West Africa Rice Development Association

Annual Report 1996

WEST AFRICA RICE DEVELOPMENT ASSOCIATION

ANNUAL REPORT 1996

About the West Africa Rice Development Association

The West Africa Rice Development Association (WARDA) is an autonomous intergovernmental research association with a mission to strengthen West Africa's capability in rice production science, technology and socio-economics through research, training and communications activities.

Conducted in collaboration with the national agricultural research systems of member states, academic institutions, international donors and other organizations, the work of WARDA benefits the mostly small-scale West African farmers 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 public- and private-sector donors (see inside back cover).

The headquarters and main research facilities of WARDA are located at Mbé, near Bouaké, Côte d'Ivoire. Regional research centers in St-Louis, Senegal and Ibadan, Nigeria focus on Sahel irrigated rice and lowland rice breeding respectively.

Donors to WARDA in 1996 were: the African Development Bank, Canada, Denmark, the European Union, France, the Gatsby Foundation, Germany, the International Development Research Centre (IDRC), the International Fund for Agricultural Development (IFAD), Japan, Korea, the Netherlands, Norway, the Rockefeller Foundation, Spain, Sweden, the United Kingdom, the United Nations Development Programme (UNDP), the United States of America, the World Bank and several WARDA member states.

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ISBN 9291131113

About the Consultative Group on International Agricultural Research

The Consultative Group on International Agricultural Research (CGIAR) is a consortium of some 53 public- and private-sector bodies that provide funding for 16 international agricultural research centers, including WARDA. Founded in 1971, the CGIAR is cosponsored by the Food and Agriculture Organization of the United Nations (FAO), the United Nations Development Programme (UNDP), the United Nations Environment Programme (UNEP) and the World Bank.

The CGIAR's mission is to contribute, through research, to sustainable agriculture for food security in developing countries. In pursuit of this mission, the CGIAR focusses on five major research thrusts: increasing productivity, protecting the environment, saving biodiversity, improving policies and strengthening national research. It collaborates with a wide range of partners, especially national agricultural research systems, advanced research institutions in the North and the South, universities, the private sector, non-governmental organizations and farmers' associations.

CGIAR centers

CIAT	Centro Internacional de Agricultura Tropical
CIFOR	Center for International Forestry Research
CIMMYT	Centro Internacional de Mejoramiento de Maiz y Trigo
CIP	Centro Internacional de la Papa
ICARDA	International Center for Agricultural Research in the Dry Areas
ICLARM	International Center for Living Aquatic Resources Management
ICRAF	International Centre for Research in Agroforestry
ICRISAT	International Crops Research Institute for the Semi-Arid Tropics
IFPRI	International Food Policy Research Institute
IIMI	International Irrigation Management Institute
IITA	International Institute of Tropical Agriculture
ILRI	International Livestock Research Institute
IPGRI	International Plant Genetic Resources Institute
IRRI	International Rice Research Institute
ISNAR	International Service for National Agricultural Research
WARDA	West Africa Rice Development Association

WARDA

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West Africa Rice Development Association

Association pour le Développement de la Riziculture en Afrique de l'Ouest

Correct citation: WARDA 1997. WARDA Annual Report 1996. Mbé, Côte d'Ivoire.

Cette publication est aussi disponible en français, sous le titre: ADRAO Rapport annuel 1996.

Cover: Ivorien children enjoy a dish of rice made from a variety developed by WARDA and its partners

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

WARDA's STANDING as a center of excellence in the global scientific community owes much to the support of its donors, its membership of the Consultative Group on International Agricultural Research (CGIAR), and the strength of its partnerships with other institutions. But these factors pale beside the contributions of two outstanding individuals, both of whom have now left WARDA's employment.

Eugene Terry took up the post of Director General of WARDA in 1987. He came with a brief for change, which he set about pursuing with a vigor, a sincerity and a commitment unparalleled in the Association's previous history. By the early 1990s, WARDA had a strategy and medium-term plan that brought its mission and program into line with other CGIAR centers, its first ever Board of Trustees, a new management structure committed to accountability and transparency, a new home in Côte d'Ivoire and—most important—renewed and growing support from the donor community.

On these foundations it was possible to build a strong scientific program. This was the brief of Peter Matlon, who arrived at WARDA as its Director of Research not long after Eugene. Peter's vision, his gifts as a scientist, his insistence on quality, his ability to inspire others and to foster good teamwork—all have contributed greatly to the scientific reputation enjoyed by WARDA today.

Eugene and Peter's combined efforts have enabled WARDA to build its new headquarters building at Mbé, to maintain a healthy funding position despite difficult times, to assemble a team of highly motivated scientists and to establish a well focussed collaborative research program with a wide range of partners both within and beyond the region. In 1996, as the closing chapter of their era, they led a new medium-term planning exercise and the restructuring of WARDA's program, leaving the Association well positioned to meet the challenges of the years ahead. WARDA wishes both men well in their new positions with the World Bank and the United Nations Development Programme (UNDP) respectively.

Dr. Eugene R. Terry, Director General of WARDA, 1987-1996 (November)

Bringing the search for a new Director General to a successful conclusion was the major task of the Board of Trustees in the first half of 1996. The search process culminated in a recommendation, made to an extraordinary meeting of WARDA's Council of Ministers held in Accra in June, to appoint Dr Kanayo F. Nwanze (see box overleaf). It is one more measure of the progress WARDA has made in the past decade that its recruitment process was singled out for praise by the CGIAR's Chairman, Dr Serageldin, for its rigor and transparency.

Following a recommendation made in November 1996 by a management consultant, the Board of Trustees began a search for a

WARDA's new Director General

Dr Kanayo F. Nwanze has had a distinguished career in the CGIAR system as both a scientist and a research manager. He has worked in several francophone and anglophone countries of West and Central Africa, in addition to India.

After obtaining a doctorate in entomology at Kansas State University, USA, Dr Nwanze joined the International Institute of Tropical Agriculture (IITA), in Ibadan, Nigeria, as a post-doctoral fellow in entomology research. In 1977 he became principal entomologist (roots and tubers) with IITA's collaborative program on cassava in Zaire. Then, in 1979, he moved to Burkina Faso, taking up the post of principal cereals entomologist with the International Crops Research Institute for the Semi-Arid Tropics (ICRISAT). He remained with ICRISAT for the next 16 years, serving successively as acting director and team leader at the Sahelian Centre, Niger, unit leader and principal scientist based in Hyderabad, India, and project team leader for the Sorghum Medium Rainfall Project, also based in Hyderabad. In 1986 he took a year's sabbatical leave as adjunct professor at the Department of Entomology and Nematology. University of Florida, Gainesville, USA.

A Nigerian, Dr Nwanze is married with four children. We welcome him and his family to WARDA and to Côte d'Ivoire.

WARDA Staff Association

Dr Kanayo F. Nwanze

Director of Administration and Finance, re-establishing a post that had been vacant for some time. Under WARDA's new structure, the post of Director of Research becomes that of Director of Programs. As Peter Matlon agreed to stay with us during the transition phase, this post too remains to be filled in 1997.

These major changes at the top of WARDA did not disrupt the pursuit of the Association's normal business. At its November 1966 meeting, WARDA's Board of Trustees approved the medium-term plan for 1988-2000 for submission to the Technical Advisory Committee (TAC) of the CGIAR in March 1997. The approach taken to formulating the plan was broadly participatory, with inputs derived from the assessments of priorities made annually by WARDA's task forces, state-of-the-art reviews conducted by WARDA scientists, and the results of diagnostic research on farmers' perceptions of their main problems. The planning exercise itself used a Delphi method to evaluate the contributions to regional rice production made by alleviating different constraints. One new feature of the plan is a provision for spillover from WARDA's research to other regions of Africa besides our main mandate region, West Africa.

Closely associated with the medium-term planning exercise was the restructuring of WARDA. This was designed to promote multidisciplinarity and the flow of information and technologies across ecosystems, to integrate training and communications activities with research, to promote policy analysis in support of technology adoption, and to increase our emphasis on technology transfer and the assessment of impact. The rationale for the restructuring process, together with its outcome, is described in more detail in the overview article on research (see page 5).

WARDA's new management team, together with its Board of Trustees, fully endorses the new structure. We particularly look forward to placing more emphasis on technology transfer as we seek to increase the impact of WARDA's research. Such a shift in emphasis should come easily to WARDA, given its unique nature as an association for rice development as well as rice research. It does not mean that we will relinquish our pursuit of excellence in science, since good science is a prerequisite to good development.

The year was crowded with many other important items of institutional business. We shall try to pick out a few that are milestones of WARDA's progress or that have implications for its future.

One milestone was the signing of a new memorandum of understanding between IRRI and WARDA. The shared mandate of the two institutes for rice research in Africa means that a clear definition of roles is vital to the efficient use of the CGIAR's resources. The memorandum, which replaces the former tripartite agreement between IITA, IRRI and WARDA, provides such a definition, together with guidelines for collaboration over the next 5 years. An early outcome of that collaboration will be the transfer from IITA to WARDA's Mbé headquarters of the germplasm, staff and equipment associated with the African operations of the International Network for the Genetic Evaluation of Rice (INGER). This will promote easier access by WARDA staff and collaborators to a wider range of germplasm, and more flexible germplasm exchange throughout the region.

An internally managed external review of our integrated pest management (IPM) activities reported favorably on our achievements in this field, but identified several areas in which we need to improve our performance. These include collaboration between the different disciplines involved in IPM, the need to appoint an entomologist, our collaboration with IITA, and resistance breeding strategies.

WARDA's task forces were also evaluated as part of a review by the United States Agency for International Development (USAID) of the networks it funds in West Africa. The review found that the task forces fostered a participatory approach to research planning and a high level of national involvement in collaborative research. It also identified several areas in which there was scope for improving their efficiency. WARDA is considering the review's many recommendations, which included a proposal to reduce the number of task forces by merging some of them.

Lastly, a word about this report, which differs from its predecessors. WARDA's previous annual reports have reflected and indeed contributed to the Association's scientific output and reputation by providing a formal, comprehensive account of the year's research results. In our report this year we lighten the load on our readers by adopting a more informal approach and by presenting a few projects only. (The need for detailed scientific information will be met through separately published technical reports.) In keeping with our new emphasis on technology transfer, we discuss our links with partners and the implications of our research for development. And we've given a voice to some of the many people—in WARDA, partner institutions and the farming community—who make it all happen. We hope you like the result and would welcome your comments on it.

Just Faaland
Chairman, Board of Trustees

Kanayo F. Nwanze
Director General (incoming)

Research

Peter Matlon

NINETEEN NINETY-SIX was a watershed year for the organization of WARDA's research, training and communications activities. Building on lessons learned during the last two medium-term plan periods and guided by a rigorous priority-setting exercise initiated early in the year, WARDA's management and scientists designed a streamlined program structure built around a new set of interdisciplinary projects. Our new structure consists of two technology generation programs (the Rainfed Rice Program and the Irrigated Rice Program), a Policy Support Program and an Information and Technology Transfer Program. We have combined the former Research Division with the Training and Communications Division to form a single Program Division, integrating research, training and information dissemination activities for greater efficiency and impact (Figure 1).

Technology generation

WARDA's new research programs mark a major departure from our earlier agroclimatic structure. Beginning in 1990, two separate research teams were assembled: the first was the Continuum Program, based in Côte d'Ivoire and covering both rainfed and irrigated rice systems in the humid and subhumid zones; and the second was the Sahel Program, based in Senegal and focussing only on irrigated rice systems in the Sahelian zone. Experience, however, showed that many of the most important constraints to irrigated rice production cut across these broad climatic zones. The result was that our climate-based structure unintentionally created program barriers that discouraged scientists in different locations from working effectively together to solve some of the most important region-wide constraints to irrigated rice production. The creation of a new Irrigated Rice Program will help solve this problem by facilitating the formation of project teams across locations.

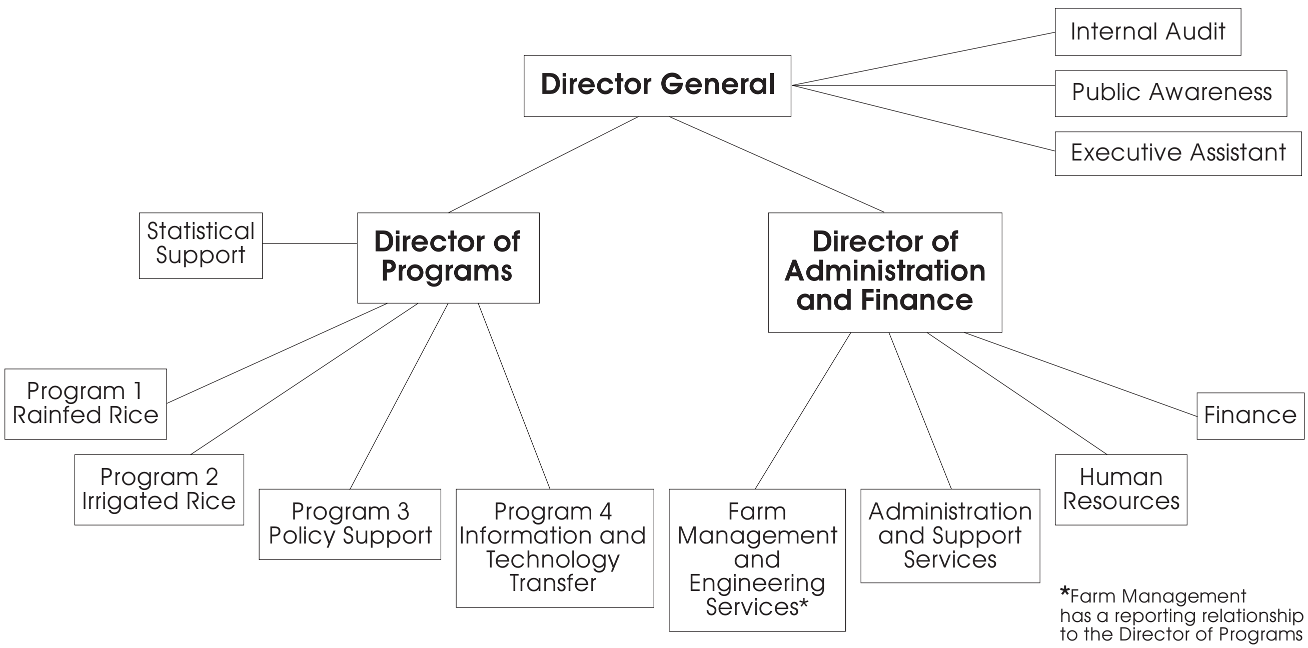
Having combined irrigated rice components into a single new program, it was logical that our research on upland and rainfed lowland rice systems should also be brought together in a new Rainfed Rice Program. This program builds on WARDA's original continuum concept by recognizing that uplands and lowlands are closely interlinked by many biophysical and socio-economic factors, requiring a coordinated research approach that explicitly cuts across the toposequence.

Within both the technology generation programs, WARDA's strategic goal has remained unchanged since our last medium-term plan: to combine productivity gains with natural resource conservation through the careful selection of target ecosystems and research interventions.

Policy support

The creation of a new Policy Support Program reflects WARDA's commitment to support national policy analysts. Experience has shown that it is not enough to develop well adapted and profitable technologies to achieve broad-based progress in rice production and yields. Government policies are often the determining factor affecting the success or failure of technical interventions. Far-reaching reforms introduced by most governments during the past 15 years under structural adjustment programs have liberalized and privatized most parts of the rice sector, creating

Figure 1. WARDA's new organizational chart.



exciting new opportunities—but also new problems, ones for which most policy makers lack appropriate analytical methods. Our Policy Support Program will respond to these new needs through methodology development and transfer and through complementary policy research. It will work closely with national policy making bodies, as well as with economists in national rice research programs.

Information and technology transfer

We have also learned that, despite the increasing availability of well adapted technologies, farmer adoption in many countries remains severely constrained by systemic problems in public development agencies. Poorly trained development workers, lacking access to knowledge of the most recent participatory extension methods as well as to new technologies, are a major obstacle to technology transfer. WARDA's past training and communications activities focussed on imparting new knowledge and skills to scientists and technicians, thereby strengthening national research capacities. WARDA's new Information and Technology Transfer Program will build on this achievement by widening our focus, with the goal of accelerating on-farm impact. Specifically, we will broaden the scope of our training and communications activities, placing greater emphasis on transferring the most recent research results to public-sector research and development institutions, non-governmental organizations (NGOs) and farmers' groups. Activities in both training and communications will therefore cut across each of WARDA's research programs as downstream extensions to research projects. Individual and group training opportunities will be designed to ensure the early diffusion of the newest methods and results generated by research in WARDA and in partner institutions and to strengthen the activities of the regional task forces.

Projects

The building blocks of the four new programs are 18 fully interdisciplinary problem-solving projects (see box). These new projects represent a major departure from our former projects, which had become too disciplinary in orientation. Diagnostic and characterization research conducted by WARDA scientists since 1990 has provided valuable information on the most important biotic and abiotic constraints that require immediate attention. That research has also helped identify the strategic research problems that need to be solved before major gains through applied research are possible. Several of these problems have become the foci of specific strategic research projects.

The new projects were developed through team planning exercises following a rigorous priority-setting exercise that combined consultation with national scientists, reviews of the literature and re-examination of the results of earlier WARDA characterization research. We explicitly considered WARDA's comparative advantage and identified opportunities to out-source research products from advanced research institutions with specialized capacities in key

WARDA's new projects

Rainfed Rice Program
- Sustainable intensification of lowland rice-based systems
- Stabilization of upland rice-based systems under shortening fallow
- Applying watershed management methods to optimize resource use in inland valleys
- Creating low-management plant types for resource-poor farmers
- Development of environment-specific breeding approaches for drought-resistant rice varieties
- Characterization of blast fungus genetic diversity and development of donors with durable blast resistance
- Integrated management of iron toxicity in lowlands

Irrigated Rice Program
- Improvement of resource use efficiency in irrigated rice-based systems
- Development of profitable land and water use systems preventing soil degradation in Sahelian rice irrigation systems
- Integrated management of rice yellow mottle virus (RYMV) in lowland ecosystems

Policy Support Program
- Rice policy formulation in the post-structural adjustment era
- Ex-ante assessment of rice research impact
- Ex-post assessment of rice research impact
- Characterization of hydromorphic rice environments prone to seasonal shallow flooding
- Reducing human health risks in lowland rice ecosystems

Information and Technology Dissemination Program
- Research on constraints to rice technology transfer
- Training for agricultural technology transfer
- Information dissemination for the transfer of agricultural technologies

areas. The projects have been designed both to focus the work of WARDA scientists and collaborators and to allow its more efficient management and monitoring. The results should be increased accountability and transparency, in both financial and research terms. The projects have also been designed to ensure that WARDA's research fully complements that of national programs and will reinforce its partnerships with them. Task forces and consortia will continue to be the major mechanisms through which we collaborate with national programs.

Afterword

Our planning process has benefitted from the inputs and participation of scientists and research managers from throughout the region. For these contributions, WARDA's management is most grateful. It has been a time-consuming exercise. But we see it as an essential investment if we are to continue to respond to changing needs and to conduct more focussed and efficient research and technology transfer in the years ahead.

The past year has also seen major changes in WARDA's management team. I am confident that the new team is well positioned to take WARDA to a new level of scientific excellence and to even greater impact on farmers' fields. To all WARDA's scientists and other staff, and to all WARDA's research partners, I wish every success in their continuing endeavors to fulfil WARDA's challenging but immensely worthwhile mandate.

Training and Communications

Anthony Youdeowei and Alassane Diallo

Training and communications activities in 1996 focussed on developing the concept of research-driven training and workshop activities, strengthening collaboration with other programs active in West Africa, and working with national and international partners to provide training for extensionists and farmers in the integrated management of rice pests. Programs in new communications technologies were initiated, including the establishment of e-mail links between national agricultural research and development institutions in West Africa. We also continued to play a leading role in the inter-center training program of the Consultative Group on International Agricultural Research (CGIAR). This program aims to build research management capacities in national agricultural research systems.

Linking research with training

The restructuring of WARDA's programs includes the integration of training activities with research. This will greatly facilitate the transfer of research methods and results developed by WARDA and its partners. In 1995, we began consulting scientists in WARDA's Research Division and in the task forces in order to identify those techniques or technologies that are ready to be transferred.

During 1996 we intensified this activity, ensuring that the training courses organized at WARDA were totally research driven. Emphasis has fallen initially on research conducted by the task forces. Consultations between the training unit and the task forces during the annual task force meetings led to a decision to go ahead with three courses, on the Diagnosis and Management of Rice Yellow Mottle Virus (RYMV), Lowland Rice Improvement and Production, and the Use of the Rice Development (RIDEV) Model in Sahelian Rice Production. The courses were organized and implemented by the Integrated Pest Management (IPM), Lowland Breeding and Sahel Task Forces respectively. Working with the relevant scientists, we designed the content and pattern of instruction as well as deciding on the most appropriate time and location for each course. Efforts were subsequently made to secure external funding for the courses.

The course on RYMV was organized in collaboration with the Technical Centre for Agricultural and Rural Co-operation (CTA), which supported the direct costs of some participants and resource persons. The remaining costs were covered by funds from the IPM Task Force. This course, which was designed for rice pathologists and breeders in West Africa, provided a forum for coordinating research on RYMV. A major output was a critical review of the existing systems for scoring RYMV infestations in rice plants. This led to a decision to adopt a uniform scoring system to facilitate cross-country comparisons of RYMV infestations and damage.

Funds for the other two courses were obtained too late to schedule them for 1996. In consultation with the scientists concerned, these courses were therefore rescheduled for 1997.

Making rice farmers IPM experts

Collaboration with the Food and Agriculture Organization of the United Nations (FAO) and with national programs in IPM training using a farmer participatory approach continued in Côte d'Ivoire and Burkina Faso. The training courses, modelled on a course given in Ghana the year before, are further described in the feature article on page 44.

The course in Côte d'Ivoire, conducted with technical and financial assistance from FAO and in collaboration with the Ministry of Agriculture and Animal Resources, was held at the Sakassou irrigation scheme, 42 kilometers southwest of Bouaké, in the center of the country. Training for trainers and farmers was organized in rice fields and in farmer field schools, which are schools without walls located close to the rice fields. By the end of the season-long course, 25 extension agents (17 from Côte d'Ivoire, 2 from Mali and 4 from Burkina Faso) and 70 small-scale farmers had been trained. The farmers were empowered to make IPM decisions in their own fields and motivated to adopt IPM practices, which enabled them to raise their incomes from rice by 35% over farmers who maintained their standard production practices using pesticides. The course generated considerable interest among researchers, donors and policy makers, as well as in the local farming community.

The course in Burkina Faso was conducted at the Vallée du Kou irrigation scheme, near Bobo-Dioulasso. There 21 extension agents were trained as rice IPM trainers and 75 smallholders were trained to adopt rice IPM practices. Farmers readily adopted the recommended practices, increasing their incomes by 34%.

Through these courses the national programs in both countries have been strengthened in the theory and practice of IPM, which they now know to be both environmentally friendly and economically profitable.

Building national capacities in research management

Efficient research management is essential for the successful performance of national agricultural research programs. Through a series of training needs assessment workshops associated with the CGIAR's inter-center training program, the International Service for National Agricultural Research (ISNAR) has identified research management as a priority area in which training is needed for national researchers. Working with resource persons from ISNAR, the International Institute of Tropical Agriculture (IITA), the International Crops Research Institute for the Semi-Arid Tropics (lCRISAT) and with Côte d'Ivoire's Institut des Savannes (IDESSA) as co-hosts, we successfully organized the third in a series of collaborative training workshops in research management. This workshop was attended by 14 program leaders or directors from five francophone countries in West and Central Africa. It provided an opportunity for participants to improve their abilities in three areas: program formulation; planning, monitoring and evaluation of research projects; and financial management.

Agricultural information management

Members of the regional rice research community need access to up-to-date information relevant to their work. Access is possible only if all levels of the information processing and dissemination chain are managed by highly skilled staff. WARDA's Library and Documentation Center is therefore putting more emphasis on capacity building, through training at both WARDA and in member states and through follow-up consultative and advisory missions.

In 1996 we conducted an in-depth consultancy for the Projet National Riz (SOPRORIZ) of Côte d'Ivoire's Ministry of Agriculture and Animal Resources. The purpose was to develop an information strategy and prepare for the establishment of a specialized library. One outcome of this exercise was a document on the procedures and mechanisms for setting up an integrated information system, to be known as the "Observatoire du Riz". Another was a 2-month training program for one staff member from SOPRORIZ at WARDA's headquarters.

From 10 to 13 June we participated in a preparatory session to plan and practice the delivery of lectures and the supervision of practical exercises for a workshop on the training of trainers in scientific writing. The workshop itself, organized by the Sahel Institute in Bamako, Mali, was held from 2 to 6 September. It was attended by senior scientists from agricultural research institutions in the member countries of the Comité Permanent Inter-Etats de Lutte contre la Sécheresse dans le Sahel (CILSS), with the objective of building a core of skilled scientists able to organize further in-country training. WARDA's contribution focussed on the use of information services and tools, with special reference to new computer-based technologies for accessing and managing information and literature.

At the Inter-African Phytosanitary Council of the Scientific, Technical and Research Commission of the Organization of African Unity (OAU), in Yaoundé, Cameroon, we assisted in establishing a computerized database of African specialists in the field of plant protection. We also provided 1 month's training in data base management for one of the council's staff.

We also played a role in preparing and implementing an international workshop on the information management policies of agricultural research institutions in Africa. This workshop was sponsored by CTA and held in Bamako, Mali, from 16 to 20 September 1996. One of its most important outputs was a working document on the establishment of an information system on current agricultural research in West and Central Africa. This system is conceived as a project of the Conférence des Responsables de la Recherche Agronomique Africaine (CORAF) that will be implemented in collaboration with WARDA once funding is secured.

The Africa Link Project

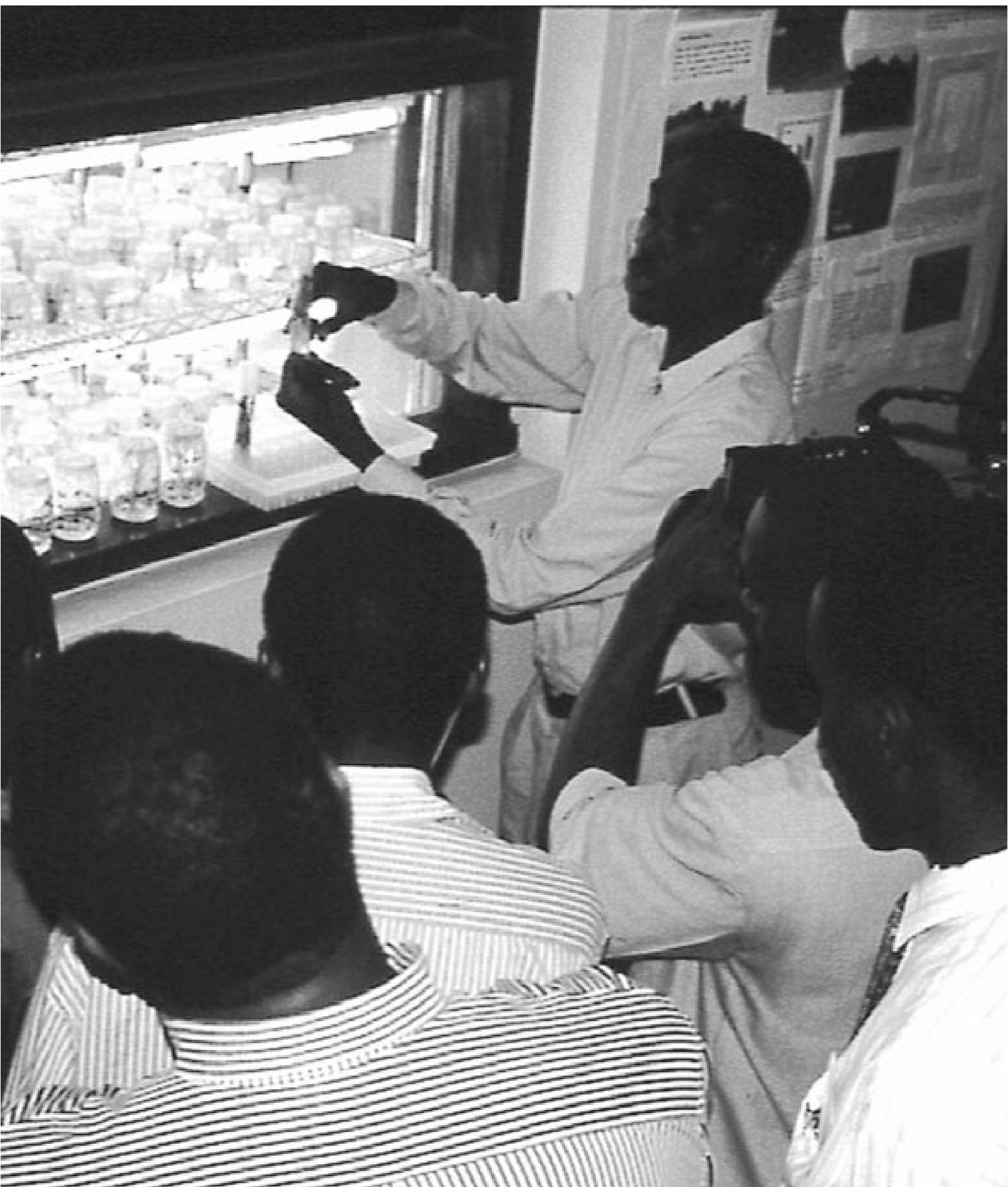
Many agricultural research networks, task forces, working groups and other inter-institutional initiatives are operational in West and Central Africa. An important component of all such activities is the exchange of information. E-mail and the Internet are efficient means of accessing and exchanging information among participants.

Under the Africa Link Project, WARDA has received a grant of US$ 300 000 from the United States Agency for International Development (USAID) to improve connectivity within the region and to the rest of Africa and the world. Since October 1996, all agricultural research institutions, networks and other relevant bodies in the region have been informed about the project. Information about the project has also been presented at various regional meetings.

Responses have been received from 33 institutions, requesting assistance in connecting some l29 sites (research stations and institutes) and providing e-mail access to between 500 and 1000 scientists. Institutions facing technical problems or having difficulty in getting the information required to submit their requests, or those in areas where there is no service provider, have been assisted wherever possible. This assistance will continue in 1997, when an expert will be sent round to study the options, put in place the appropriate mechanisms and provide complementary training for users.

The funds provided by the project cover the costs of connection and communication for the first few months (modem, installation, subscription fee and lump sum for the payment of the first quarter or year's bill), together with on-site training in the use of e-mail and the Internet. The project may also purchase additional computer hardware if necessary.

Allocation of funds is scheduled to start in January 1997. It is expected that all institutions will be connected by the end of that year. Workshops will then be held to ensure that participants make the fullest possible use of the potential of e-mail and the Internet. Participating organizations and networks may be assisted in establishing discussion forums and a home page.



Something New Out of Africa

A TEAM OF WARDA scientists has developed a new type of rice plant with a superior ability to compete with weeds. West Africa's poorest farmers look set to reap the benefits. And there could be environmental gains too.

Number one constraint

As part of a recent planning exercise, WARDA's scientists listed possible research topics in order of priority according to their perception of each topic's potential impact on regional rice production. Top of the list by a wide margin was combatting weeds —with a payoff estimated at a staggering 1.5 million tonnes of extra rice.

Weeds achieve their significance for rice yields not so much by devastating individual fields, as insect pests and diseases often do, but rather by exerting a steady downward pressure over huge areas, year after year. The problem is ubiquitous across West Africa, and particularly severe in the upland and hydromorphic parts of the savanna and forest zones.

Besides depressing yields, weeds cause serious equity and environmental problems. In terms of equity, they are the major constraint keeping small farmers small. In a WARDA survey, 80% of respondents said they would increase their rice area if only they could be sure of being able to weed it properly. Most farmers rely heavily on family labor for this task, herbicides being too expensive or not available. In upland and hydromorphic areas, they typically spend 40 to 60 days per hectare on weeding every season. With that sort of labor requirement, it is no wonder that weeding is often done late or not at all.

Environmentally, the weed problem drives one of West Africa's most damaging production systems—shifting cultivation. In this system, millions of hectares of forest are sent up in smoke each year as farmers clear new land for cultivation. Weeds are a major factor forcing farmers

Weeding takes hours of back-breaking labor, provided mostly by women

Shifting cultivation is Africa's most environmentally damaging production system. Weeds are a major factor forcing farmers to cultivate new land

Euphorbia heterophylla, one of the worst culprits

to move on. "There's a common misapprehension that shifting cultivation is just about declining soil fertility. In fact, it's every bit as much about the build-up of weeds", says David Johnson, WARDA's weed scientist. "Weeds compete with the crop more seriously each year. After 3 years, yields are so low that most farmers abandon the struggle and make a fresh start elsewhere."

The problem is getting worse as the region runs out of land and the production system intensifies. WARDA's researchers found that the weight of weeds removed from fields that had lain fallow for less than 5 years was double that from fields left uncultivated for 6-15 years. Rice yields were 24% lower, with 54% of the yield difference attributable to weeds (Table 1). "This means that controlling weeds is very much the challenge of the future", notes Johnson.

With cash and labor both in short supply, resource-poor farmers at present have few options for combatting weeds. In the early 1990s, WARDA's scientists began

Table 1. Impact of shortened fallow period on rice grain yield, weed infestation and soil fertility in upland rice-based production systems, Côte d'Ivoire, 1994-96.

	Guinea savanna			Derived savanna			Bimodal forest			Monomodal forest			Across sites
Parameters	LF		SF	LF		SF	LF		SF	LF		SF	Intensification-induced changes (%)
Rice yield (t ha $^{-1}$)	1.48	ns	1.15	1.12	ns	1.02	1.55	*	1.02	0.84	*	0.71	- 24
Weed weight (g m $^{-2}$)	36.8	ns	39.4	27.4	*	43.9	15.6	*	30.2	17.8	ns	20.6	+ 72
Soil characteristics													
Soil pH (H20)	5.4	ns	5.7	5.7	ns	5.6	5.3	ns	5.5	5.1	*	4.9	+ 2 ns
Soil pH (KCl)	4.6	ns	4.9	4.4	ns	4.5	4.3	ns	4.4	4.1	*	3.4	+ 1 ns
Organic carbon (%)	1.68	*	1.21	2.49	ns	2.28	1.65	*	1.54	1.79	*	1.53	- 19 *
N supply (mg kg $^{-1}$)	14.0	ns	11.8	24.9	*	16.6	14.9	*	11.3	27.3	ns	21.6	- 26 *
Yield difference (t ha $^{-1}$)		0.33			0.10			0.53			0.13		24 *
Due to weeds (%)		44			34			68			78		54 *
Due to N (%)		24			39			28			19		31 ns
Unaccounted for (%)		32			27			4			3		18 ns

Notes:
LF: long fallow = 6-15 years; SF: short fallow = 3-5 years; * = significantly different at 5%; ns = not significantly different.

exploring the potential of plant breeding to solve the problem.

A goldmine

Sierra Leonese plant breeder Monty Jones first came across *Oryza glaberrima* in the 1970s, while he was working at the Rokupr Rice Research Station, in his home country. He was struck by the fact that farmers in difficult environments continued to grow the species in preference to the higher-yielding *O. sativa* varieties that were also available. Clearly, *O. glaberrima* was better adapted to local stresses.

O. glaberrima is an indigenous African rice species that has been selected and cultivated in West Africa for at least 3500 years. It is not particularly high-yielding, but is a rich reservoir of genes for resistance to several stresses, including weeds. The Asian rice *O. sativa* was first introduced to Africa 500 years ago by Portuguese traders. Despite being more vulnerable to weeds it has a relatively high yield potential that has made it popular with farmers. As a result it has steadily replaced *O. glaberrima,* which is now thought to account for less than 20% of West Africa's rice area.

Jones' move to Mbé in the early 1990s to take up the post of upland rice breeder with WARDA gave him the opportunity to realize his long cherished dream of crossing the two species. By embarkin¡g on such a project, he took WARDA's breeding program in a new direction, away from the Green Revolution approach of the past.

"The Green Revolution 'answer' to the weed problem would have been to continue breeding for yield while encouraging the farmer to control the weeds", Jones says. "When I arrived in 1991, WARDA was still using a high level of inputs when evaluating possible new releases. The result was the typical plant breeder's syndrome: 'improved' varieties that did well on the research station but flopped on farmers' fields. Being short-stemmed *sativa* types, they were quickly smothered by weeds. We realized we were only catering for the 20% of farmers who used herbicides. We had to do something for the majority who couldn't afford them."

Jones and his colleagues began by requesting African rice materials from national and international genebanks. They assembled a collection of 1500 lines of *O. glaberrima,* which they then screened for a wide range of traits.

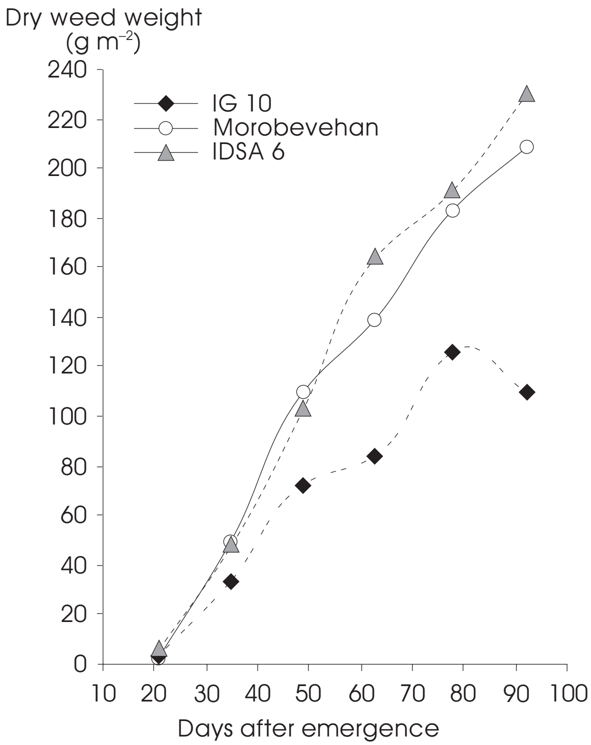
"What we found was a goldmine", says Jones. "The *glaberrima* lines showed tremendous diversity in their resistance to major stresses, including drought, blast disease and iron toxicity. They also varied greatly in their growth duration, response to fertilizer, grain quality and yield."

The screening exercise enabled the scientists to explore the traits that made *O. glaberrima* so effective at combatting weeds. Most of the accessions showed vigorous early growth and had droopy lower leaves—traits that enabled them to fill up the available space rapidly, physically elbowing out competitors in the early stages and then providing a canopy of shade to slow down their development still further (Figure 2).

Also evident were the traits that make *O. glaberrima* generally a poor grain yielder. Most lines produced only 74-150 grains per panicle, compared to 250 or more in *O. sativa.* Unlike *O. sativa,* the *O. glaberrima* accessions had few secondary branches on their panicles and hence

O. glaberrima elbows out competitors

Figure 2. Weed growth in rice fields sown to one O. glaberrima (IG 10) and two O. sativa (Morobevehan and IDSA 6) varieties.



a lower number of spikelets. They were also prone to lodging, seed shattering and long seed dormancy. Traits such as these explain why farmers have switched away from *O. glaberrima* to *O. sativa* varieties.

New plant type

As a result of the screening exercise, the scientists were able to identify eight *O. glaberrima* lines to serve as parents in a "wide crossing" program with *O. sativa.* These lines were relatively productive and had good grain quality, while displaying the characteristic *O. glaberrima* plant architecture. For the *O. sativa* parents, the scientists chose five high-yielding improved varieties developed by WARDA. They then made 48 crosses between the two species.

Crossing different species is a hit-and-miss business, with a high probability of sterility in the offspring. "We were all in suspense", recalls Jones. "But gene flows between the two species do occur in farmers' fields, so we thought we had a fair chance of success."

In the event, 7 of the 48 crosses produced a few fertile grains. The plants raised from these fell into three distinct groups: those that looked like one or other of their parents, which were the most numerous, and a few plants that were true interspecifics, combining features from both parents. Among the latter group were a handful of progeny that had the high number of spikelets typical of *O. sativa,* together with the droopy leaves and vigorous early growth of *O. glaberrima.*

These progeny were back-crossed twice to the *O. sativa* parents, to restore fertility and raise the yield potential. Progeny of the backcrosses were then subject to pedigree selection through a further six generations, until the desired traits appeared stable. The new plant type had been born.

Tested on the research station, two of the interspecific progeny outyielded both the *O. sativa* and the *O. glaberrima* checks when grown under low-input conditions, indicating a high degree of adaptation to difficult environments. Under high-input conditions, the

Realizing a long cherished dream: WARDA's upland rice breeder, Monty Jones interspecifics regularly yielded 3.4 to 3.8 tonnes per hectare, significantly more than the *O. glaberrima* parent and equal to the *O. sativa* check (Table 2). They combined early vigor with short duration, high yields and good grain quality.

WARDA's new plant type will not solve the weed problem by itself. Rather, it will form the kingpin of a package of measures, including improved agronomic practices such as higher sowing density, that will prove most effective when used together. Until now, that kingpin has been missing. As Johnson puts it, "If you have a good plant, then you can fight a winning battle on other fronts too".

New tools

The WARDA team is developing and applying new tools to increase the efficiency of its breeding program.

In the laboratory at Mbé, the scientists are using anther culture as a short cut to their final product. Anther culture is a form of tissue culture in which whole plants are regenerated from the anther or male part of the flower, using various growth media. The technique makes use of the fact that anthers, and the pollen they contain, are haploid—containing only one copy of each chromosome. Chromosome duplication thus gives rise to fertile diploid plants, with two identical sets of chromosomes. Anther culture can be used to produce genetically stable lines with a high level of fertility in around 24 months, compared with the 5 to 6 years needed in conventional selection. An additional advantage is the conservation of genetic material that would otherwise have been discarded.

In applying this sensitive technique to the regeneration of a new type of rice plant, WARDA's scientists were breaking new ground. At first, they didn't succeed: the medium N6, normally used to induce callus formation in *O. sativa,* produced zero results when used on the interspecifics. Jones went to China's National Institute of Agricultural Research, in Hangzhou, which has expertise in anther culture, to find out more about how to overcome the problems. His assistants, Hortense Sehi and Semon Mande, received specialized training in Taiwan and Colombia respectively. On their return the three tried several modifications, among which the addition of coconut milk and the hormone naphtaline acetic acid proved successful. Jones also developed a new medium

Table 2. Grain yield of 22 interspecific progenies and their parents under high and low levels of management.

	Grain yield (kg ha $^{-1}$)	
Variety	High input [1]	Low input [1]
WAB450-I-B-P-106-HB	3692 a	1613 bcde
WAB450-24-2-3-P33-HB	3665 ab	1496 de
WAB450-I-B-P-38-HB	3610 ab	1833 abcde
WAB450-24-2-1-P-5-HB	3600 ab	1511 de
WAB450-I-B-P-20-HB	3583 ab	2003 abc
WAB450-I-B-P-160-HB	3578 ab	2164 a
WAB450-24-3-2-P18-HB	3565 ab	1463 de
WAB450-11-1-1-P3-HB	3533 ab	1395 de
WAB450-I-B-P-133-HB	3525 ab	1685 bcde
WAB450-I-B-P-91-HB	3448 abc	1533 cde
WAB450-I-B-P-31-HB	3370 abc	1703 abcde
IDSA 6 (O. sativa parent)	3368 abc	1390 e
WAB450-I-B-P-32-HB	3305 abc	1521 de
WAB450-I-B-P-23-HB	3278 abcd	1498 de
WABC 165	3270 abcde	1885 abcd
WAB450-I-B-P-62-HB	3259 abcde	1714 abcde
WAB56-104	3255 abcde	1460 de
WAB450-I-B-P-142-HB	3220 abcde	1456 de
WAB450-24-3-1-P135-HB	3120 bcdef	1793 abcde
WAB450-I-B-P-147-HB	2933 cdef	1705 abcde
WAB450-I-B-P-105-HB	2715 defg	1667 bcde
WAB450-15-3-1-P8-HB	2699 efg	1640 bcde
WAB450-11-1-8-KB	2608 gf	1542 cde
WAB450-I-B-P-137-HB	2493 g	1409 de
WAB450-I-B-P-28-HB	2373 g	1668 bcde
CG 14 (O. glaberrima parent)	1693 g	2073 ab

[1]Means with the same letters do not differ significantly from each other.

Anther culture is being used to speed up the breeding effort

A newly developed medium promotes rooting

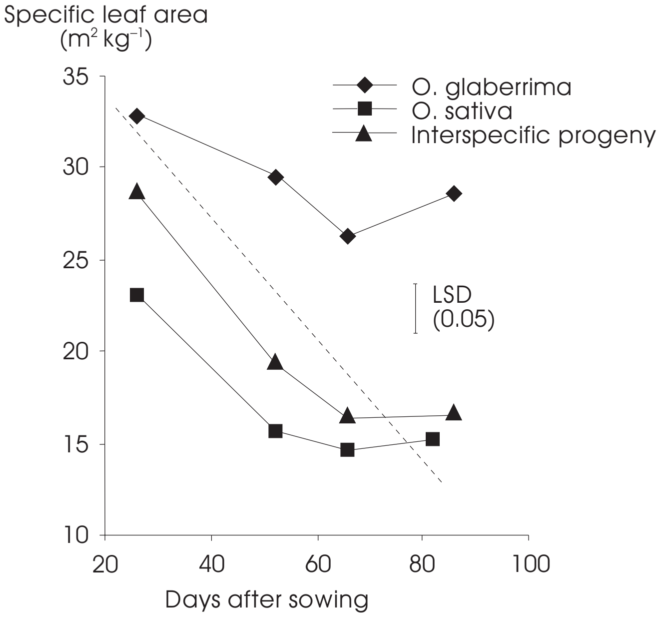
called multi-effective triazole—a hardening chemical that allows profuse root development—to improve on the poor survival rate initially experienced when plants were transferred to the soil.

Another tool being used by the team is modelling. The scientists were well aware that the interspecifics' ability to combat weeds comes at a cost to other useful attributes, especially yield potential. "We're not going to get something for nothing", observes Johnson. "And we don't want to pay the highest price in terms of yield. The interspecifics must still produce a lot of good quality grain if they are to appeal to farmers."

Michael Dingkuhn, the team's systems analyst, has developed a model that plots the relationships between attributes such as tillering ability and leaf area index—the ratio of leaf area to ground area—against yield potential. According to Dingkuhn, the model is proving a useful predictive tool, avoiding the lengthy and expensive business of growing out each and every cross to study its performance empirically.

An important concept in the modelling work is that of specific leaf area (SLA). This is defined as the area of leaf per gram of leaf weight and is thus a measure of leaf thickness. A high SLA indicates the ability to produce large but thin leaves, or in other words a plant that spreads well while incurring relatively low loss of grain. SLA varies greatly between genotypes but appears relatively stable across environments, suggesting that the parameter could be a useful selection criterion for plant breeders. The ideal plant will have a high SLA during early growth but a rapid decline in SLA thereafter, as it puts less into vegetation and more into the production of grain (Figure 3).

Figure 3. Specific leaf area (SLA) over time for an interspecific progeny (WAB 450-24-3-2-P18-HB) and its O. sativa (WAB 56-104 5) and O. glaberrima (CG 14) parents. The broken line indicates the ideal SLA for a weed-competitive high-yielding plant.



Lastly, the team has come up with what they hope will be a better way of screening varieties empirically for their ability to compete with weeds. Weed growth is highly variable, so screening work at present requires many replications and has to be done in field plots rather than in pots in the greenhouse. This has meant that only a small number of progenies from the crossing program could be screened each season, slowing the pace of research considerably.

The new approach, which is still at the experimental stage, uses other crop plants to simulate the role of the weeds. These plants are easier to sow and hence produce a more predictable biomass, offering even competition and so enabling the number of replications to be reduced. Candidates tested so far include include maize, cowpea and even the *O. glaberrima* rice line, IG 10. The results look promising, with IG 10 proving a particularly good predictor of average levels of competition from weeds (Table 3).

"This method promises a sixfold increase in the number of lines we can screen", says Johnson. "That means we'll be able to provide feedback to breeders much earlier in the varietal development process."

Powerful weapon

The new rice plant represents a powerful new weapon in the resource-poor farmer's struggle against weeds. Women farmers in particular stand to benefit, since they

Table 3. Biomass of rice vareties in response to competition from different species relative to monoculture (ratio).

		Competitiveness against:			
Rice variety		Weeds	Cowpea	O. glaberrima (IG 10)	Maize
O. sativa:					
Morobevehan		0.88	1.35	0.94	0.74
OS 6		1.04	1.25	1.05	0.82
WAB 56-104		0.39	0.99	0.69	0.34
WAB 56-50		0.83	1.35	0.89	0.56
IDSA 6		0.67	1.31	0.75	0.67
IDSA 10		0.78	1.36	0.66	0.51
Bouaké 189		0.76	1.60	0.71	1.07
O. glaberrima:					
IG 10		1.16	2.19	1.16	1.13
CG 14		0.95	1.21	0.96	0.94
V 4		0.68	1.72	0.94	0.75
Interspecifics:					
WAB 450-11-1-P40-1-HB		0.70	1.64	0.96	0.53
WAB 450-I-B-P-106-HB		0.79	1.52	1.20	0.64
WAB 450-I-B-P-133-HB		0.60	1.31	0.95	0.42
Average		0.77	1.43	0.91	0.69
Standard error (±)	0.043				
Coefficient of variation	36				

An improved screening method promises faster verification of competitiveness

Something new out of Africa

provide the bulk of the labor to rice cultivation in West Africa. By reducing labor inputs while raising yields, the new rice will lower the costs of production, thereby making the classic contribution of new agricultural technology to economic growth and equity. It could also bring sizeable environmental gains, helping to stabilize the shifting cultivation system and hence to reduce deforestation, while enabling countries to cut back on herbicide imports.

The most promising interspecific lines have already reached farmers' fields, where they are getting an enthusiastic reception from growers (see p. 21). In collaboration with Côte d'Ivoire's national program, trials are under way at a range of sites across the country. Seed of the new lines has also been sent to several other West African countries, including Togo, Ghana and Benin.

Jones believes adoption rates in West Africa will be high. "Five to six years from now, I see these new materials flowing onto farmers' fields throughout the region", he says. As is typical in resource-poor farming systems, the new plants are likely to complement existing varieties rather than totally replace them, so there will be gains in biodiversity too.

Lastly, the benefits of the new technology could spread beyond Africa to other developing regions. Resource-poor Asian farmers, for example, face mounting problems in combatting weeds as rising population density forces them to cultivate increasingly marginal areas. In bringing gains to such farmers, the new rice plant would demonstrate the coming of age of African science, reversing the conventional flow of technologies into the region from elsewhere.

"Ex Africa semper aliquid novi", wrote the Roman poet Pliny the elder in the first century A.D.—there is always something new out of Africa. A product of African science at its most creative, WARDA's new rice plant demonstrates that Pliny's words are still true today.

Farmers in the Driving Seat

WARDA's scientists have long conducted surveys to determine the varietal preferences of rice producers and consumers. Now, through participatory on-farm research, they are forging a deeper understanding of why farmers select some varieties and not others. The aim is to promote adoption by making the farmer an equal partner with the scientist in the development of new technology.

Famine to feast

"It was like Christmas", says Tim Dalton, agricultural economist with WARDA. He's describing the mood of excitement and curiosity among farmers as they examined rice plants during an evaluation day held at the village school in Ponondougou, Côte d'Ivoire. "In an area where no new varieties have become available for at least a decade, farmers were keen to explore what was on offer. For them, it was a case of famine to feast."

The farmers had been exposed to 60 different rice lines, chosen to represent the diversity of rice germplasm in the region. The lines included already released varieties of *Oryza sativa* together with possible new releases, a few traditional *O. glaberrima* types, and 10 of the new interspecifics developed by WARDA scientists and their national partners (see p. 13). After a session in which all the farmers inspected the display together, each was asked to pass through separately and to make his or her selections. The scientists then asked the farmers to give the reasons for their choices, again separately so as to minimize the influence of others.

The day was part of a broader 3-year exercise conducted in different rice-growing environments across the country and at different stages in the rice cycle. During the first year, farmers are asked simply to select the varieties that most interest them; in the second, they are given seed of these varieties for trials in their own fields, allowing them to make a direct comparison with their traditional varieties; in the third, they will be asked to pay for the seed. The third year will be the acid test of farmers' willingness to adopt: will they put their money where their mouths were?

Research in the savanna zone is conducted at two villages, Ponondougou and Pondou, 15 km apart, near the town of Boundiali. At these locations the exercise is now in its second year. Activities in the forest zone, due to begin in 1997, will be based at Gagnoa and Danané. At

Farmers showed great interest in the diversity of rice types on display

To avoid farmer-to-farmer influences, each farmer was interviewed separately

each location, WARDA's technicians launch the exercise by sowing the set of accessions in the fields of a farmer selected for his or her willingness to innovate. During the season around 80 farmers in the neighborhood are invited to visit the crops at up to three different stages: the vegetative growth stage, 40 to 45 days after sowing, when early vigor and the ability to suppress weeds can be assessed; the flowering stage, at which characteristics such as height, duration and resistance to pests and diseases become evident; and just after harvesting, when farmers can evaluate grain quality and quantity before making the final choice of an overall favorite.

Setting the trend

Master of ceremonies at most of the evaluation days is WARDA's upland rice breeder Monty Jones, himself responsible for developing much of the material on display. Jones sees the exercise as setting the trend for future rice breeding efforts in the region.

"Participation and biodiversity go hand in hand", he explains. "Putting the farmer in the driving seat as regards technology development makes it far more likely she or he will adopt. Our aim is to expose farmers to the full range of germplasm available, allowing them to enrich the local stock by making new choices." In this respect the exercise represents a break with traditional approaches to technology development and dissemination, in which multilocational trials are followed by the nationwide release of a few varieties only.

The exercise is also designed to be gender-sensitive. Rice is primarily a women's crop in West Africa, and women's views on new genetic materials, which often went unheard in the conventional station-based research of the past, may be different to those of men—with important implications for the breeding program. Women's choices and criteria are therefore distinguished from men's in the data recorded during evaluation days. Interviews with women are conducted by a separate team of three women scientists, to remove any possible bias caused by male interviewers.

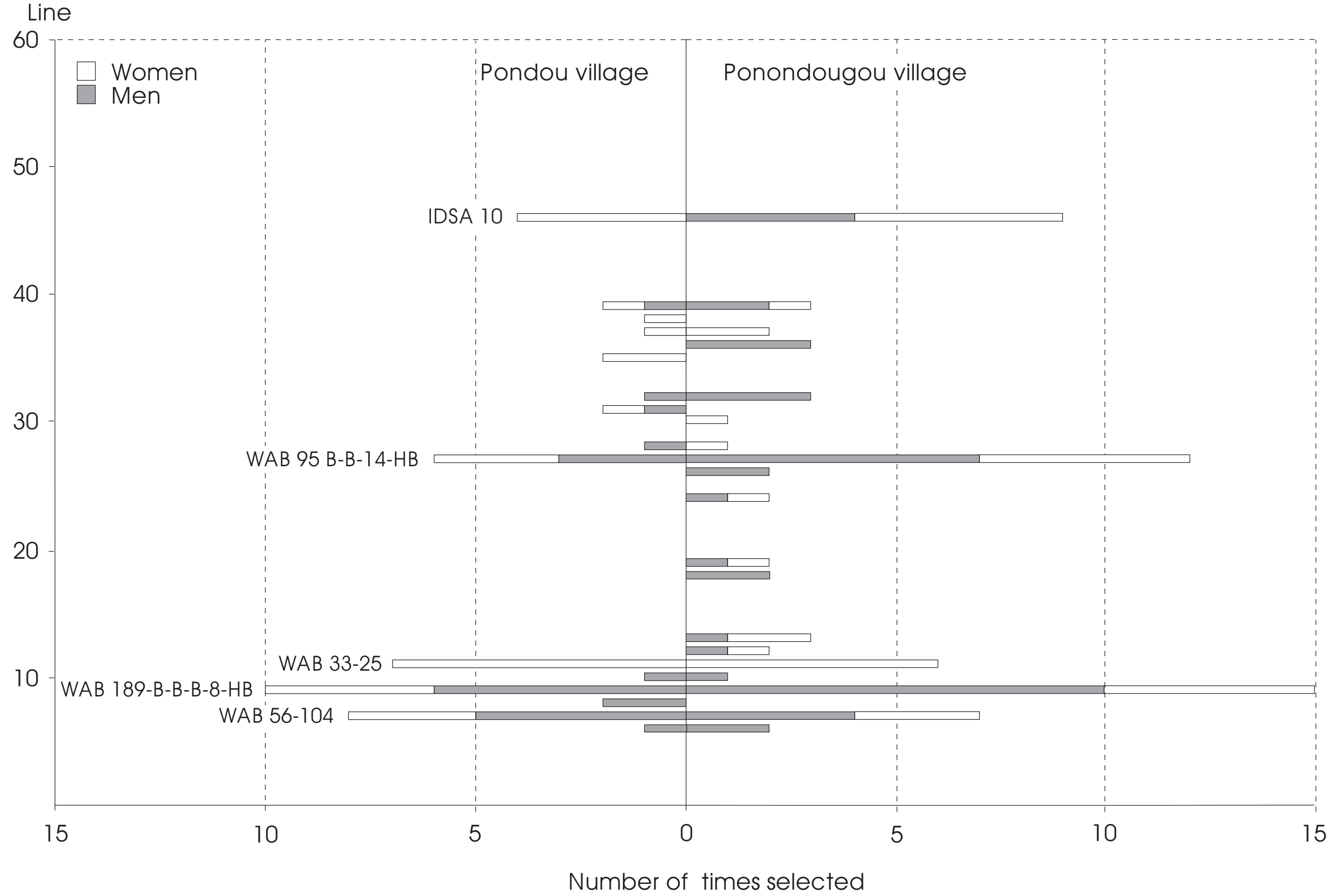
Putting farmers in the driving seat has proved a popular move with the farmers themselves. The exercise in the Boundiali region started with 61 farmers but soon expanded to 81—the maximum number the researchers felt they could handle—as farmers flocked to join it. As word spread, farmers from more distant villages came to ask that the exercise be repeated there. In a similar exercise launched at Saioua, in the south of the country, the farmers present at the first evaluation day were so enthusiastic about the experience that they went to tell their Chief and elders, all of whom came along during the second half of the day to make their own selections.

Farmers' choices

As the exercise is still in its early stages, the results so far must be treated with caution. That said, the initial findings from the Boundiali region suggest that breeders have correctly gauged farmers' needs (Figure 4).

Farmers' first and second choices in both villages were WAB 189-B-B-B-8HB and WAB 95 B-B-14-HB, both of which are new breeding lines developed from interspecific hybrids. The farmers were impressed by the ability of these lines to beat weeds during the early growth stages and to go on to produce a high yield of attractive,

Figure 4. Men and women's choices of rice germplasm lines at two locations in the savanna zone of Côte d'Ivoire, 1996.



large-sized grains with good cooking qualities. Third and fourth places went to IDSA 10 and WAB 56-104, both improved *O. sativa* varieties. The first of these was developed by WARDA's national partner in Côte d'Ivoire, the Institut des Savannes (IDESSA), while the second was developed by WARDA.

Interestingly, farmers' first few selections were broadly similar at the two locations. The conventional wisdom regarding varietal preferences in West Africa is that preferences vary greatly from one village to the next. This was not borne out by the results from Boundiali, but it remains to be seen whether greater differences become apparent at other locations—either locally or between regions.

Besides the four or five most popular lines, there were some significant minority choices at both locations. These selections, which show greater variability across locations, probably cater for farmer-specific conditions, including taste and cooking quality. The existence of this "second tier" of selections bodes well for future biodiversity at local level.

Women valued the same traits as men, but ranked them differently

Figure 5. Main selection criteria of men and women at two villages in the savanna zone of Côte d'Ivoire, 1996.

Men	Rank	Women
Produces well with/without fertilizer	1	Yield
Large grains	2	Long grains
Yield	3	Swelling
Good taste	4	"Pretty" grains
Long grains	5	Easy to dehull
74	Percentage choosing according to these criteria	86

Women and men valued the same plant traits but ranked them differently, reflecting their different roles in the marriage and business partnership (Figure 5). The women chose lines primarily for their yield—an important consideration when feeding a large family. Men were also interested in yield, but with the added qualification that fertilizer inputs should be kept low, since they are responsible for buying fertilizers. Predictably, women were more interested than men in ease of dehulling, while the men focussed more on the taste of the cooked rice. Some women also went for tall plant height, which takes the backache out of harvesting, especially when carrying a baby.

Two varieties, WAB 450-I-B-P-28-HB and WAB 33-25, were selected by women only at both locations. The first of these is an interspecific progeny with good early vegetative growth, giving it a head start over weeds. The women, all of whom were responsible for weeding, spontaneously named this characteristic as a reason for their selection. They also said the line would do well in areas with problem soils—another facet of local farming with which they were familiar. WAB 33-25, a new breeding line derived from *O. sativa* materials, was popular on account of its large grain size and the ease with which it could be pounded.

Women frequently described the grains they liked as "jolie"—literally, "pretty". Prettyness appeared to be a composite quality in which grain color, pattern, length and width all played a part. In many cases it was associated with the presence of an apiculus—a purple or red spot on the tip of the grain that is a characteristic of *glaberrima* varieties and thought to be an indicator of good aroma and hence good taste. If this proves to be the case, the apiculus could serve as a useful morphological marker for plant breeders.

Lastly, one woman selected a line with awns—the slender bristles that project from the spikelets in some varieties. The reason she gave was that the awns are anathema to birds, piercing them the moment they alight on a panicle, so growing this variety would allow her children to spend less time on bird-scaring and more on doing their homework and helping about the house. This was an eye-opener for the breeders, who usually select against the presence of awns.

Methodological issues

Participatory on-farm varietal selection is a new area of research in which methods are evolving rapidly. The WARDA team is giving considerable thought as to how to improve both data collection and the interpretation of results.

The team's main concern while gathering information on farmers' selection criteria has been not to prejudice farmers' responses by asking leading questions or steering the conversation in certain directions—habits that often dogged the formal questionaire-based surveys typical of farming systems research. To combat this problem the researchers adopted an "open" approach, allowing farmers to express themselves in their own words rather than being bound by a specific set of questions with "yes or no" answers. This approach yielded a wealth of information, but it did lead to some ambiguity and overlap between different criteria—as in the case of *jolie grains* described above.

One way of improving the usefulness of the results is to match farmers' varietal preferences with socio-economic characteristics such as household size and income. Among other things, this will enable the team to discover whether the farmers use different criteria to judge rice intended for home consumption or marketing. Dalton plans to use cluster analysis to analyze these and other factors, with the aim of improving the targeting of new varieties to users once they are released. He also hopes to use conjoint analysis, a technique borrowed from product marketing, to find out which traits are most important in determining farmers' choices and how farmers trade off one trait against another—information that could prove useful to plant breeders.

A host of other intriguing questions remain to be answered. For instance, how similar are farmers' choices to what they already grow? Are more adventurous choices correlated with relatively favorable financial

Processing qualities, such as ease of dehulling and pounding, were of more interest to women

One woman chose a variety with awns

circumstances and good access to inputs and markets? And do farmers' choices change over time, according to such factors as their perception of the type of season, or market preferences?

Spreading the benefits

Despite the unanswered questions, WARDA's participatory research on varietal selection has already paid handsome dividends. Besides speeding up the development of new rice varieties, it is helping to gauge the acceptability of what is already available and to stimulate the demand for new varieties in the farming community. Most importantly, it has confirmed that past diagnostic research has correctly identified farmers' needs, with the result that breeders are now coming up with the right answers.

Jones and his colleagues have lost no time in seeking to spread these benefits to other countries in West Africa. Similar exercises are planned to start in Ghana and Togo in 1997; and in 1998, with Japanese funding, a further four countries will join in, namely Benin, Gambia, Guinea Bissau and Nigeria.

Rice Cultivation: Kill or Cure?

MALARIA IS Africa's single biggest killer, claiming the lives of half a million children every year. Over a lifetime, the average African may experience up to 60 episodes of the disease, each of them potentially fatal. It is often assumed that lowland rice fields provide an ideal breeding ground for the malarial mosquito. But do they really? And if so, do increased populations of the vector actually increase the incidence of malaria?

A vigil for science

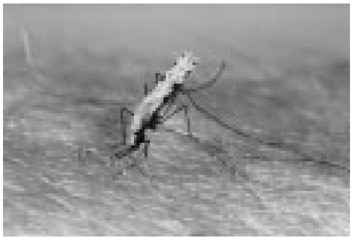
It's 2.00 a.m. on a pitch-black African night. Alone in a dark room sits a man, stock-still, his chest, legs and arms naked, lit only by the torch he is holding. An eery *chiaroscuro* figure, from a painting by Rembrandt.

The man makes a brief forward movement of the head, accompanied by a gentle hissing sound as he sucks in through the plastic tube he holds in his mouth. From the spot on his arm on which it had alighted, another mosquito joins its companions in the glass jar to which the tube is connected.

The scene is a house in a small village on the Office du Niger irrigation scheme, in Mali. The man is one of a team of research assistants working in 6-hour shifts through the night. In the morning, the team's catch of mosquitoes will be sent to the laboratory for analysis, to find out how many carry malaria. The aim is to assess the average number of infective mosquito bites to which the local population is exposed at different seasons of the year.

This experiment is one of several being conducted under the auspices of the Rice and Human Health Research Consortium, a group of national and international research institutes and donor organizations formed in 1994 and based at WARDA's Mbé headquarters (see box overleaf). The consortium's objective is to answer the many questions surrounding the links between rice cultivation and malaria.

Malaria kills half a million African children a year



The disease is spread by several species of mosquito, notably Anopheles gambiae

The consortium partners

In Côte d'Ivoire:
- Centre Universitaire de Formation en Entomologie Médicale et Vétérinaire
- Institut Pierre Richet (Organisation de Coordination pour la Lutte contre les Grandes Endemies)

In Mali:
- Ecole Nationale de Médecine et de Pharmacie
- Institut d'Economie Rurale (IER)
- Institut National de Recherche en Santé Publique

International:
- West Africa Rice Development Association (WARDA)
- Joint Panel of Experts on Environmental Management for Vector Control (PEEM) of the World Health Organization (WHO), the Food and Agriculture Organization of the United Nations (FAO), the United Nations Environment Programme (UNEP) and the United Nations Center for Human Settlements (UNCHS)

Donors:
- International Development Research Centre (IDRC)
- Government of Norway
- Danish International Development Agency (DANIDA)

The shallow, sunlit waters of lowland rice fields appear to provide the perfect habitat

The health conundrum

The epidemiology of malaria is extremely complex, and there are plenty of pitfalls for the unwary.

Lowland rice fields have long been under suspicion as breeding grounds for malarial mosquitoes. With their wide expanses of clean, shallow water exposed to air and sunlight, they appear to provide ideal conditions, at least until the crop is established. Mosquitoes sleep during the day, so people actually working in the fields are not at any heightened risk of being bitten. But the night-time risk to the local population as a whole could increase if mosquito numbers rise following the introduction of irrigated or wetland rice cultivation. And intensifying cultivation through double cropping could make matters even worse, raising numbers still further by prolonging the breeding period.

That, at least, is the theory. The trouble starts when you look for concrete evidence to support it. Socio-economic research by WARDA during the early 1990s did reveal that some farmers in Côte d'Ivoire regard lowland rice cultivation as risky for health reasons, including malaria. But beyond these subjective perceptions the scientific literature on the subject is inconclusive, with some studies pointing to increased frequencies of malaria when rice cultivation is introduced, others to reduced frequencies and still others to no change.

So are ricelands in fact any more culpable as habitats than other damp areas, including uncultivated swamps and the hydromorphic fringes that typically surround wetlands? Some argue that, as the rice crop establishes, providing shade, rice fields pose *less* of a threat than these other areas, or at least do so for a shorter period. Here the effect of agronomic variables, such as seeding density and method, could be decisive.

The relative importance of ricelands as a breeding ground can be expected to vary from zone to zone. In humid areas, ricelands are far from the only potential habitat. Provided it is filled with shallow water, an area as small as a footprint in the mud may serve. The irrigation schemes of the Sahel, in contrast, represent virtually the only available year-round breeding ground in a zone that has only a short rainy season and hence, away from the schemes, a low mosquito population for all but a few months of the year. The savanna represents an intermediate situation between these two extremes.

Beyond these considerations lie still more complex issues. The population dynamics and life-cycle of the malarial mosquito are such that higher mosquito populations do not necessarily lead to increased risk of disease transmission. And even if they do, that does not mean there will necessarily be more cases of malaria. Incidence depends on the susceptibility of local people and on the preventive measures they take, factors which vary greatly according to previous levels of exposure and to education, income and the perception of risk.

A cross-sectoral study

In 1995 the consortium launched a study to investigate these questions. The study's unique feature is its cross-sectoral nature, integrating the agricultural disciplines with those of human health and the social sciences.

Research is conducted in the three major rice-growing zones of West Africa. Twenty-four villages each were selected in the humid forest and savanna zones of Côte d'Ivoire, eight representing single-cropping rice systems and eight double-cropping systems, while the remaining eight have wetlands that are uncropped or at least not cropped to rice. In the Sahel, villages on the Office du Niger irrigation scheme in Mali are compared with villages in the dry rangeland, inhabited by pastoralists.

In each village, consortium scientists assess the effects of different agricultural systems and practices on mosquito populations throughout the wet and dry seasons. At 6-weekly intervals, they also measure the average number of infective mosquito bites per person and record the number of new malaria cases occurring.

It's not crop growth!

In a typical forest-savanna transition ecology, the scientists detected a sharp fall in the density of mosquitoes in rice fields about 6 weeks after sowing/planting. Similar falls found in previous studies had been put down to the effect of shading provided by the rice crop. But in the consortium experiments the same fall occurred at different sowing densities and regardless of whether the crop had been transplanted (and was therefore more mature) or seeded directly.

Surprised, the scientists repeated the experiment, adding an empty plot that had been prepared for sowing but not actually sown. Preparations for sowing include the creation of a clean seedbed using herbicides, and the application of fertilizers.

To their astonishment, the scientists found that the mosquito population of the empty plot behaved in exactly the same way—falling drastically after 6 weeks. "Something happens that is associated with soil preparation and the use of inputs, not with the growth of the rice", says Thomas Teuscher, the Swiss medical doctor who coordinates the consortium.

Teuscher and his colleagues are now conducting a further set of trials, comparing plots with and without inputs and separating the effects of fertilizers and herbicides. In the first year of these trials, both hydromorphic and lowland (with standing water) plots produced similar amounts of mosquito larvae. However, in lowland plots with inputs, the breeding period doubled in length from 6 to 12 weeks compared to plots without inputs, leading to a fivefold leap in the mosquito population. "Inputs appear somehow to change the acquatic environment, making it more favorable for larvae over a longer period", concludes Teuscher.

Once bitten...

Although unexpected, these findings still appear to support the case against rice systems and their intensification. Common sense suggests that, especially in villages where the high use of inputs is coupled with double cropping, higher populations of mosquitoes should lead to more infective bites per person and hence to more outbreaks of malaria.

Rice growing does not appear to increase the risk to villagers in the savanna and forest zones, where malaria is endemic...

Figure 6. Possible relationships between malaria mortality and exposure to malaria.

But the data on the number of infective bites per person do not provide clear evidence of such a relationship. True, during the dry season double-cropping villages in the savanna zone had levels of exposure twice as high as those of single-cropping villages (10 bites per person per month, compared with 5). Awkwardly, however, the figure for non-rice villages was at the same high level as for double-cropping villages—10 bites per person per month.

And the common sense hypothesis unravels completely when the figures for new malaria cases are considered. A total of 2.6 new fever cases were reported per 1000 inhabitants in double-cropping villages, compared with 2.0 in single-cropping villages and 2.4 in non-rice villages. In other words, broadly similar levels at a time of year when double-cropping villages could be expected to have a significantly higher level. These figures should be interpreted cautiously, since they cover only one season and fever cases are not necessarily malarial. But they do suggest strongly that rice cultivation systems do not, after all, increase the risk of malaria, at least in the savanna zone.

The key to the mystery, according to Teuscher, lies in the relationship between infective bites and disease incidence. This relationship is already known from other studies (Figure 6). As the number of bites per year rises from 0 to 10, incidence and mortality increase sharply. But from 10 upwards, the curve levels off rapidly, with incidence remaining remarkably stable through levels of exposure ranging up to 1000 bites per year. The explanation is that, at increasing levels of exposure, people acquire immunity. At the highest levels of exposure, of over 1000 infective bites per year, there may even be a decrease in the number of malaria cases, although the exact shape of the curve remains unknown.

Extrapolating the dry-season figures for the number of bites per person in savanna villages gives levels ranging from 50 to 100 infective bites per person per year. All types of village thus lie well above the point at which the curve levels off. In other words, at infestation levels this high, whether or not you grow rice is unlikely to make any difference to the incidence of malaria in the medium to long term.

The data from the Sahel zone suggest that growing rice could even provide some measure of protection. Here the seasonality of exposure appears to make a big difference to susceptibility. In dry rangeland villages over a fifth of the human population, or 220 people in 1000, go down with malaria during the brief rainy season, whereas on the Office du Niger irrigation scheme, where exposure is year-round, incidence is four times lower, at only 57 cases per 1000 inhabitants.

But visiting irrigation experts shouldn't throw away their chloroquin, Teuscher warns. Newcomers to the scheme, including migrant laborers, traders and others, are particularly vulnerable. Higher incomes, allowing people to afford protective measures such as bed-nets and prophylactics, may be a further factor explaining the lower incidence. And in any case, since the human population density on the scheme is far greater than in surrounding rangeland areas, the absolute number of people falling ill is still higher.

Mosquito survival rates could be another factor explaining the relatively high incidence of malaria in rangeland areas. When mosquito populations rise beyond a certain point, the life of each individual starts to shorten as competition for resources increases. A malarial mosquito must be at least 12 days old before it becomes infective. On the irrigation scheme, where populations are high, only 1-3% of mosquitoes live that long, whereas in relatively depopulated rangeland areas the figure can be as high as 79% during the dry season. Paradoxically, decreasing the population of mosquitoes could increase the risk of disease by prolonging the lives of those that do survive.

No threat

The consortium's research is not yet complete, so the findings so far must be treated with caution. But the picture that is emerging suggests that introducing or intensifying lowland rice cultivation will not increase the risks of malaria in either the forest or savanna zones, where the disease is already endemic. In the Sahel, the creation of new irrigation schemes or the expansion of existing ones may lead to increased dangers in the short term, as new colonists and laborers settle the area. However, these dangers pass as the settlers acquire immunity.

By the year 2000, Teuscher and his colleagues hope to be able to map the risk of contracting malaria in different agro-ecological zones and rice production systems. The map should prove a useful tool for planners.

...but in the Sahel, new arrivals on new or expanding schemes are a high-risk group...

...as also are short-term visitors to schemes

A Tradition in the Making

DESPITE IMPRESSIVE strides forward over the past 30 years, Senegal still has a long way to go before it makes full use of its substantial investment in irrigation. For many of the farmers in the Senegal River Valley, irrigated rice is a new crop of which they have little experience, with the result that their yields often fall below the level needed to cover the costs of production. WARDA is one partner in a dynamic national research and development system that is determined to overcome the obstacles to further progress.

Sunshine and water are plentiful on Senegal's irrigation schemes, but yields remain well below potential

Saer Kane Diop (center) talks with WARDA scientists and (left) Moustapha Diaw, president of the local farmers' association. In the mid-1960s, Diop and Diaw became the first irrigated rice farmers in Thiagar village

Easing the learning curve

When it comes to fertilizers, Saer Kane Diop knows his stuff. "If I apply 50 kg of 18-40-6 DAP at 23 days after sowing, then make two further applications at 50 and 70 days, I can be sure to get a yield of 7 tonnes per hectare", he says. He has an equally firm grasp of the dates by which all the other operations in his busy cropping calendar should be completed, including sowing, weeding, harvesting and threshing.

Now in his sixties, Diop farms land near the village of Thiagar, on the left bank of the Senegal River. These days he grows rice alone, but he hasn't always done so. In fact, he can remember a time when no one in his area grew rice. "Before the mid-1960s we were all floodplain farmers, producing beans, cowpea and cucumber", he recalls. "Thiagar was one of the first villages to agree to have irrigation, and I was among the first farmers to cultivate irrigated rice here. We had to learn from scratch."

Diop's story is typical of his generation. Thousands like him have had to master a completely new kind of farming as, under government schemes, they saw their land transformed by the introduction of irrigation canals and structures. With the switch to irrigated rice came the need to acquire the skills of land preparation, water management and the use of inputs such as fertilizer and herbicides. The year-round supply of water also brought with it the opportunity to grow an extra crop during the dry season, besides the traditional rainy season crop. Here the Sahelian climate imposed its own harsh lessons: sow too early, and the emerging plants were blasted by a cold, dust-laden wind; too late, and they wilted under the summer heat. Even the normal wet-season crop could be lost to cold if sown too late in the season.

Diop has learned much by experience, but his learning curve has been eased by strong institutional support. Recently, he attended a *journée de restitution*—a one-day seminar allowing farmers to brush up on their technical knowledge of all aspects of irrigated rice production, including fertilizer applications. Held in the village of Thiagar, the seminar was one of many organized in different parts of the Senegal River Valley by the Société Anonyme du Développement du Delta (SAED), the body responsible for providing advice to the valley's farmers and one of WARDA's leading research partners (see box).

Asked what he thought of the seminar, Diop immediately attests to its relevance. "I was expecting recommendations that would be unrealistic for us poor farmers", he says. "But to my surprise we got information that complements what we do already. The seminar did not ask us to spend extra money but instead taught us how to use existing resources more efficiently, so that we get better results."

Relevant research

Two topics emphasized at the seminar were the importance of observing the cropping calendar, and the appropriate rates and dates for fertilizer applications. The choice of both topics, as well as the recommendations made on them, reflected recent research results.

Surveys conducted yearly since 1995 show that non-observance of the cropping calendar is still the major reason why farmers in the Senegal River Valley fail to obtain good yields. For a variety of reasons—not just inexperience, but also the unavailability of credit and inputs—farmers regularly start the season late and then fall further and further behind as it goes on. The surveys highlight the fact that timely operations matter from beginning to end of the season: late sowing of the dry-season crop, for example, can lead to 100% failure as the plants succumb to the extreme heat of the Sahel in April and May; late weeding also reduces yields sharply, with the weeds increasingly competing with the rice for nutrients and water; and late harvesting and threshing result in further losses caused by declining grain moisture content and post-harvest pests.

The surveys also show that farmers obtain extremely variable results when they use fertilizer. Either they cannot obtain fertilizer when they need it, or else they lack information on how and when to apply it. Once applied, fertilizer is often swept away by excessive flooding or, where it does remain in the field, benefits the growth of weeds rather than that of the rice crop.

To underpin the recommendations made to farmers, WARDA's systems analyst Michael Dinkuhn has devel-

A strong extension service

Founded in 1965, SAED is responsible for the development of irrigated rice production throughout the Senegal River Valley. It provides an advisory service to farmers, and also conducts research.

SAED is that rarety among African institutions, a strong extension organization. Several factors help to explain its strength, including dynamic leadership and well trained and motivated professional staff. The organization's limited geographical scope has enabled it to focus its resources well. The dual mandate—research as well as extension—ensures strong links with other research institutions and a strong sense of ownership of the products of collaborative research.

With donor support, SAED has built a detailed data base on irrigated areas throughout the Senegal River Valley, recently complementing this with the introduction of a geographical information system (GIS). This serves as an effective tool for agro-ecological analysis and planning, resulting in the provision of well targeted advice to farmers.

To ensure the continuing relevance of collaborative research, SAED organizes a yearly meeting between researchers and farmers. This is attended by WARDA and ISRA scientists, as well as those of SAED.

oped a simulation model known as Rice Development, or RIDEV for short. The model predicts yield losses due to cold or heat stress at flowering time, as a function of the crop variety chosen, the establishment method (direct sowing or transplanting), the sowing date and the characteristics of the site. It provides users with cut-off dates for each operation—sowing, applying fertilizer, draining the field, and harvesting. RIDEV has been adapted for use in several Sahelian countries, where training courses on it have been organized for extensionists.

Fertilizer application dates and rates are also the subject of joint experiments by SAED and WARDA, conducted in farmers' fields near Thiagar and at other locations. The experiments compare a range of farmers' practices with those of researchers. "The aim is to allow farmers to see for themselves what works and what doesn't", says Salif Diack, WARDA research assistant. The results feed directly into the seminars, many of which are conducted by extensionists who are themselves involved in the research.

The seminars are as popular with extensionists and researchers as they are with farmers. Arona Touré, agricultural advisor with SAED, thinks the one at Thiagar was highly effective and that farmers will adopt the recommendations made. He has written to Kouamé Miezan, WARDA's team leader in Senegal, to thank him for WARDA's input and to suggest repeating the exercise each year. For Cynthia Donovan, economist with the WARDA team, the seminars provide researchers with a welcome reminder of the relevance of what they are doing. "It's good to hear farmers asking questions that research really can answer", she says. "That's typical of farmers who are learning how to grow a new crop."

Seed production enjoys close links with research: Fodé Sarr (right), regional seed inspector, with (left) Marco Wopereis, agronomist with WARDA

New seeds

Central to the drive to raise yields is the development and dissemination of new rice varieties. In partnership with WARDA, the Institut Sénégalais de Recherche Agricole (ISRA) has screened over 1000 lines of *Oryza sativa* germplasm imported from Asia through the International Network for the Genetic Evaluation of Rice (INGER). Following on-farm trials conducted in collaboration with ISRA and SAED, three new varieties were released in 1994: Sahel 108, a short-duration variety suitable for double cropping, and Sahel 201 and 202, both medium duration.

Of the three, Sahel 108 stands to make the biggest contribution to production increases, say the scientists. The potential for the expansion of double cropping in the Senegal River Valley is vast—only 10% of the irrigated area is managed in this way at present. Until now, farmers have lacked a suitable variety for double cropping. The shorter duration of Sahel 108 will allow them to sow a dry-season crop with less risk of losing the harvest to extreme heat or cold. Sahel 108 also has the long, slender grains preferred by a growing number of consumers for their cooking qualities and taste.

Belief in the new technology isn't restricted to the scientists who developed it: SAED's extensionists are also right behind the new releases, having seen for themselves their superiority to farmers' existing varieties. Their commitment owes much to their involvement in adaptive research. Touré, for example, became familiar with Sahel 108 during the collaborative fertilizer trials at Thiagar. The experience convinced him the variety would be a big hit with farmers.

The seed production service also enjoys close links with research. Fodé Sarr, regional seed inspector in the St-Louis area, is a regular visitor to WARDA's experiment stations, where he conducts trials to assess the characteristics of possible new releases. His research makes him a part owner of the final product, which he helps the scientists to "defend" when they present data on it to the Ministry of Agriculture's central advisory committee on new releases, in Dakar. Once committee approval is obtained, the new variety is officially entered in the national seed catalogue, and seed production and dissemination can begin (see box).

To promote the new varieties, SAED, ISRA and WARDA organized a field day at WARDA's Ndiaye station for representatives of 25 farmers' organizations from throughout the Senegal River Valley. When they returned to their villages, the participants took seed with them to launch their own local demonstration plots. Demand for seed now vastly outruns supply.

Cost-cutting equipment

"I'm certain it will succeed. I'll get my fingers burnt if it doesn't!" The speaker is Ibre Seck, technical director of the Société Industrielle Sahélienne de Machinisme Agricole, de Mécanique et de Représentation (SISMAR),

Mme Cissé (foreground) with members of the WARDA team

Seed production par excellence

Ask anyone in Senegal about seed production, and they are bound to refer you to "Mme Cissé". A legend in her own life-time, this civil servant-turned-farmer has, over the past 3 years, produced 70% of the St-Louis region's foundation seed.

Cissé began her professional career in the accounts department at ISRA. She quickly developed a strong interest in research, voluntarily helping the scientists finish their field tasks after working hours. In the 1980s, while maintaining her career at ISRA, she went into business as a rice farmer. Her fields soon became a byword for good farming practices, as she applied the knowledge she had gained from researchers to ensure high yields and high-quality grain.

Word of Cissé's farming exploits got back along the grapevine to senior management at ISRA and SAED, who sent a delegation of scientists to see her fields for themselves. The outcome of the visit was a request that she should become a foundation seed producer.

Cissé has produced over two-thirds of the foundation seed of Sahel 108 and Sahel 202, achieving average yields of 7 tonnes per hectare. Orders for her seed have come from far and wide, including a request from Mauritania for 20 tonnes of Sahel 108.

Asked about her experiences, Cissé has only one complaint. When she began farming she had to buy her own inputs, since credit is unavailable to women in Senegal. Nor can women farmers be allocated land free-of-charge, as men can. Besides her many other activities, Cissé now runs a pressure group to get that changed. Quel dynamisme!

a Dakar-based company that markets throughout West Africa. His words refer to an important new venture for the company, the manufacture and marketing of a new rice threshing machine.

Still carried out manually by most Senegalese farmers, harvesting and threshing are two of the most time-consuming tasks in rice production. And because everybody's crop needs processing at the same time, labor is scarce and expensive during this period. The results are delay, leading to losses in grain quantity and quality, and prices to the consumer that are up to 25% higher than they need be.

Importing large combine harvesters proved an expensive mistake

Smaller machines, made locally, are more affordable

The obvious answer is mechanization. But previous attempts to mechanize have ended in failure. Large combine harvesters imported at US$ 80 000 apiece from industrialized countries proved ill adapted to Senegal's muddy field conditions. They frequently broke down and could not be mended for lack of spare parts. Now the Senegal River Valley is littered with their rusting hulks.

In 1994, on a visit to the International Rice Research Institute (IRRI) in the Philippines, Miezan saw two machines—a stripper-gatherer and a thresher-cleaner—that looked better suited to Senegalese conditions. They were small and low-cost, and could be made from locally available materials, saving on imports and solving the spares problem. At Miezan's request, IRRI sent a prototype of each machine to WARDA's Ndiaye station.

ISRA's comparative advantage in post-harvest processing made it the obvious choice of partner to try out the machines in farmers' fields. Following this initial evaluation, a small-scale manufacturer in a village close to the research station was asked to make the first Senegalese models. When these became available ISRA, SAED and WARDA conducted further trials, then convened an intensive 4-day workshop to discuss the results.

The workshop proved a turning point in the machines' introduction to Senegal. Present were participants from each stage of the R&D process, including the original designer, IRRI's Boru Douthwaite, the scientists and villagers who had done the testing in Senegal, and Ibre Seck from SISMAR, invited for his potential interest in manufacture and marketing. The evaluation process had shown that, although the machines were promising, they still needed further modification for use in Senegal. Together, the participants pieced out the major problems—and their solutions.

In the case of the thresher, the main challenge was to increase the capacity to suit the relatively large farm size of Senegal's irrigation schemes, while still maintaining grain quality. A larger machine was also needed for ease of handling, since Senegalese farmers tend to be taller than Philippino farmers. Lastly, Senegalese field conditions demanded a more robust machine, made from thicker steel.

The design of the stripper-gatherer needed an even more radical overhaul. The main problem here was that the Philippino model was too light. In addition, the chain broke too easily when the machine was used in thick mud. And there was a need to reduce grain losses through the storage box.

Despite these problems, Seck felt that the machines had a future, not only in Senegal but throughout West Africa. With its international connections, his company would be well placed to market them. On the last day of the seminar, after taking a deep breath, he volunteered to build new prototypes and subsidize further on-farm testing.

SISMAR has now completed work on the thresher, and Seck says he's delighted with the results. At a third of the cost of previous threshers, the new Senegalese model can process up to 80 sacks a day of good clean grain, radically improving productivity over hand threshing. The machine has been listed by the Ministry of Agriculture as an item for which farmers can obtain credit, and the official launching will take place shortly.

Ibre Seck: unlikely to get his fingers burnt

The best news of all is that it looks as if Seck's fingers won't get burnt. To introduce the thresher to farmers, SAED organized three *journées de restitution* in different villages. Farmers were impressed by what they saw, and news of the new machine has since spread like wildfire. SISMAR has now received more than 100 advance orders from farmers' groups or individual farmers. That's on top of a large order already placed by the government.

According to Miezan, the introduction of the machines to Senegal provides a textbook example of successful inter-institutional collaboration. "In the public sector, national and international institutions worked closely together to assess the relevance of the technology, adapt it for local use and demonstrate it to farmers", he says. "That paved the way for private-sector involvement in production and marketing. SISMAR's own investment in building the second generation of prototypes and funding on-farm research raised its stake in the venture and hence its commitment to success."

The miller's tale

The design on the packet shows a middle-class housewife wearing a bright yellow dress, proffering a full bowl of cooked rice. In the background is the bridge across the Senegal River, a familiar landmark in down-town St-Louis. It's a cheerful image, blending elements of the new urban affluence with references to the older traditions of African hospitality and the role of woman as provider.

"Riz du Fleuve", Senegal's latest brand of high-quality long-grained whole rice, is currently retailing on a trial basis in a few urban supermarkets and stores. "We'll do some more aggressive marketing soon", says Amadou Ndiaye, the miller and businessman whose company, Delta 2000, launched the product earlier this year.

The new urban middle classes are developing a taste for long-grained whole rice

Ndiaye, who designed the packet himself, is confident of its appeal to Senegal's broadening market and changing tastes in rice. Demand for the commodity is growing at 6% a year—roughly twice as fast as the human population. As in other African countries, people are switching to rice from millet and sorghum, finding it more convenient to cook and tastier to eat. The country's traditional rice dish is *thiébou dience,* prepared by boiling broken rice in a spicy fish sauce. Consumers prefer broken rice for this, as it absorbs oil and flavors easily. But tastes are diversifying, and the market for separately cooked whole grains is expanding rapidly, especially among the urban middle classes. Within this market there is a new demand for quality, with long slender grains attracting a premium price.

This trait makes Ndiaye especially keen to get hold of the newly released Sahel 108. "With this variety I get higher rates of milling recovery and a better milled product", he says. Ndiaye first came across Sahel 108 when WARDA asked him to test its milling characteristics. Now he is actively encouraging farmers in the St-Louis area to switch to it, offering them a higher price than for their older wide-grained varieties. Ndiaye also has his own 3-hectare plots on WARDA's two research stations, where he conducts research on the grain quality of other possible future releases. Under this arrangement WARDA and its partners benefit by the inputs of an important user of their products, while Ndiaye gets the bulk of the crop for milling and marketing.

"Including millers in the R&D process is a powerful mechanism for checking the relevance of technology and promoting its transfer", comments Miezan. "Millers are part of what we now call the NARDS—the national agricultural research and development system."

Partnerships for progress

Good partnerships are essential for both the development and the dissemination of relevant new technology for the Sahel's unique irrigated rice environments.

Most of the protagonists in Senegal's small but informal R&D system know each other well, facilitating cooperation. They share a common perception of problems and solutions, forged by frequent contacts and intensive collaboration. Particularly impressive is the integration of research and development, which stands in marked contrast to the gulf separating the two in some other countries.

"There is a new dynamism in research here", says Miezan, "a new sense that research *matters*. Over the past decade we've learned that our environments are different to those of Asia, that we need our own solutions to problems. Led by its national partners, WARDA is helping to forge a modern African tradition in irrigated rice production. That is at once a great privilege and a great responsibility. We're delighted to be involved."

Tooling Up for Inland Valley Development

POORLY DESIGNED water management interventions have thwarted the development of West Africa's inland valleys. Working with national partners in Mali and Ghana, scientists at the Centre de Coopération Internationale en Recherche Agronomique pour le Développement (CIRAD) have come up with a new diagnostic tool that should help improve the future success rate. Their research forms part of the work of the Inland Valley Consortium, of which WARDA is also a member.

Wash-out

Farmers at Boundiali, Côte d'Ivoire, were looking forward to a bumper harvest of irrigated rice. Participants in an on-farm experiment to test the use of contour bunds to improve water control, they had worked hard with scientists to design and build the bunds, in addition to planting, weeding and fertilizing their crop.

But the weather had other ideas. One night during the rainy season, violent storms swept the area. Flash floods destroyed the bunds and washed away the crop.

The incident was a potent reminder—if any were needed—that attempts to develop West Africa's inland valleys can go badly wrong. Even the simplest interventions to improve water control must be carefully designed if they are to withstand the extremes of West Africa's climate. Similar misjudgements have wrecked many other small-scale irrigation schemes in the region.

Strategic resource

Accounting for only a small proportion (5%) of the region's arable land, the inland valleys of West Africa are an important, underused asset.

Blessed with fertile soils and relatively abundant water supplies, these lands have a high potential for agriculture. Provided water is properly controlled, production here is less risky than in the uplands, with the result that farmers can make use of a higher level of inputs. Valleys with access to urban markets provide opportunities for intensive vegetable cropping and horticulture, besides rice cultivation and livestock production. Where water is available year-round, fish farming can be integrated into the system.

The inland valleys could thus be the engine of agricultural development in the region. Yet the vast proportion of these lands—an estimated 30 million

Inland valleys could be the engine of regional development

hectares—are not cultivated at all at present. Researchers estimate that if a mere 3% of this area could be brought into use, and yields could be raised to a modest 3 tonnes per hectare, West Africa's rice production would increase by 2.25 million tonnes a year, turning the region into a net exporter.

Improved control of the water resource is the key to realizing this happy scenario. But past water management interventions in the valleys have a dismal record. Miscalculations in the physical design of interventions must take much of the blame. The commonest mistake of this kind is to underestimate the peak discharges that structures will have to deal with during storms, as occurred in Boundiali. But there are plenty of others, including failure to take into account the soil type and its permeability, or to ensure that the area irrigated will be sufficiently large to justify the costs of new structures.

Yet these physical miscalculations tell only half the story. Over and above them loom larger failures to appreciate users' needs and to adapt interventions to socio-economic and geographical circumstances. Areas remote from markets, for example, may not be suitable for off-season cropping. People may need water for domestic use and for livestock more than they need extra rice. The results in these cases are schemes that are poorly maintained after construction, underused or used for different purposes than those for which they were designed, or—in the worst cases—abandoned altogether.

Après nous le déluge: past interventions have had a high failure rate

Despite the high failure rate of the past, the prospects for successful inland valley development are improving. Public-sector projects are giving way to private ones, organized by users who have a high stake in their success. Interventions are no longer the result of a top-down approach but are identified through a participatory process in which the rural community has a say in the design of the intervention, provides at least some of the funding for it and carries out much of the construction work.

Diagnostic tool

Against this background, it is more than ever necessary to get the design of interventions right while cutting down on the costs of the design process. One reaction to past failures is an exhaustive process in which, in their anxiety to avoid mistakes, designers try to measure all the parameters that might or might not be relevant. But in a climate where funding is ever more scarce, this approach is no longer practical. Needed is a tool that can guide designers straight to the key parameters that will show whether or not a given intervention is likely to work.

CIRAD and its partners have developed just such a tool. Known by its French acronym DIARPA (diagnostique rapide de pré-aménagement), the tool is the result of more than a decade of painstaking research conducted in collaboration with Mali's Institut d'Economie Rurale (IER) and Ghana's Savanna Research Institute (SARI). The research was one of the activities supported by the Inland Valley Consortium, an informal association of national and international institutions hosted by WARDA (see box).

The researchers began by analyzing the types of water management intervention used at key sites in the two countries. They described the design characteristics of each intervention, and the purpose it was intended to serve. They then defined the conditions conducive to the success of the intervention, the management constraints likely to be encountered, and the factors limiting the potential for impact.

The Inland Valley Consortium

The decision to form the Inland Valley Consortium came during a workshop on inland valley development held at WARDA's headquarters in June 1993. Members currently include:

- Ten African countries: Benin, Burkina Faso, Cameroon, Côte d'Ivoire, Ghana, Guinea, Mali, Nigeria, Sierra Leone and Togo
- Three international research centers: WARDA, the International Institute of Tropical Agriculture (IITA) and the International Livestock Research Institute (ILRI)
- The Winand Staring Centre of the Dients Landbouwkundig Onderzoek (DLO) and Wageningen Agricultural University, in the Netherlands
- The Centre de Coopération Internationale en Recherche Agronomique pour le Développement (CIRAD), in France
- The Food and Agriculture Organization of the United Nations (FAO).

Consortium members conduct activities in three major areas: the characterization of inland valleys, the design of low-cost water management interventions, and technology testing and transfer. Research on decision support systems (such as DIARPA) forms an important part of activities in the second of these areas.

The advantages of the consortium lie chiefly in gains in research efficiency. These accrue through the use of comparative advantage, the development and dissemination of shared methodologies, the multi-locational testing of interventions, the transfer of suitable technologies and the exchange of information and materials.

The analysis led to the identification of six basic kinds of intervention:

- Contour bunds
- Contour bunds with spillover
- Water retention dykes
- Water retention dykes with seepage barrier
- Diversion barriers for gravity irrigation
- Diversion barriers for groundwater recharge.

Soil permeability is the most important determinant of intervention type

Next, the researchers defined seven key indicators determining the suitability of these interventions in different situations:

- *Soil permeability*. This is the main indicator determining the choice of intervention. High permeability means that retention dykes must be accompanied by a seepage barrier if they are to be effective. When permeability is low, diversion barriers for gravity irrigation can be introduced. The researchers found that not taking soil permeability into account is the commonest cause of design failures.
- *Presence (and depth) of impermeable layer*. This determines the feasibility of using a seepage barrier. These barriers can only be installed by hand if the layer is not lower than 2 meters.
- *Average longitudinal slope and extent of irrigable area*. This affects crop production and is therefore an important determinant of economic viability.
- *Presence and profile of stream channel*. This helps estimate maximum discharge rates during peak flooding periods. These discharges determine the dimensions of the structures needed and hence their approximate cost.
- *Peak discharge per meter of valley width*. This is a complex indicator derived from average 10-year rainfall patterns, the catchment area and its condition, the slope

of the catchment and the width of the valley bottom. Again, it is important in determining the dimensions of structures.

- *Presence and depth of groundwater table at a certain date*. This indicates the suitability of the site for off-season cropping and hence affects the potential profitability of the intervention. The correct date for the Sudanian zone in which the research was conducted is the end of January, but this should be adapted for other zones.
- *Presence of a base-flow and its irrigation potential*. The base-flow is the underlying flow of water through the catchment area, outside peak rainfall periods. It is another complex indicator, highly variable from one year to the next. If there is no flow of this kind, the water supply at the end of the rainy season will be limited to that stored by the new structure, which may be insufficient to produce an off-season crop.

For each indicator, the researchers defined threshold values triggering the choice of an intervention and its design characteristics (Table 4). These data could then be used to estimate the cost of the intervention.

The DIARPA tool should be used in conjunction with a further set of socio-economic indicators that assess the intervention's likely impact in terms of cropping intensification and diversification and hence its returns to users. This assessment can be used to determine a cut-off point for the cost of interventions, or in other words the level at which they become uneconomic.

Table 4. Threshold values of key indicators for different water management interventions in the Sudanian zone of southern Mali.

	Indicators						
Structures	Soil permeability ($m\ s^{-1}$)	Depth of impermeable layer (m)	Average longitudinal slope (%)	Presence and profile of stream channel	Peak discharge per meter width ($l\ s^{-1}$)	Presence and depth of ground-water	Irrigation potential of base-flow
Contour bunds	< 10	Neutral	< 1	No distinct channel	1	Neutral	Neutral
Contour bunds with spillover	< 10	Neutral	< 1	With or with-out distinct channel	20	Neutral	Neutral
Water retention dykes	< 10	Neutral	< 0.5	Shallow channel	130	Neutral	Neutral
Water retention dykes with seepage barrier	> 10	< 2	< 0.5	Shallow channel	130	Neutral	Neutral
Diversion barrier for gravity irrigation	< 10	Neutral	< 1	Deep channel	2	Neutral	1 month
Diversion barrier for groundwater recharge	> 10	> 2	< 2	Deep channel	200	< 2	1 month

Agro-ecological zone is a major determinant of the kind of water supply problem an intervention will be designed to solve, and of whether or not the intervention will be economically worthwhile. The extremes of the Sahelian climate—prolonged drought with high rates of evaporation, followed by sudden, violent storms—mean that structures must be designed on a large scale, both to retain enough water for off-season cropping and to cope with high rates of discharge when rains finally come. Given the generally low crop yields associated with small-scale schemes in this zone, most interventions are unlikely to be viable. Similar conditions obtain in the Sudanian zone, albeit to a lesser degree. Here early and mid-season drought may be associated with sudden shortages of surface water. Storage is therefore important, and is somewhat more likely to be worthwhile. In the humid forest zone, in contrast, the problem is usually one of how to get rid of excess water.

The benefits of the DIARPA tool lie as much in its use to prevent risky or ill-judged interventions as to promote successful ones. When the scientists applied the tool to four sites in the Sudanian zone of southern Mali, the analysis came out positive for only one of them. In this case a ceiling of 700 000 CFA francs (US$ 1170) per hectare was placed on the cost of interventions. A combination of the sites' topographical conditions and the expected discharge rates during storms drove costs above this level for three out of the four sites. At the fourth, a water retention dyke was recommended.

Will it be economically worthwhile? Climate is a major determinant

Technology transfer

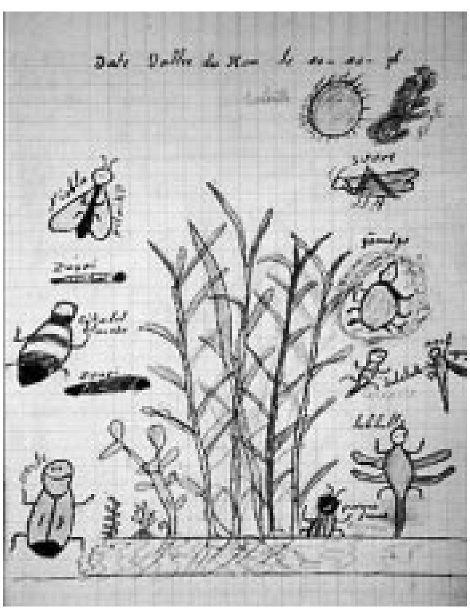
The DIARPA tool appears a promising way of simultaneously cutting the costs of designing water management interventions and avoiding expensive failures. The tool is currently being adapted for use in a more humid environment in central Benin. If it proves a success there, its further adaptation and use will be more widely promoted through the Inland Valley Consortium.

From Asia with Knowledge

INTEGRATED PEST management (IPM) has become a viable alternative to the use of chemicals to control insect pests on rice and other crops in Asia. The Food and Agriculture Organization of the United Nations (FAO) is working with national governments and programs to introduce IPM methods to West Africa. WARDA's scientists have been providing technical back-up.

Learning fields

Beside a dusty track, six poles support a tarpaulin, forming a rudimentary shelter in the midst of the rice fields. Beneath the shelter, wooden tables and chairs are loosely arranged to face a flip chart. On the open page of the chart someone has made amateur but lively drawings of insects, including caterpillars, grasshoppers, beetles, wasps, even a spider in its web. Crouching or stooping in different parts of the field surrounding the shelter are 25 farmers, each equipped with a notebook and pen.



Farmers' drawings showed accurate powers of observation coupled with an affectionate response to nature

It's eight-thirty on a Friday morning in July 1995, at the Dawhenya Irrigation Scheme in Ghana. The shelter and the field form the simple physical setting for an important new concept in IPM technology transfer—the farmer field school—being tested here for the first time in West Africa. The farmers, all of whom live on the scheme, have been attending the school every Friday since the start of the growing season. At present they are observing the growing rice plants and the insects they find on them. Soon they will return to the shelter, where they will record their observations on flip charts for presentation to the rest of the group. The presentations will be followed by discussion, leading to a decision on what, if any, pest control measures are needed.

The school is first and foremost a place where people learn by doing, through direct observation and discovery in the rice field. But it's also a meeting of minds—a forum at which farmers can exchange experiences and outsiders such as extension workers and researchers can contribute their knowledge too. The result, in an irrigation scheme known for its overuse of pesticides, is a more subtle, knowledge-based approach to the control of pests using a range of measures including the conservation of natural enemies, cultural practices and resistant crop varieties, with chemicals applied only as a last resort. What were once killing fields have become learning fields, the crucible in which the future of pest control on Africa's farms is being forged.

An Asian success story

The farmer field school is new to Africa but not to Southeast Asia, where it has been successfully used to spread the IPM message for more than a decade.

The concept originated when the FAO launched a series of training courses to combat the overuse of pesticides in the region during the mid-1980s. By then, the dire effects of overuse on both human health and the environment had become all too apparent. Among the most harmful environmental effects were the disappearance of the natural enemies that would otherwise control many insect pests, and the development of "superpests" resistant to most chemical products.

The courses taught farmers and extension workers to observe the populations of insect pests and natural enemies in the field and to take action on the basis of their observations. That sounds like common sense today, but at the time it was a radical departure from accepted practice, which was to spray a cocktail of chemicals at regular intervals throughout the season, regardless of actual pest population levels. Combined with subsequent government programs, the courses proved highly effective in such countries as Vietnam, the Philippines, Indonesia and Cambodia, where large numbers of farmers have been able to reduce their use of pesticides dramatically.

In the early 1990s, the FAO decided it was time to spread the benefits of the course to West Africa. To generate interest, it organized a study tour of the participating Asian countries for West African directors of plant protection. After the tour three countries—Ghana, Côte d'Ivoire and Burkina Faso—requested the FAO's assistance in running an introductory course. While national programs were to organize and implement the courses, WARDA was asked to provide technical back-up.

Indigenizing IPM

The IPM needs of farmers in West Africa diverge from those of Asia. The region's different agro-ecologies give rise to different rice pests. More importantly, whereas the challenge in Asia was to wean farmers from the overuse of pesticides, that in most African production systems is to prevent future overuse. The high cost and unavailability of pesticides means that few African farmers have access to them at present. Africa, in other words, can learn from Asia's mistakes.

The three pilot courses were timed and organized so as to build up a core of African expertise in IPM as rapidly as possible. Teaching the course in Ghana were three FAO staff based in Asia. Farmers and extension agents trained on this course served as teaching staff on subsequent courses held in 1996 in Côte d'Ivoire and Burkina Faso, gradually replacing the Asian input. In each country, the majority of extension participants went on to organize up to 10 more field schools the next season, each in a different rice-growing area. The course in Ghana culminated in a national seminar on IPM, at which a national IPM policy and strategy were agreed.

WARDA also helped adapt the course to West African needs. "We made a big input, reflecting the importance we attach to IPM", notes Tony Youdeowei, Director of Training and Communications. "Our experience of pests and other stresses specific to the region was particularly

The farmer field school at Sakassou irrigation scheme, Côte d'Ivoire

Extension agents were intensively trained in agro-ecosystems analysis

On Fridays, it was the farmers' turn to analyze the system and present their findings

useful." The Association sent 7 of its scientists and technicians to the course in Ghana and 6 to the one in Burkina Faso, while the course in Côte d'Ivoire, held on a scheme within easy reach of Bouaké, was covered by no less than 15 staff members.

Key to the success of the courses was their painstaking organization. In each country, a Project Oversight Committee was established to guide the incoming team of trainers and steer project planning and implementation. Next, a suitable irrigation scheme where farmers were already heavily dependent on pesticides had to be found—quite a rarity in Africa. Once identified, the site was equipped with the basic facilities and teaching materials required by the course. The organizers then held a demanding 3-day workshop for potential participants from the extension service in order to select those who would prove most receptive to the course and most articulate in spreading its messages. These became the "Train the Trainers" or TOT participants. Lastly, 75 farmers from the irrigation scheme were invited to participate. They were divided into three separate field schools of 25 farmers each.

Once the course began, it followed a set routine. From Monday to Thursday, the participants from the extension service received intensive training in analyzing the local agro-ecology, diagnosing problems and deciding on solutions, with pests and their natural enemies taking central place. Typically, they spent the first 3 hours of the day in the field, observing and recording; this was followed by 2 hours of discussions, with afternoons being devoted to synthesis and the exploration of special topics. On Fridays it was the turn of the farmers to follow a similar routine—and of the extension participants to practice their skills as trainers and facilitators, passing on what they had learned during the week.

Besides field activities and group discussions, the courses had a strong research component. At the start of the season the participants conducted a baseline study of how farmers managed their rice fields, including the amount and frequency of pesticide applications. Throughout the course each farmer group had access to two trial plots, one in which it continued to apply pesticides regularly, according to the calendar, and one in which it tested IPM methods. Yields and profitability from each plot were assessed after harvest. In addition, special trials were conducted on such topics as the ability of the crop to compensate for the loss of leaves and tillers.

Pay-off plus

Economic analysis at the end of the Ghana course showed that the net returns to rice cropping using IPM practices were 32% higher than when pesticides were applied. Farmers could save up to US$ 100 per hectare, and still obtain comparable yields.

A survey conducted 12 months later showed that participating farmers had stopped using pesticides altogether. “The cash incentive alone is enough to persuade farmers to adopt IPM practices, without counting the human health and environmental benefits that have yet to materialize fully”, comments Youdeowei. Similar outcomes are expected at the host irrigation schemes in Burkina Faso and Côte d’Ivoire. All three countries now have ongoing IPM programs fully supported by the FAO and the government.

The key to the courses’ success lies in allowing farmers to see for themselves the advantages of IPM practices. According to Youdeowei, the farmer field school re-establishes the traditional primacy of the farmer and his or her knowledge as the basis for taking management decisions. In Ghana, the training was so successful that even a deaf-and-dumb farmer was able to demonstrate his mastery of IPM techniques by the end of the course, using sign language and his flip chart. As the farmer who gave the closing address on the course claimed, “We can now be recognized as IPM experts”.

As the schools spread, more and more West African farmers can be expected to put their newly acquired knowledge to good use—with immense benefits for the profitability of rice production, the health of rice producers and the quality of the environment.

Financial Statement

1. Position for the year ended 31 December 1996 (in US $)

	1996	1995
ASSETS		
Current Assets		
Cash and Bank Balances	1 201 134	930 792
Accounts Receivable:		
Donors	1 713 412	1 592 487
Employees	237 600	255 741
Others	1 948 584	1 282 079
Inventories	716 279	602 772
Prepaid Expenses	138 026	198 166
Other Current Assets	228 217	324 359
Total Current Assets	6 183 252	5 186 396
Fixed Assets		
Property, Plant and Equipment	17 100 112	15 753 441
Less: Accumulated Depreciation	(3 599 738)	(2 905 083)
Total Fixed Assets (Net)	13 500 374	12 848 358
TOTAL ASSETS	**19 683 626**	**18 034 754**
LIABILITIES AND FUND BALANCES		
Current Liabilities		
Cash and Bank Balances (Overdraft)	763 419	
Accounts Payable:		
Donors	2 703 203	1 873 144
Employees	195 874	115 109
Others	1 838 276	2 159 574
Provisions and Accruals	787 475	556 634
Total Current Liabilities	**6 288 247**	**4 704 461**
Long-term Liabilities	-	-
Total liabilities	6 288 247	4 704 461
Net Assets		
Capital Invested in Fixed Assets		
Center-owned	13 500 374	12 848 358
Capital Fund	(182 850)	(68 187)
Operating Fund	77 855	550 122
Total Net Assets	13 395 379	13 330 293
TOTAL LIABILITIES AND FUND BALANCES	**19 683 626**	**18 034 754**

2. Statement of activities by funding for the year ended 31 December 1996 (in US $)

	Unrestricted	Restricted	Total 1996	Total 1995
REVENUE				
Grants	4 956 990	4 189 100	9 146 090	8 462 172
Member States' Contributions	379 675		379 675	
Other Revenues	82 851		82 851	93 677
TOTAL REVENUE	**5 419 516**	**4 189 100**	**9 608 616**	**8 555 849**
OPERATING EXPENSES				
Research Programs	2 784 559	3 445 868	6 230 427	5 887 543
Training and Communications	674 736	252 147	926 883	825 359
Administration and General Operations	2 052 671		2 052 671	1 874 818
Depreciation	694 655		694 655	621 859
Gross Operating Expenses	6 206621	3 698 015	9 904 637	9 209 579
Recovery of Indirect Costs	(342 819)		(342 819)	(181 530)
OPERATING EXPENSES (NET)	5 863 803	3 698 015	9 561 818	9 028 049
EXCESS/(DEFICIT) OF REVENUE OVER EXPENSES	**(444 287)**	**491 085**	**46 798**	**(472 200)**
Allocated as Follows:				
Operating Fund	444 287		444 287	762 626
Capital Fund		(491 085)	(491 085)	(290 425)

MEMO ITEM

Operating Expenses by Natural Classification

	Unrestricted	Restricted	Total 1996	Total 1995
Personnel Costs	*3 239 513*	*1 440 155*	*4 679 668*	*4 585 841*
Supplies and Services	*1 920 619*	*2 061 457*	*3 982 076*	*3 274 361*
Operational Travel	*351 834*	*196 404*	*548 238*	*727 518*
Depreciation	*694 655*		*694 655*	*621 859*
Gross Operating Expenses	***6 206 621***	***3 698 016***	***9 904 637***	***9 209 579***

3. Grants and contributions for the year ended 31 December 1996 (in US $)

Unrestricted research agenda	1996	1995
Canada	612 423	485 317
Côte d'Ivoire	304 616	
France	105 508	72 883
Germany	397 921	417 797
Japan	1 497 116	1 179 033
Korea	49 980	50 000
Netherlands	295 299	312 110
Norway	170 121	201 518
Spain	30 000	25 000
Sweden	551 116	505 393
United Kingdom	187 890	175 368
United States of America	150 000	200 000
World Bank	605 000	810 000
Total unrestricted grants	**4 956 990**	**4 434 419**

Restricted research agenda		
African Development Bank (Institutional Support)	447 345	757 606
Canada (IDRC) (Vector-borne Diseases Project)	249 665	151 090
Denmark (Phytosanitary and Seed Health Project)	16 348	
Denmark/IITA/TAC (Inland Valley Consortium Project)	151 759	
Denmark (Vector-borne Diseases Project)	68 074	37 183
European Union (Crop and Resource Management Project)	725 328	614 639
France (Agrophysiology Project)	85 351	94 106
France (Inland Valley Consortium Project)	156 693	13 342
Germany (BMZ/GTZ) (Temperature Stress Project)	170 215	545 162
Germany (BMZ/GTZ) (Salinity Project)	27 876	69 886
Germany (GTZ) (Pesticides Project)	37 109	16 469
Germany (GTZ) (Soil Nitrogen Project)	36 642	41 748
IFAD (RADORT Project)	129 421	
Japan (Grain Quality Studies)	70 000	63 080
Netherlands (Inland Valley Consortium Project)	393 010	537 145
Norway (Vector-borne Diseases Project)	84 925	21 599
Rockefeller Foundation (Anther Culture Project)	103 055	62 210
United Nations Development Programme (Training and Communications)	252 147	236 308
United Kingdom (ODA/NRI) (Weeds Project)	12 321	50 946
United Kingdom (ODA) (INGER Project)	245 011	166 805
United Kingdom (ODA/NRI) (Nematology Project)	28 886	34 743
United Kingdom (ODA/NRI) (Weed/Insect Interaction)	12 401	11 105
United Kingdom (ODA/CABI) (Gall Midge Project)	11 803	25 359
United States (USAID) (Rice Network Project)	473 186	459 016
United States (USAID) (Technology Dissemination Project)	163 012	
United States (USAID) (Africa Link Project)	4 139	
Miscellaneous	33 378	18 206
Total restricted grants	**4 189 100**	**4 027 753**
Total Grants	**9 146 090**	**8 462 172**

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(All positions located at Mbé, near Bouaké, Côte d'Ivoire, unless otherwise noted)

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Weed Scientist	David Johnson (NRI)
Director of Training and Communications	Anthony Youdeowei
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* Joined 1996
** Left 1996

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Acronyms

ACP	Africa-Caribbean-Pacific
BMZ	Bundesministerium für Wirtschaftliche Zusammenarbeit (Germany)
CABI	Commonwealth Agricultural Bureaux International (UK)
CIRAD	Centre de Coopération Internationale en Recherche Agronomique pour le Développement (France)
CFA	Communauté Financière Africaine
CGIAR	Consultative Group on International Agricultural Research
CILSS	Comité Permanent Inter-Etats de Lutte contre la Sécheresse dans le Sahel
CORAF	Conférence des Responsables de la Recherche Agronomique Africaine
CTA	Technical Centre for Agricultural and Rural Co-operation
DANIDA	Danish International Development Agency
DAP	Di-ammonium phosphate
DIARPA	Diagnostique rapide de pré-aménagement (diagnostic tool)
DLO	Dients Landbouwkundig Onderzoek (Netherlands)
ECA	United Nations Economic Commission for Africa
FAO	Food and Agriculture Organization of the United Nations
GIS	Geographical information system
GTZ	Gesellschaft für Technische Zusammenarbeit (Germany)
ICRISAT	International Crops Research Institute for the Semi-Arid Tropics
IDESSA	Institut des Savannes (Côte d'Ivoire)
IDRC	International Development Research Centre (Canada)
IER	Institut d'Economie Rural (Mali)
IFAD	International Fund for Agricultural Development
IITA	International Institute of Tropical Agriculture
ILRI	International Livestock Research Institute
INGER	International Network for the Genetic Evaluation of Rice
IPM	Integrated pest management
IRRI	International Rice Research Institute
ISNAR	International Service for National Agricultural Research
ISRA	Institut Sénégalais de Recherche Agricole
IVC	Inland Valley Consortium
KIT	Royal Tropical Institute (Netherlands)
NARDS	National agricultural research and development system
NGO	Non-governmental organization
NRI	Natural Resources Institute (UK)
OAU	Organization of African Unity

ODA	Overseas Development Administration (UK)
PEEM	Joint Panel of Experts on Environmental Management for Vector Control (WHO/FAO/UNEP/UNCHS)
RADORT	Research on Accelerated Diffusion of Rice Technology (project)
R&D	Research and development
RIDEV	Rice development (model)
RYMV	Rice yellow mottle virus
SAED	Société d'Aménagement et d'Exploitation des Terres du Delta du Fleuve Sénégal et des Vallées du Fleuve Sénégal et de la Falème (Senegal)
SARI	Savanna Research Institute (Ghana)
SISMAR	Société Industrielle Sahélienne de Machinisme Agricole, de Mécanique et de Représentation (Senegal)
SLA	Specific leaf area
SOPRORIZ	Projet National Riz (Côte d'Ivoire)
TAC	Technical Advisory Committee (of the CGIAR)
TOT	Train the trainers
UHP	Université Henri Poincaré (France)
UNCHS	United Nations Centre for Human Settlements
UNDP	United Nations Development Programme
UNEP	United Nations Environment Programme
USAID	United States Agency for International Development
WARDA	West Africa Rice Development Association
WHO	World Health Organization

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Photos:
Front cover: WARDA
Text: p. 20 (below), p. 31 (above and below), p. 32 (above and below), p. 34 (below), p. 35, p. 36 (above and below), p. 37, p. 38: Simon Chater; p. 40, p. 41, p. 43: Jeremy Hartley/Panos Pictures; p. 27 (below): World Health Organization; others: WARDA

Figures:
p. 30: based on Snow and Marsh (Parasitology Today 11 (5): 188-190); others: WARDA

Tables:
p. 42: Legoupil et al./CIRAD; others: WARDA

Printed and bound by:
Ebenezer Baylis & Son Ltd
The Trinity Press
London Road
Worcester WR5 2JH
United Kingdom

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Fax: +44-1905-354919

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