundation (Containment Facility)	30 708	
Germany (GTZ) (Pesticides Project)		14 448
Germany (GTZ) (Soil Nitrogen Project)	48 691	17 673
Germany (GTZ) (Projet riz nord)	78 032	40 499
Germany (GTZ) (Improved Nutrient Management)	91 011	59 910
IFAD (RADORT Project)	132 984	277 226
IVC/CFC Spirivwa	149 391	
Japan (Post-doctoral Studies)	41 120	57 542
Japan (Grain Quality Studies)	40 381	98 892
Japan/UNDP (TCDC Project)	427 000	427 000
Japan/MAFF/WARDA Project	115 951	
Netherlands (Inland Valley Consortium Project)	323 258	361 297
Norway (Vector-borne Diseases Project)	132 997	34 555
Norway (Training Project)	46 745	72 967

* UK funds are 'attributed' to specific WARDA Core Medium-Term Plan projects.

Restricted research agenda (continued)

	1999	1998
Rockefeller Foundation (Anther Culture Project)	178 250	157 745
Rockefeller Foundation (Post-doctoral Studies)	5 978	
United Kingdom (Weeds Project)	15 851	
United Kingdom (Nematology Diagnosis and Control Project)		11 065
United Kingdom (RYMV CRF Project)	22 439	38 000
United Kingdom (Soil Degradation CRF Project)	27 128	33 590
United Kingdom (Seed Priming Project)	14 343	11 732
United Kingdom (INGER-Africa Phase 2)	7 895	
United Kingdom (Wild Rice Project)	11 716	
United Kingdom (University of Wales)	19 400	
United Kingdom (University of Aberdeen)	7 026	
UNDP (IAEG Germplasm Assessment Project)	13 999	
United States of America (USAID) (Arkansas Linkage Grant)	11 199	5 712
United States of America (USAID) (Network Project)	194 409	356 670
United States of America (USAID) (Sub-Sahara Africa Technology Dissemination Project)	2 732	50 286
United States of America (USAID) (Sub-Sahara Africa Email Project)	43 477	63 797
Total restricted grants	**2 557 817**	**2 813 333**
Total Grants	**9 069 642**	**8 077 201**

Board of Trustees

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Guézi Norberte Zézé*	Public Awareness Assistant

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Gabriel Dao	Interim Head of Human Resources and Administrative Services
Vincent Elegbo	Mechanical Maintenance Manager
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	Policy Support Program Leader
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Mark Abekoe*	Soil Agronomist (Visiting Scientist)
Abdoulaye Adam	Biometrician
	Acting Training Coordinator**
Folkard Asch**	Crop Modeler (Laval University/CIDA)
Mathias Becker**	Cropping Systems Agronomist
Amadou Moustapha Bèye**	Agronomist/Breeder (Visiting Scientist)
Thierry Cadalen**	Molecular Biologist
Timothy J. Dalton**	Production Economist
Alassane Diallo	Documentalist

Sitapha Diatta	Soil Physicist
Koichi Futakuchi	Crop Ecophysiologist
Robert Guei	INGER-Africa Coordinator
Monty P. Jones	Rainfed Rice Program Leader
	Upland Rice Breeder
Mohamed Kebbeh*	Agricultural Economist (Visiting Scientist, Sahel)
Frédéric Lançon*	Policy Economist
Nina Lilja**	Agricultural Economist
Guy Manners	Information Officer
Kouamé Miézan	Irrigated Rice Program Leader (Sahel)
	Irrigated Rice Breeder
Sié Moussa**	Rice Breeder (Visiting Scientist, Sahel)
Marie-Noëlle Ndjiondjop*	Molecular Biologist
Francis Nwilene*	Entomologist
Olumuyiwa Osiname	Interim Coordinator, WARDA Nigeria Station
Kanwar L. Sahrawat	Soil Chemist
Fassouma Sanogo*	Translator
Yacouba Séré	Pathologist
Mémouna Sidi-Touré	Translator
Brent Simpson	Systems Development and Technology Transfer Program Leader
B.N. Singh**	Lowland Rice Breeder
Aïssata Sylla	Desktop-publishing Assistant
Thomas Teuscher	Human Health Project Coordinator
Marco Wopereis	Irrigation Agronomist (Sahel)

Collaborating Scientists

Alain Audebert	Plant Physiologist (CIRAD)
Olivier Briët*	Associate Medical Entomologist (DGIS)
Niels Hannsens**	RADORT Project Coordinator (Winrock International)
Stephan Häfele	Associate Agronomist (Sahel, GTZ)
Wilfried Hundertmark	Water Management Specialist (IWMI)
Jean-Yves Jamin	Inland Valley Consortium Regional Coordinator (Coopération française)
David E. Johnson	Weed Scientist (NRI)
Rebecca Kent*	Associate Weed Scientist (DFID)
Takeshi Sakurai*	Agricultural Economist (JIRCAS)
Satoshi Tobita	Physiologist/Molecular Biologist (JIRCAS)
Petrus van Asten	Associate Soil Scientist (Sahel, DGIS)
Hideo Watanabe	Grain Quality Specialist (JICA)
Peter Windmeijer**	Inland Valley Consortium Research Coordinator (SC-DLO)

* Joined in 1999
** Left in 1999
† Mory Cissé passed away on 1 January 2000

Training

Courses Given in 1999

Title and dates	Location	Language	Participants		
			Male	Female	Total
Systems Analysis and Simulation of Rice Production and Rice–Weed Interactions [Postgraduate course of the Department of Theoretical Production Ecology, Wageningen Agricultural University] 22–30 March	M'bé, Bouaké, Côte d'Ivoire (WARDA)	English	18	2	20
Participatory Rice Improvement and Gender/User Analysis 19–25 April	Yamoussoukro, Côte d'Ivoire (Hotel President)	English, French	28	3	31
Community-based Seed Production 26–29 April	Sérédou, Guinea	French, Kissien, Mandingou	28	8	34
Formation agronomique de base 26–30 April	M'bé, Bouaké, Côte d'Ivoire (WARDA)	French	30	0	30
Community-based Seed Production 1–3 May	Kindia, Guinea	French, Peulh, Soussou	22	6	28
Les techniques de production de riz irrigué 29 May to 10 June	Rosso, Mauritania	French	24	1	25
Rice Seed Production Techniques, Organization, Management and Varietal Release Procedures 26 September to 9 October	Ghana (CRI)	English	17	1	18
Total			**167**	**21**	**186**

Postgraduate Trainees in 1999

Name and thesis topic	Institution	Sponsor	Degree
*Ajayi, Oluyedi Olutomide Clifford** Pesticide use practices, productivity and farmers' health: the case of cotton-rice system in Côte d'Ivoire, West Africa	University of Hannover	GTZ/WARDA	PhD
Akanvou, René Optimizing rice–legumes intercropping in inland valleys in West Africa: A systems approach to interspecific competition	Wageningen Agricultural University	Netherlands/ WARDA	PhD
Aluko, Kiodé Gabriel Genetic studies of soil acidity tolerance in rice	Louisiana State University	Rockefeller Foundation	PhD
Bousquet, Violaine Variation de l'enracinement du riz pluvial en fonction du cultivar et du type de sol	Institut National Polytechnique de Nancy	CIRAD	DEA
Cairns, Jill Root penetration and QTL mapping in upland rice	University of Aberdeen	DFID	PhD
Clark, Cary Rural finance systems and related constraints for lowland rice intensification	University of Reading	Private/ WARDA	PhD
Guèye, Talla Nitrogen use efficiency in irrigated rice	University of Göttingen	DAAD	PhD
Häfele, Stephan Soil fertility management in irrigated rice	University of Hamburg	GTZ	PhD
Jalloh, Alpha Bella Genetics of iron toxicity tolerance in *indica* rice	University of Sierra Leone	AfDB	MPhil
Keïta, Moutar Criblage de variétés de riz pour la résistance horizontale à la pyriculariose à Bouaké M'bé et à Man (Côte d'Ivoire)	Ecole supérieure d'agronomie (ESA), Yamoussoukro	MESRS/WARDA	DAA
Maji, Alhassan Tswako Genetics of resistance to African rice gall midge in *Oryza glaberrima*	University of Ibadan	Rockefeller Foundation	PhD

Mandé, Sémon Assessment of biodiversity in *Oryza glaberrima* using microsatellite markers	Cornell University	Rockefeller Foundation	PhD
*Masiyandima, Mutsa** Impact of land use on recharge to shallow groundwater	Cornell University Foundation	Rockefeller	PhD
Ojehomon, Ohifeme Effects of parboiling, storage, and cultivar management on rice grain quality	University of Ibadan	WARDA	PhD
*Ouassa, Anne-Marie** Control of mosquito populations in Gambian rice fields	University of Abidjan/ Institut Pierre Richet	AfDB/WARDA (Health Consortium)	PhD
Soko, Dago Faustin Variabilité pathologique de quelques isolats du virus de la panachure jaune du riz (RYMV) de Gagnoa (Côte d'Ivoire)	Université de Cocody, Abidjan	MESRS/WARDA	DEA
Somado, Eklou Attiogbévi Enhancing nutrient cycling in rice–legume rotations through phosphate rock in acid soil	University of Göttingen	DAAD	PhD
*Timmerman, Henk-Jan** The impact of land use intensity on soil degradation	University of Amsterdam	IVC/University of Amsterdam	MSc
van Asten, Petrus Salt-related soil degradation in irrigated rice-based cropping systems in the Sahel	Wageningen UR	DGIS	PhD

* Completed in 1999

Publications

Afun, J.V.K., D.E. Johnson and A. Russell-Smith, 1999. The effects of weed residue management on pests, pest damage, predators and crop yield in upland rice in Côte d'Ivoire. *Biological Agriculture & Horticulture* 17: 47–58.

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Abbreviations and Acronyms

ADRAO	Association pour le développement de la riziculture en Afrique de l'Ouest (French name of WARDA)
AfDB	African Development Bank
AMVS	Autorité de mise en valeur de la vallée de Sourou (Burkina Faso) [Sourou Valley extension service]
BMZ	Bundesministerium für Wirtschaftliche Zusammenarbeit (Germany)
Ca	calcium
CABI	Centre for Agriculture and Biosciences International (United Kingdom)
CBSS	community-based seed (production) system(s)
CCER	Center-Commissioned External Review
CEMV	Centre universitaire de formation en entomologie médicale et vétérinaire (Côte d'Ivoire)
CFC	Common Fund for Commodities [donor]
CG	Consultative Group on International Agricultural Research
CGIAR	Consultative Group on International Agricultural Research
CIAT	Centro Internacional de Agricultura Tropical
CIDA	Canadian International Development Agency
CIRAD	Centre de coopération internationale en recherche agronomique pour le développement (France)
CNRA	Centre national de recherche agronomique (Côte d'Ivoire)
CNRADA	Centre national de recherche agronomique et de développement agricole (Mauritania)
CORAF	Conseil Ouest et Centre africain pour la recherche et le développement agricoles (*formerly*, Conférence des responsables de la recherche agronomique africaine)
CRDI	Centre de recherche pour le développement international (French of IDRC)
CRF	Competitive Research Funds (DFID)
CRI	Crops Research Institute (Ghana)
CSSA	Crop Science Society of America
CTA	Technical Centre for Agricultural and Rural Cooperation (the Netherlands)
cv.	cultivar
DAA	Diplôme d'agronomie appliquée
DAAD	Deutscher Akademischer Austauschdienst
DANIDA	Danish International Development Agency
DEA	Diplôme d'études approfondies (degree)
DEAP	Département d'épidémiologie des affections parasitaires (Mali)
DFID	Department for International Development (*formerly* ODA, UK)
DGIS	Directorate General for International Cooperation (The Netherlands)
ECA	Economic Commission for Africa (UN)
ECSA	Eastern, Central and Southern Africa
ed.	editor(s)
EPMR	External Program and Management Review
FAO	Food and Agriculture Organization of the United Nations
FDCIC	Fonds de contrepartie ivoiro-canadien
GFAR	Global Forum for Agricultural Research
GTZ	Gesellschaft für Technische Zusammenarbeit (Germany)

HHC	Human Health Consortium (WARDA)
HRI	Horticultural Research International (UK)
IAEG	Impact Assessment and Evaluation Group (CGIAR)
IARC	international agricultural research center (CGIAR)
IDC	Information and Documentation Center (WARDA)
IDRC	International Development Research Centre (Canada)
IFAD	International Fund for Agricultural Development
IFDC	International Fertilizer Development Corporation
IHP	Interspecific Hybridization Project (WARDA)
IITA	International Institute of Tropical Agriculture (Ibadan, Nigeria)
INERA	Institut de l'environnement et de recherches agricoles (Burkina Faso)
INGER	International Network for the Genetic Evaluation of Rice
IPR	Institut Pierre Richet (Côte d'Ivoire)
IRD	Institut de recherche pour le développement (*formerly* ORSTOM, France)
IRRI	International Rice Research Institute (Los Baños, The Philippines)
ISBN	International Standard Book Number
ISNAR	International Service for National Agricultural Research (The Hague, The Netherlands)
IVC	Inland Valley Consortium (WARDA)
IWMI	International Water Management Institute
JICA	Japan International Cooperation Agency
JIRCAS	Japan International Research Center for Agricultural Sciences
K	potassium
LSD	least significant difference
MAFF	Ministry of Agriculture, Forestry and Fisheries (Japan)
MARA	Mapping malaria Risk in Africa
MESRS	Ministère de l'enseignement supérieur et de la recherche scientifique (Côte d'Ivoire)
Mg	magnesium
MOFA	Ministry of Foreign Affairs of Japan
MPhil	Master of Philosophy (degree)
MSc	Master of Science (degree)
MTP	Medium-Term Plan
N	nitrogen
NARS	national agricultural research system(s)
NERICA	New Rice for Africa
NGO	non-governmental organization
NRI	Natural Resources Institute (UK)
OCCGE	Organisation de Coordination pour la lutte Contre les Grandes Endémies (Côte d'Ivoire)
OCP	Organizational Change Program
ODA	Overseas Development Administration (*now* DFID, UK)
OMS-TEAE	Organisation mondiale de la santé - Tableau mixte d'experts sur l'aménagement de l'environnement pour la lutte antivectorielle (French of WHO-PEEM)
ORSTOM	Institut français de recherche scientifique pour le développement en coopération (*now* IRD, France)
P	phosphorus
p./pp.	page(s)/pages
PAGE	polyacrylamide gel electrophoresis
PEEM	Joint Panel of Experts on Environmental Management for Vector Control (WHO/FAO/UNEP/UNCHS)
PhD	Doctor of Philosophy (doctorate)
PRIGA	Participatory Rice Improvement and Gender/User Analysis (WARDA)
PVS	participatory varietal selection

QTL(s)	quantitative trait locus (loci)
RADORT	Research on Accelerated Diffusion of Rice Technology (WARDA/Winrock International project)
RFLP	restriction fragment length polymorphism
ROCARIZ	Reseau Ouest et Centre africain du riz (WARDA/CORAF Rice Research and Development Network for West and Central Africa)
R-to-D	research-to-development
RYMV	rice yellow mottle virus
SARA	Salon international de l'agriculture et des ressources animales
SC-DLO	Winand Staring Centre for Integrated Land, Soil and Water Research (Wageningen, the Netherlands)
SONADER	Société nationale pour le développement rural (Mauritania)
subsp.	subspecies
TCDC	Technical Cooperation among Developing Countries (UNDP)
TSP	triple superphosphate
UK	United Kingdom
UN	United Nations
UNDP	United Nations Development Programme
US	United States
USA	United States of America
USAID	United States Agency for International Development
WARDA	West Africa Rice Development Association
WCA	West and Central Africa
WECARD	West and Central African Council for Research and Development (English of CORAF)
WHO	World Health Organization
WHO-PEEM	World Health Organization Panel of Experts on Environmental Management for Vector Control
YAAS	Yunnan Academy of Agricultural Sciences (China)


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CGIAR Centers

CIAT	Centro Internacional de Agricultura Tropical (Cali, Colombia)
CIFOR	Center for International Forestry Research (Bogor, Indonesia)
CIMMYT	Centro Internacional de Mejoramiento de Maiz y Trigo (Mexico, DF, Mexico)
CIP	Centro Internacional de la Papa (Lima, Peru)
ICARDA	International Center for Agricultural Research in the Dry Areas (Aleppo, Syria)
ICLARM	International Center for Living Aquatic Resources Management (Penang, Malaysia)
ICRAF	International Centre for Research in Agroforestry (Nairobi, Kenya)
ICRISAT	International Crops Research Institute for the Semi-Arid Tropics (Patencheru, India)
IFPRI	International Food Policy Research Institute (Washington, DC, USA)
IITA	International Institute of Tropical Agriculture (Ibadan, Nigeria)
ILRI	International Livestock Research Institute (Nairobi, Kenya)
IPGRI	International Plant Genetic Resources Institute (Rome, Italy)
IRRI	International Rice Research Institute (Los Baños, Philippines)
ISNAR	International Service for National Agricultural Research (The Hague, Netherlands)
IWMI	International Water Management Institute (Colombo, Sri Lanka)
WARDA	West Africa Rice Development Association (Bouaké, Côte d'Ivoire)