West Africa Rice Development Association

Annual Report 2000

CGIAR

About the West Africa Rice Development Association (WARDA)

The West Africa Rice Development Association (WARDA) was formed as an autonomous intergovernmental research association 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). Today, the Association 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. Since 1987, WARDA has also been a member of the Consultative Group on International Agricultural Research (CGIAR), a network of 16 international research centers supported by more than 50 public- and private-sector donors.

WARDA's mission is: to contribute to food security and poverty eradication in poor rural and urban populations, particularly in West and Central Africa, through research, partnerships, capacity strengthening and policy support on rice-based systems, and in ways that promote sustainable agricultural development based on environmentally sound management of natural resources.

WARDA's research and development activities are carried out in collaboration with the national agricultural research systems of members states, academic institutions, international donors and other organizations, to the ultimate benefit of West and Central African farmers—mostly small-scale producers—who cultivate rice, as well as the millions of African families who eat rice as a staple food.

WARDA Headquarters are at M'bé, 25 km north of Bouaké, a major commercial center in Côte d'Ivoire. WARDA also operates research stations at N'Diaye, near Saint Louis, Senegal, and at the International Institute of Tropical Agriculture (IITA), Ibadan, Nigeria.

Donors to WARDA in 2000 were: the African Development Bank, Belgium, Canada, CGIAR (Finance Committee), Common Fund for Commodities (CFC), Côte d'Ivoire, Denmark, the Food and Agriculture Organization of the United Nations (FAO), France, the Gatsby Foundation (UK), Germany, the International Development Research Centre (Canada), the International Fund for Agricultural Development, Japan, the Netherlands, Norway, the Rockefeller Foundation (USA), Sweden, the United Kingdom, UNDP, the United States of America, the World Bank and WARDA member states.

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

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

THE YEAR that was 2000 had been the subject of much speculation among the 'prophets of doom,' not least of which was the global threat of computer problems in the 'Y2K scenario.' Thankfully, most of the doom-prophets were proved wrong. At WARDA it was very much 'business as usual,' or rather a continuation of the 'busy-ness' that characterized 1999. Yes, 2000 was another busy year for us, but not one without its rewards.

The Fourth External Program and Management Review (EPMR) of WARDA was completed in February. The report spoke in glowing terms of the excellence of our science and the effectiveness of our partnership approaches. It highlighted and commended management for putting in place strategic directions, new policies and procedures for efficient running of the Center. Some comments in the report were reported in our message last year.

In confirmation of the excellent evaluation by the EPMR, WARDA received the 'Millennium' edition of the CGIAR King Baudouin Award for the breakthrough in interspecific hybridization of rice, the development of the NERICAs and effective participatory approaches in technology dissemination. This award gives international recognition to our achievements, and support to our ongoing drive for a massive upsurge in rice productivity within our mandate region.

Impressed by WARDA's successful transformation and uniqueness as a successful African institution, the Harvard Business School undertook a case study, *WARDA: Leading a rice revolution in West Africa*. For more details on these, and on our other activities, we would draw your attention to *The Year in Review: 2000* on page 55.

During the year, we completed a study of the impact of rice varietal improvement in West Africa. The study, sponsored by the CGIAR Impact Assessment and Evaluation Group, looked at the financial gains attributable to the use of improved rice cultivars in seven major rice-producing countries in the region: Côte d'Ivoire, Ghana, Guinea, Mali, Nigeria, Senegal and Sierra Leone. On average, genetic enhancement and transfer have increased (net) farm revenues by US$100 per hectare; however, gains have been uneven across ecologies: from $232/ha in irrigated lowlands, through $163 in rainfed lowlands, $69 in mangrove swamps, to $32 in both deep-water/floating and upland ecologies. Overall, varietal improvement is estimated to have contributed approximately $374 million to the $1.85 billion rice-production economy in the seven countries in 1998. Projections to 2004 are promising: 10% adoption of upcoming upland varieties (including NERICAs) in just Côte d'Ivoire, Guinea and Sierra Leone would contribute nearly $8 million per year, while 25% adoption—a not unlikely scenario according to our experience in Guinea—would add some $20 million per year to the economy in these countries.

As the year drew to a close, WARDA's Director General accepted the responsibility of chairing the CGIAR Center Director's Committee (CDC) Sub-Committee on Sub-Saharan Africa. This responsibility immediately involved two major activities in response to the CGIAR's decisions at International Centers Week 2000. The first of these is to lead the process toward regional planning, priority-setting and coordination-cum-integration of CGIAR activities in Sub-Saharan Africa. The second is to develop a System-wide Initiative on the impact of HIV/AIDS on agriculture.

It was with great sadness that we bade farewell to Michael Goon, Deputy Director General for Administration and Finance, in December. Michael joined the management team in early 1998, and helped us make significant progress in reducing our operating deficit and putting in place new financial management structures that will make WARDA a stronger place in the coming years. We also said goodbye to Amir Kassam, Deputy Director General for Programs, at the end of his two-year leave-of-absence from his position at FAO in July.

These changes presaged a reclassification and restructuring exercise. The two Deputy Directors General positions are being replaced by Directors. And, in response to the EPMR recommendations, the Policy Support Program (Program 3) and the Systems Development and Technology Transfer Program (Program 4) have been merged into one Rice Policy and Development Program (new Program 3).

The last year also saw the arrival of: Godwin Akpokodje (Policy Economist Visiting Scientist, Nigeria Station), Aliou Diagne (Impact Assessment Economist), Marie-Josèphe Dugué (Inland Valley Consortium Regional Coordinator, *Coopération française*), Olaf Erenstein (Production Economist), Pierrick Fraval (Water Management Economist, Sahel Station, IWMI/*Cemagref*), Assétou Kanouté (Technology Transfer Scientist, Visiting Scientist), Mohamed Kebbeh (Production Economist, Sahel Station), Augustin Munyemana (Participatory Technology Development Scientist, Nigeria Station, Hohenheim University), Hla Myint (Information and Data Analyst, United Nations Volunteer), Myra Wopereis-Pura (Technology Transfer Officer, United Nations Volunteer), and N'guéssan Yoboué (Germplasm Scientist, Visiting Scientist).

The days when we thought only of the 'quick-fix,' single solution to a single problem in agriculture are long gone. The theme of this year's report is 'integrated management,' be it at the crop level or targeted at a particular pest.

One of the benefits of having out-stations is the continuity that they lend to long-term research and development. Our Sahel Station in northern Senegal has been active in Sahelian irrigated rice research for over 10 years, and there is now a substantial body of knowledge and technologies available for our partners and ultimate clients (farmers). The time has come to put all the components together and start wide-scale dissemination of advice and technologies that can have a significant impact on irrigated rice farming in the Sahel. Our first feature story looks at just this issue—how we have developed the components, and how we intend to promote integrated crop management in this high-potential ecology (page 9).

Over the last few years, our Annual Reports have sadly neglected the realm of pests—particularly insects and diseases. This year, we bring you up to date with our work on integrated pest management for key constraints in the region. African rice gall midge is the principal insect pest of rainfed lowland rice in concentrated 'pockets' in four of our member countries, causing losses of between 45 and 90% (page 20). Rice yellow mottle virus is a major problem in irrigated and

WARDA Director General Kanayo F. Nwanze (left) with new Board Chairman Linsay Innes, appointed in 2000

lowland rice throughout the region, again causing significant crop losses. We look at the massive screening effort aimed at developing plant resistance to the disease, and other components of integrated management (page 27).

Another major pest group is weeds. Here our integrated approach involves computer modeling, which helps to guide our work on varietal improvement. The focus of the story is weed-competitiveness and the model is used to determine how some theoretical plant types would behave in direct-seeded systems in the Sahel. This in turn should give our breeders target traits for improving weed-competitiveness in irrigated rice varieties (page 39).

This year's *Donor Country Profile* looks at Canada. A diverse array of research topics has been funded over the years by the Canadian Government through the two-pronged route of direct grant and monies channeled through the International Development Research Center (IDRC), and we are particularly grateful for their continued commitment to our core program through unrestricted funding (page 45).

We cannot finish with 2000 without mention of the security situation in our host country. As many of you will know, Côte d'Ivoire went through a difficult transition between the military coup d'état in December 1999 and the establishment of a democratically elected president in October 2000. Various socio-political disturbance through the year could not pass without some impact on WARDA's operations—none moreso than the invasion of our property by rebel military personnel during a mutiny in July. Overall, however, the impact of such disturbances was not great and mainly indirect, leading to restrictions on in-country travel and cessation of headquarters operations for several days. The pace of WARDA's vital work may have been slowed during parts of the year, but it will not stop—too many people, present and future generations, are depending on an agricultural revolution in Sub-Saharan Africa for our work to come to a complete halt!

Last, but not least, a word of thanks to all of our partners—from donors to farmers, from the advanced research institutions to the national agricultural research and extension services, from the CGIAR community to the NGO community, and many, many more: without you, WARDA would not be what it is today. Without you, WARDA will not reach its potential in the spheres of rice research and development, and information and technology dissemination for the West and Central Africa region. Without *you*, the rice farmers of the region would face a bleaker future. So from us and from them: "Thank you."

Kanayo F. Nwanze
Director General

N. Lindsay Innes
Chairman, Board of Trustees

Towards more African Rice to Fight Poverty in Sub-Saharan Africa

Monty P. Jones
Deputy Director of Research

THE YEAR 2000 was a very busy, but successful one for WARDA, with its highlight in the presentation of the CGIAR King Baudouin Award to WARDA for the development of the 'New Rice for Africa' (NERICA). NERICAs are now a key component of WARDA's research strategy to tackle poverty, food security and environmental protection in West and Central Africa. WARDA is developing a range of germplasm, profiting from the African rice gene pool, to address the diversity of African rice-growing environments. Combined with natural-resources management techniques, this provides a basket of options for farmers, with great potential to increase local rice production, reduce rice imports and improve the livelihoods of farm households, while conserving natural resources and biodiversity.

Given the growing intensity of upland use and its inherent fragility, potential production gains in upland rice-based systems are modest. WARDA's applied research aims at sustaining productivity gains while stabilizing environmental equilibria in watershed production systems undergoing intensification. Our strategy has two components: (i) the stabilization of upland systems through improved land and crop management, and (ii) relieving pressure on uplands by making the cultivation of adjacent lowlands more attractive and sustainable. Our technology-development research targets various stages in the transition from extensive to intensive cropping systems. Since limited labor availability remains an important constraint during early stages in the transition from land-using to land-saving production systems, our research focuses on developing labor-saving and environmentally compatible technical solutions. That uplands can be intensified in a sustainable way is shown in Guinea, where NERICA lines are making rapid headway, providing scope for farmers to grow leguminous crops in the same season because of their shorter growth cycle compared with traditional cultivars. The success of the NERICAs in Guinea is based on a combination of participatory varietal selection (PVS) and community-based seed systems (CBSS), highly motivated farmers and solid Governmental support. The Guinea experience shows that an enabling environment is essential. This may require policy interventions to address institutional constraints or the development of improved rice processing, marketing and distribution systems. CBSS is clearly an answer to address weak national seed multiplication systems for rainfed-rice farmers.

The research strategy for inland valley lowlands recognizes that intensification is only sustainable if it maintains the natural-resource base, including crop and ecosystem biodiversity. The technical approaches to intensification, however, must be different for rural, labor-limited production systems on the one hand, and land-limited systems—such as peri-urban lowlands—on the other. For rural areas, we are developing low-management rice varieties with multiple biotic and abiotic stress resistance derived from diverse genetic sources, as well as affordable water and soil-fertility management practices that, when combined, will make swamp rice cultivation an environmentally safe and economically attractive enterprise. This will also allow resource-poor farmers to gradually shift from fragile uplands to the more robust lowlands.

Research on land-limited, high-input lowland systems, however, will not necessarily aim at further intensification. Instead, we seek greater diversification by developing economically attractive crop rotations and soil–crop management systems that protect the environment and improve input-use efficiency. Farmer-participatory approaches are central to our strategy to ensure a good local fit and acceptance of the resulting technologies. The strategy is, therefore, to develop lowland cultivation methods that are profitable, safe for human health, provide local food and income security, require minimal initial investment, and allow for sufficiently flexible individual calendars for labor use. These systems must build on varieties that have horizontal (i.e. broad-based) resistance to the major local biotic stresses.

The development of rice-based vegetable production provides important opportunities in terms of diversification (income generation, food consumption) and intensification (optimization of resource use) in WARDA's target area, particularly in peri-urban lowlands. WARDA's investments in trying to initiate complementary vegetable research in the region are now starting to pay-off. By end of 2000, three new restricted-fund projects became operational. These projects include the recruitment of a visiting scientist and a vegetable specialist.

Complementary to the rice-based vegetable production projects, WARDA initiated a new peri-urban project in 2000, again with restricted funding. The project is entitled 'The evolution of agricultural systems in the peri-urban lowlands of West Africa and the development of policy and technologies for their sustainable intensified use.' It aims to sustainably intensify peri-urban lowlands, by (1) identifying areas and conditions that favor lowland intensification, diversification or both; (2) developing technologies and decision aids that reduce tradeoffs between economic performance and environment risks; and (3) providing options for currently less exploited lowlands along the rural to peri-urban gradient.

Regional capacity building on the design, planning and implementation of rice research have implications not only for improving the delivery and impact of research, but also for wider human and social capital formation among the actors as well as in the targeted communities. Our training activities include a series of specific training efforts and events that include: international workshops and hands-on work as visiting scientists or fellows at WARDA; developing regional capacity in the form of trainers; international conferences and symposia; developing and disseminating training materials; and producing guidelines, state-of-the-art studies and reports of rice research experiences. Over 100 rice scientists from West and Central Africa attended the first Regional Rice Research Review for West and Central Africa in April 2000. A large number of quality papers was presented, soon to be published in a proceedings.

Beyond the accomplishments that are featured in this Annual Report, there were several others that deserve mention. WARDA continued widening the genetic base of the West African rice germplasm by successfully introgressing useful genes from the indigenous *Oryza glaberrima* into *O. sativa.* We are continuing to develop interspecific progenies that show higher levels of tolerance and resistance to major yield-limiting stresses in West Africa, including drought, rice yellow mottle virus (RYMV) and acidity, together with good grain quality and stable high yields under low- and high-input conditions—these are being adopted by farmers.

Participatory approaches to technology development and dissemination are being adopted and adapted in 17 countries in West and Central Africa by WARDA and its national partners to facilitate farmers' involvement in the processes. These studies allow for accelerated diffusion of new technologies, as farmers themselves take the lead in selecting acceptable materials using their own criteria. The approach has provided feedback to WARDA's technology-development programs. It has also provided direct information on technology dissemination processes, highlighting promising technologies that address the needs of rural agricultural populations in West and Central Africa. The approach has already paid handsome dividends, for besides speeding up the development of new varieties, it is helping to gauge the acceptability of available materials as well as stimulating demand for new varieties.

Our research on crop and natural resource management (C&NRM) in the upland systems showed the potential of the use of leguminous cover crops and the benefits of rock-phosphate on poor upland soils. These technologies, in combination with weed-competitive and acid-soil adapted interspecific rice varieties, will enable resource-poor farmers to stabilize upland rice cultivation, concentrating their farming on limited areas, thereby reducing destructive slash-and-burn practices. Yields will be stabilized, while labor productivity will be increased.

Water control and access to markets are key factors influencing the possibilities for cropping intensification and diversification in rainfed lowland systems. Given the extent of the lowland valleys, i.e. 20 million ha in West Africa alone, potential impact of improved C&NRM practices on food security in West Africa is tremendous. Options include dry-season cultivation of legumes, vegetables and root crops, and double-cropping of rice. Retaining and recycling upland soil nitrogen (N) *in situ* through deep-rooting crops (e.g. pigeon-pea), capturing loss-prone N in the hydromorphic fringe or during the pre-rice cropping niche in lowlands may reduce N losses to the atmosphere. Nutrient management through the use of N, phosphorus, potassium and zinc nutrients, along with the use of iron-tolerant lowland rice varieties, provides technology for increasing the productivity and production of rice in the wetlands where iron toxicity is present. Use of tolerant cultivars with proper water and nutrient management for reducing iron toxicity will help extend wetland rice cultivation in the inland valley systems.

Crop and fallow management and crop rotations have a profound impact on weed growth and form important components of integrated management strategies. Management practices have been identified that substantially reduce weed growth in the differing positions of the toposequence in the humid zone and in the irrigated ecologies of the Sahel. In the latter, it has been shown that improving the timing of application of inputs, rather than quantity, can lead to a 50% increase in yield—half of which is due to improved weed control.

A substantial proportion of the weed research has been conducted in support of the varietal improvement activities to develop weed-competitive plant types. Methodologies have been developed that enable the mass screening of rice cultivars for their competitive ability with weeds, enabling weed-competitive lines to be selected from the large numbers of interspecific progenies at an early stage.

We believe that these studies will contribute significantly to the expected boom in regional rice production, which is likely to draw from diverse hydrological environments and water management systems. New technologies from these studies will provide farmers with low-cost water management technologies and low-management plant types, as an incentive to increase and intensify the cultivation of lowlands. In the uplands, low-management (e.g. weed-competitive) but input-responsive interspecific rice varieties are now available and are being evaluated with farmers in participatory research. This will improve yield stability and create incentives for resource-poor farmers to replace nutrients extracted from the soil in short-fallow systems. The long-term recovery of destabilized upland systems would also require more substantial investments in resource-base quality. The major challenge will be to ensure the dissemination of these technologies to poor farmers, national agricultural research and extension systems (NARES), advanced research institutions (ARIs) and non-governmental organizations (NGOs) in a way that they can adopt and adapt them to their needs. Our PVS and CBSS work is a first step in the right direction. The integrated crop management (ICM) approach for irrigated systems featured prominently in this report is another. However, such activities require an enabling environment, and this is the focus of our policy research—to provide options that foster enabling environments, including raising awareness among decision-makers on the potential benefits of rice technologies for poverty alleviation and rural development. This in turn should lead to renewed action to alleviate socio-economic constraints to rice development.

In conclusion, the year 2000 was successful, but a lot remains to be done to produce more NERICAs and complementary technologies to fight poverty in Africa. As indicated elsewhere in this Report (*see* pages 1 and 58), the potential for success is high—for example, 25% adoption of NERICAs in three countries (Côte d'Ivoire, Guinea and Sierra Leone) by 2004 would add US$ 20 million per year to the economy in these countries. We wish to thank all our partners, 'upstream and downstream,' for their efforts. We look forward to strengthening our collaborative activities with you in the years ahead.

Integrated Crop Management: Getting it Right on the Farm on a Wide Scale

WARDA'S RESEARCH program in the Sahel has been active for over 10 years. In that time we have learnt a lot about crop management at the farm level, and we've shown that many techniques work. Now it is time to 'spread the news' and get irrigated rice farming in the Sahel onto a higher plain.

Over the last 10 years or so, WARDA's research program in the Sahel has covered numerous aspects in the general fields of variety development and evaluation, and crop and natural resource management. Characterization studies have been conducted in several Sahelian countries to identify and tackle relevant socio-economic issues with hundreds of farmers. We have learnt a lot about crop management at the farm level, and we've shown that many techniques work. In the last couple of years, we have started to put these all together in 'baskets' of advice to farmers that amount to an integrated crop management (ICM) approach. ICM practices were successfully tested, so that we now want to make the technologies and tools for integrated crop management available to many more farmers.

A brief history of the Sahel program

Before 1989, WARDA's activities in the Sahel were dispersed among various sites, particularly along the Senegal River. In 1989, Sahel Station activities were consolidated in northern Senegal, with offices, laboratories and a research farm at N'diaye (25 km east of Saint Louis), and additional research fields at Fanaye (180 km east of Saint Louis).

In the early 1990s, the work was focused on strategic research at research stations, with a view to addressing rice-plant/environment interactions in the Sahel. An important aspect was, for example, physiological responses (by variety) to temperature and solar radiation levels. This work led to the development of crop models RIDEV and OryzaS. RIDEV helps determine sowing dates to avoid cold-induced sterility, and gives best predictions for cropping calendars on the basis of varietal choice, site and sowing date. OryzaS uses weather data (solar radiation, and minimum and maximum temperatures) and variety-specific photothermal constants to predict the potential yield and growth duration of a given variety at a given site, sown on a given date. Other research looked at varieties' physiological responses to salinity (a major constraint in the Senegal River delta and elsewhere) and screening varieties for salinity tolerance. It was also during this period that trials were established to follow the impact of continuous double-cropping on soil fertility (*see* Box 'Long-term fertilizer trials').

At the same time, we selected varieties that were better adapted to the Sahelian environment (high yield, short cycle, better grain quality). During this period, promising varieties were tested in collaboration with the

Long-term fertilizer trials

When changing an existing cropping system or introducing a new cropping system, one important question is always whether the new system will be sustainable. Sustainable development should (1) maintain or enhance production and/or services, (2) reduce the level of production risk, (3) protect the potential of natural resources and prevent degradation of soil and water quality, (4) be economically viable, and (5) be socially acceptable.

Although irrigated rice cropping systems have proven to be sustainable by their long history in Asia, this may only apply to traditional systems. The introduction of highly intensive cropping systems during the green revolution with up to three cropping seasons a year and intensive use of fertilizers and pesticides is relatively recent—dating back no more than 35 years. Because of the considerable changes associated with their introduction, the long-term sustainability of modern irrigated rice systems is not beyond doubt. Some studies have shown stagnant or even declining yields combined with declining soil nutrient supply in highly intensive irrigated rice cropping systems. An important tool to analyze the impact of cropping systems on the soil resource base is Long-Term Fertility Experiments (LTFE), where the same crop management is applied to the same field over decades. Several LTFEs for intensive irrigated rice cropping were established in Asia, but they are rare in Sub-Saharan Africa. WARDA is running two such trials in two different bio-physical environments in Senegal (in N'diaye and Fanaye). Both trials were established in 1991, and contain six treatments with fertilizer doses; rice is grown twice a year.

In 17 consecutive seasons, best treatments at both sites and in both seasons yielded on average between 7.1 and 7.5 t/ha per season. Negative yield trends were observed at one site, but they might be explained by less favorable weather conditions during later years. At both sites, intensive rice cropping without phosphorus application (current practice in Mauritania) led to P-deficient rice plants after only six seasons. Later on, zero potassium (K) application combined with complete straw removal caused a considerable decline of the soil K supply. Both practices are therefore considered unsustainable, although lack of K application will not cause K deficiency quickly due to the immense soil stocks, and deficiency can be delayed further by appropriate rice straw management.

These results and ongoing soil quality monitoring in farmers' fields help to develop ICM techniques which not only increase productivity and profitability of irrigated rice, but maintain the resource base quality at the same time.

Senegalese national research institute, *Institut sénégalais de recherches agricoles* (ISRA) and Senegal's extension service for the Senegal River, *Société d'aménagement et d'exploitation des terres du Delta du Fleuve Sénégal et des vallées du Fleuve Sénégal et de la Falémé* (SAED). From the variety evaluations, particular successes were Sahel 108, Sahel 201 and Sahel 202—all released in Senegal in 1994 (and subsequently in Mauritania; *see* Box 'Sahel 108 and other Sahel rice varieties'). In addition, several other high-yield-potential varieties were identified for use in the breeding program.

By 1995, we had started to look more closely at how farmers manage their rice crop: what they do, and the influence of socio-economic and bio-physical factors on their practices and performance. To get a good picture of irrigated rice cultivation in the region, survey sites were chosen in Senegal, Mauritania, Mali and Burkina Faso. To develop close contact with farmers, we opted for true partnership (a practice in its infancy at that time). We worked with extension agents from the national agriculture research and extension services (NARES) and met the farmers before embarking on any work with them. Having duly shared and discussed our ideas, we then asked for volunteers in each community we visited, and the NARES helped select farmers for the work. Marco Wopereis, then agronomist at the Sahel Station, takes up the story: "We looked at farmers' practices and then compared their performance with yields predicted by our models." It was clear that the potential of the varieties that farmers used was not being achieved on the vast majority of farms. "Perhaps the main problem was that there was a huge variation in farmers' rice yields, from a few who achieved levels close to those achieved in research-station trials and predicted by OryzaS, right down to others who produced minimal rice in neighboring fields and using the same varieties!"

With clear yield-gaps that had to have some logical explanation, Wopereis and his team embarked on a series of agronomic trials to try to determine which factors were

Sahel 108 and other Sahel rice varieties

Rice variety Sahel 108 was released along with two other varieties (Sahel 201 and Sahel 202) in Senegal for irrigated cropping in the Senegal River valley in 1994, and then released in Mauritania for the same ecology in 1996.

The three varieties had been introduced in nurseries distributed by the International Network for Genetic Evaluation of Rice (INGER, then hosted by IITA under the auspices of IRRI) and were selected by WARDA in Senegal and Mauritania. Sahel 108 was an IRRI variety, Sahel 201 came from Sri Lanka, and Sahel 202 from IITA.

The Sahel varieties were released for their improved performance over long-standing cultivars Jaya (medium duration) and I Kong Pao (IKP, short duration), both introduced around 1970. While Jaya has a high yield potential, it is not tolerant to the saline conditions of the Senegal River delta and its cycle length prohibits double-cropping. IKP, on the other hand, may be grown in any season, but has poor grain quality and lower yield potential than Jaya.

Sahel 108 was targeted for the dry season when short duration is important for enabling farmers to double-crop. Sahel 201 and Sahel 202 are medium duration and therefore targeted for use in the wet season. Sahel 201 was introduced for high yield and moderate tolerance to salinity and Sahel 202 for high yield with good grain quality.

The Sahels yield approximately 10% more than the existing varieties in the wet season and Sahel 108 about 11% more (than IKP) in the dry season. Net revenue gains per hectare are even more impressive, with Sahel 108 giving 18% more than IKP in the wet season; Sahel 201 giving 21% and Sahel 202 some 24% more revenue than Jaya in the same season. Sahel 108 gives net revenues 23% higher than IKP in the dry season.

More importantly, Sahel 108 matures about 15 days earlier than Jaya during the wet season. This earliness results in a saving of 1000 cubic-meters of water per hectare. Scaling up for the whole Senegal River valley (in Senegal), Sahel 108 saves at least 11 million cubic-meters of water per year. If we now assume an irrigation efficiency of 40%, this amounts to 28 million cubic-meters of pumped water, or about US$ 400,000 in saved fuel! In addition, the short cycle opens up new possibilities for double-cropping on the same parcel of land, potentially doubling per-hectare annual output—10% of the cropped area in Senegal is currently double-cropped.

Initial estimates of Internal Rate of Return (IRR) were based on conservative adoption estimates (25%, 10% and 15% for Sahel 108, Sahel 201 and Sahel 202 in the wet season, and 40%, 5% and 5% for the same cultivars in the dry season), but were nevertheless high, i.e. 118%. By the end of 1999, Sahel 108 already occupied 31% of the rice area in the Senegal River valley in Senegal in the wet season, and 66% in the dry season, so the IRR estimate has already been exceeded. In Mauritania, the three Sahels occupied about 35% of the total area under rice in 1999.

(Text originally published in *CGIAR Annual Report 1999*, page 33.)

to blame for the poor performance on many of the farms. Wopereis again: “we developed a suite of farming-practice tools to assess the productivity achieved by farmers against an achievable potential” (*see* stories in 1998 and 1999 Annual Reports). “In particular, we looked at weed and soil fertility management, and harvest and post-harvest practices, including the timing of all farm activities. Our results made it clear that there was no one-single cause of loss of productivity, but rather an array of factors that affected different fields to a greater or lesser extent.” However, fertilizer management and weed control were common denominators, improvement of which were most promising for increasing productivity and

Farmer counting the panicle branches of variety Sahel 108 to determine its potential yield profitability. Using the models OryzaS, RIDEV and the newly developed FERRIZ, a framework was developed to design new fertilizer recommendations tailored to soil characteristics and potential yield. The combined impact of improved fertilizer management and weed control was proven in the wet season of 1998, when participatory trials with small groups of farmers in the Senegal River valley in Senegal and Mauritania were conducted. These tests showed that both recommendations together could easily increase yields by almost 2 tonnes per hectare—a 50% increase from an average of 4 t/ha (*see* 'Soil Nutrients and Fertilization in Irrigated Rice in the Sahel,' *WARDA Annual Report 1998*, pages 16–22). Concurrent financial and risk analyses of proposed fertilizer use showed advantages both ways—better management (timing, dose and mode of application) of fertilizers not only improved financial returns (by an average of 85%), but also reduced the risk of financial loss.

Putting the components together

Perhaps a major failing of agricultural research in the past was the focus on single or few factors as a means to improving production. Much as these have proven valuable, their benefit often vanishes when other crop management components are not optimal. Stephan Häfele, then PhD student at the station, explains: "Take, for example, our work with fertilizer and weed management. When we improved only the fertilizer management, half of the gain was lost to weeds. And even the best fertilizer and weed management will yield nothing when a late sowing date or a wrong variety results in sterility due to extreme temperatures." And the factors that influence the number of sacks of rice a farmer will finally sell are numerous. Therefore, we firmly believe that lasting improvement will only come when the whole farm system is taken into account and problems are addressed in a holistic way. "In 1998, we decided that it was time to start looking at integrated crop management," explains Wopereis. "We had access to a whole range of management interventions that we either knew would increase productivity on farm, or else had good reason to believe they would." Based on our work and the experience of researchers from NARES, we developed a set of integrated crop management recommendations for the Senegal River valley (*see* Box 'Integrated crop management options for the Senegal River valley'). Since these recommendations covered a large part of good management practices at farm level, they were also used in training programs for collaborating extension agents in Senegal and Mauritania. To facilitate communication with collaborating farmers, we eventually developed a poster that visualized recommended crop management practices (*see* Box 'The printed "word"'). In collaboration with the extension services, 30 of these posters, together with the ICM recommendations, were distributed to farmers' unions in the Senegal River valley.

Participatory evaluation and socio-economic characterization in Mauritania

This year's story really begins in 1999 with the arrival of Mohamed Kebbeh as a Visiting Scientist (Agricultural Economist) at the Sahel Station. He was to bring a new perspective to the work. "Farmers' performance is not a simple result of bio-physical constraints reducing yield on the farm," he explains. "When farmers consider their farms, they are not just looking at the biological and weather factors, their lives extend beyond the rice field to their families, communities and general socio-economic environment. Thus, a whole host of socio-economic factors compounds the effects of nature."

To build on the success of the 1998 trials, the team went to eight sites in Mauritania in the 1999 wet season, and they added mechanical threshing using the WARDA-promoted thresher–cleaner to the integrated crop management (ICM) package. This time, the research had two aspects—participatory evaluation of the ICM package with a larger group of farmers and consequently reduced researcher control of the 'experiments,' and characterization of the farmers' socio-economic environment to explain the performance of the recommended technologies.

Integrated crop management options for the Senegal River valley

Factor	Recommendation(s)
Land preparation	Cultivate on suitable soil (heavy clay soil) Ensure field is properly tilled and leveled
Seeds	Use pre-germinated certified seeds
Variety	*Dry season:* Sahel 108 (good grain quality, salinity sensitive) or I Kong Pao (poor grain quality, salinity tolerant) *Wet season:* Sahel 108, Jaya, Sahel 201 or Sahel 202
Sowing date	Determined (guided) by RIDEV to avoid spikelet sterility due to heat or cold
Seeding rates (certified seed)	*Direct seeding:* 100 kg/ha *Transplanting:* 40 kg/ha
Fertilizer application	*Fertilizer doses are adjusted to soil characteristics, potential yield and season.* *Maximum:* Triple super phosphate (TSP, 20% P) or diammonium phosphate (DAP, 20% P, 18% N) basally at 100 kg/ha; plus urea (46% N) at 250–300 kg/ha in 3 splits: 40% at start of tillering, 40% at panicle initiation, 20% at booting *Timing:* Guided by RIDEV
Weed management	Propanil at 6 L/ha plus 2,4-D at 1.5 L/ha, applied a few days before first urea application (2–3 leaf stage of weeds), plus one manual weeding before second urea application
Water management	Drain fields before applying herbicides Reduce water level to 3 cm for 4–5 days at fertilizer application Completely drain field 15 days after flowering
Harvest	Harvest at maturity, that is when about 80% of panicles are yellow
Post-harvest	Thresh within 7 days of (timely) harvest Preferably use the WARDA-promoted thresher–cleaner (ASI)

As usual, farmers' practice (TF) was always compared to the ICM practice, but this time on large plots. ICM practices were supervised by extension officers of the *Societé nationale pour le développement rural* (SONADER), who also monitored crop management practices of sample farmers throughout the season. All inputs for the ICM plots (with the exception of costs for labor, irrigation water and land preparation) were provided at no cost to participating farmers, but farmers took total responsibility for the plots under their own management (TF).

The socio-economic characterization was done through surveys and participatory appraisals. The appraisals were informal—there were no questionnaires, merely open-ended discussions with farmers. "One factor we thought vital," explains Kebbeh, "was involving the farmers in the analysis of the findings. All too often, farmers have been 'grilled' for information, then they have never seen the results, much less understood them! By doing the analysis with them, we showed that we were genuinely interested in their needs and not just in collecting data for our own research."

The printed 'word'

Our involvement in farmer-participatory work over the years has shown that farmers and extension agents often simply lack pertinent information of the best crop management options available. We have tried to overcome this problem by introducing ICM posters and preparing a manual on irrigated-rice production in the Senegal River valley.

Our experience has shown that what farmers need is not rigid recommendations detailing a precise package that must be adopted, but rather options—choices from which they can select those components that they can afford (in terms of labor and finances) and that would be most beneficial for them.

The crop model RIDEV predicts the growth of the rice plant (it is variety-specific), and also gives recommendations for the timing of major crop management interventions. The model is widely used by the extension agencies in both Mauritania and Senegal. The timing recommendations generated by RIDEV have been tabulated and are used by extension agents in the field. In order to 'spread the word,' WARDA, SAED and ISRA developed a simple poster for circulation to, and use by, farmers' organizations. Posters are location, season and variety specific, but are cheap to generate, so can be provided for all appropriate combinations. Other relevant information is provided to enable farmers to adapt the timings to their own financial and other circumstances. As the ICM technology spreads out in ever-wider circles, we envisage producing fliers—handbills comprising miniature versions of the poster with the detailed ICM recommendations printed on a single sheet (back and front). These could be distributed in large numbers to farmers and extension personnel.

The first edition of the irrigated-rice manual is for extension agents in the Senegal River valley of Mauritania and Senegal. It is about 120-pages long, and gives an overview of the best-bet crop management options for irrigated rice in the Senegal River valley. The first edition is in French, but we expect to have it translated into Arabic and local languages, such as Wolof and Pulaar.

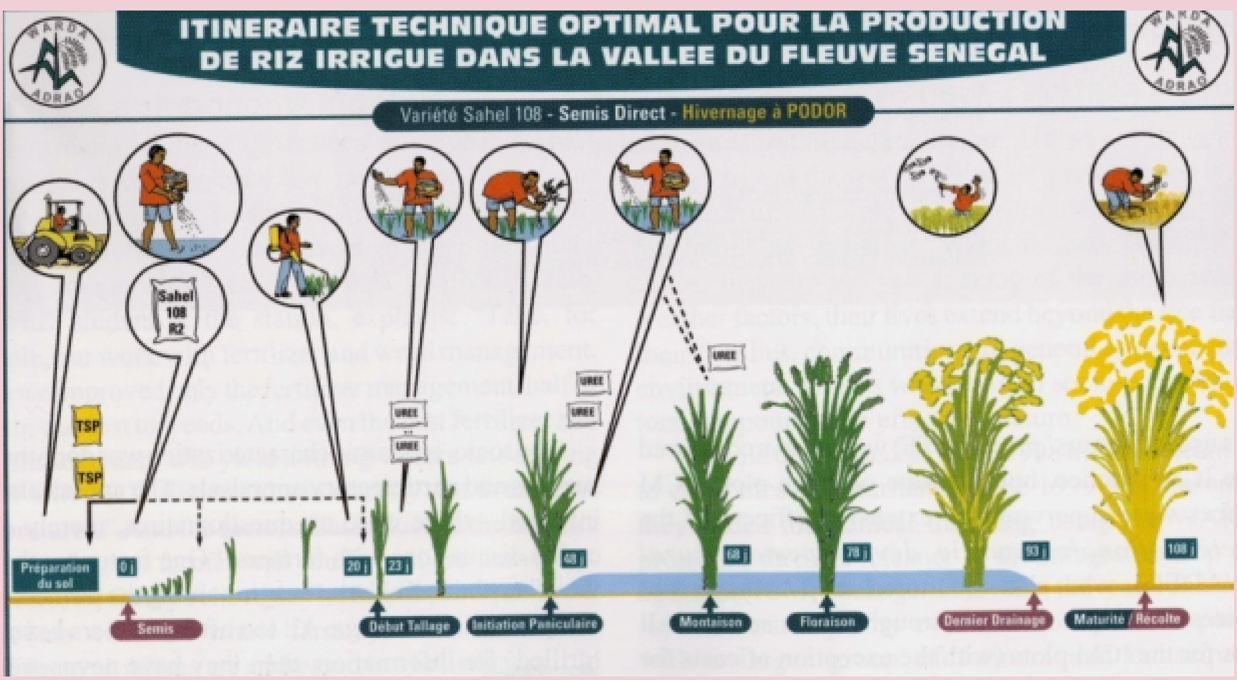


Figure 1. Posters were used to visualize recommended crop management options during meetings with farmers. This one is for variety Sahel 108, direct-seeded in the wet season in Podor region, Senegal—crop duration and growth stages for crop management actions were simulated with RIDEV and local weather data

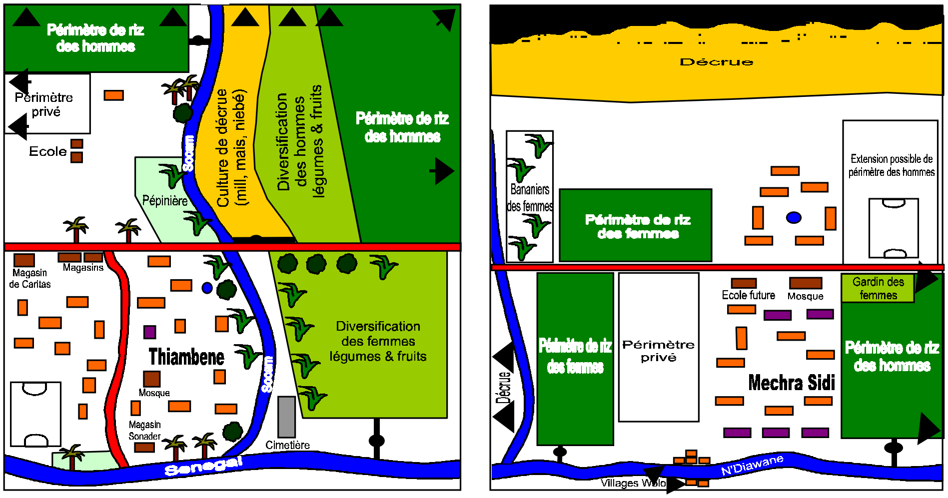


Figure 2. Maps (like these for Thiambene and Mechra Sidi) were developed to identify major production resources in each community and their allocation to different activities

The characterization results were built up in layers, starting with a graphical representation, or 'map,' of resources available to the community. Next, we developed a profile of socio-economic activities that used those resources, typical examples being irrigated rice farming and fishing. A calendar of these activities was then used to identify times of resource constraint, especially for labor. A profile of interactions within and between households and community was developed in relation to resource use. These led into an analysis of both general and rice-specific constraints. Irrigated rice production constraints were further analyzed through the development of problem trees and ranking matrices.

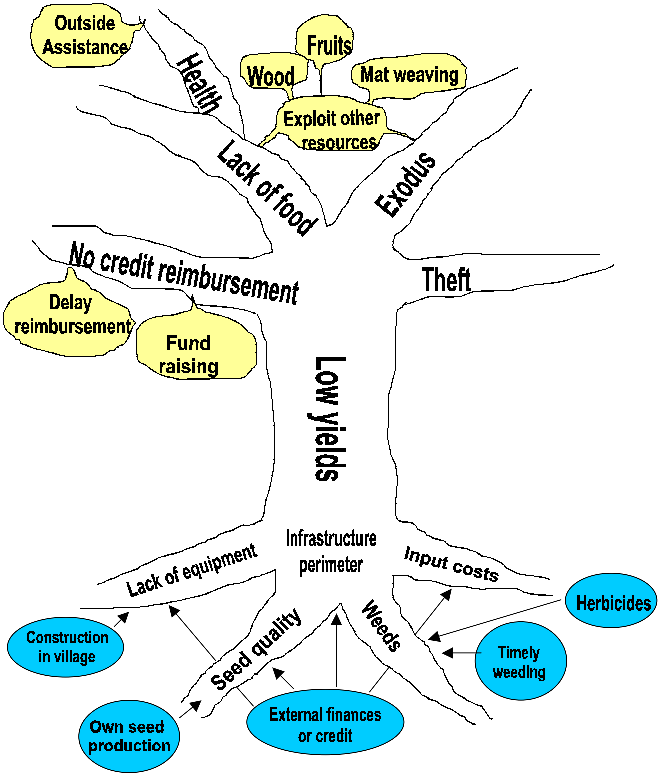


Figure 3. In Mechra Sidi, female farmers developed this problem tree for the analysis of irrigated-rice production constraints

"We must bear in mind that this is still research," explains Kebbeh. "One year's results are never enough to 'prove a point' and move on to the next stage." Thus, the validation of the integrated crop management package and the socio-economic characterization, which had been done with 80 farmers in 1999, were repeated with a further 150 farmers in Mauritania in 2000. "Now it starts to get exciting," enthuses Kebbeh, "as the 2000 results were consistent with those of the previous year."

Highlights and key results

So, just what did the team discover from all this interaction with farmers?

"The trials in the 1999 wet season confirmed earlier work on improving yields," says Kebbeh. "As before, the integrated management gave a yield advantage of 2 tonnes per hectare over farmers' practice. What's more, almost every other indicator of profitability and risk rated the ICM superior to the farmers' practice." Thus, whereas inputs for the ICM would cost farmers an extra 11 to 24% in cash (or credit) at the start of the season, the net revenue at the end of the season was increased by anything from 49 to 142%! The extra costs were associated mostly with herbicide and phosphate fertilizer. "The inference," continues Kebbeh, "is that the major advantages of the ICM package accrued not from increased inputs, but rather from better management of inputs, in particular the mode and timing of their use."

The following year was not so dramatic, but still significant. "What we have to bear in mind here," explains Häfele, "is that as more farmers come into contact with ICM, their production practices change. Over time, we are comparing the ICM with modifications of farmers practices as they pick up some elements of the ICM." But that's not all. "As we scale up," explains Wopereis, "more and more farmers see the advantages of the new system, so we have a two-way effect. First, we have the adoption of only part of the package in the farmers' management of the ICM plots so that the potential yield of those plots is no longer as high as with the full package, but then we have the adoption of some of the components in the farmers' treatment plots, which acts to increase farmers' overall performance. The net result is clearly going to be a smaller gap between farmer-practice and ICM plots."

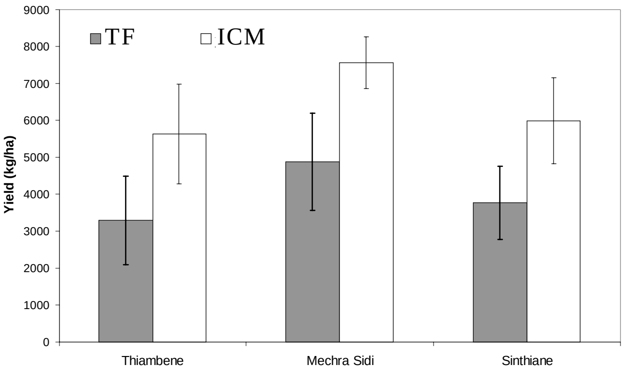


Figure 4. Comparison of mean yelds for ICM and farmers' practice in three villages in Mauritania, wet season 1999

"Here we also got our first taste of spill-over," enthuses Irrigated Rice Program Leader Kouamé Miézan. "Some of the neighbors—farmers who were not involved in the research—saw what was going on and were obviously impressed. After asking questions of the farmers working with us, they then adopted some of the ICM options themselves." These farmers were also able to increase their rice yields.

With the ICM thus vindicated, it is the turn of the socio-economic analyses to 'show the way' for improving productivity at farm level.

Back to Kebbeh: "Irrigated rice is only one component of a community's life, even when it is their principal economic activity. There are always other economic activities, and some of these may be considered as important as the irrigated rice production. This may then cause competition for limited resources. Differences in gender roles are always important when looking at the farming activities of individual community or family members." As a rule, in communities where both men and women are involved in farming activities, they tend to have different roles. In other communities, it may be only one gender that engages in irrigated rice farming (either men and women). "One real surprise from case studies involving only three villages in 1999," explains Kebbeh, "was the significantly better performance of the women-only village cooperative." This cooperative outperformed both the men-only and the men-dominated ones, not only in terms of the performance of the farmer-practice plots, but even in the ICM plots! In one cooperative with both male and female rice producers, the only woman farmer in our sample outperformed her male counterparts in terms of both yield and farm revenue.

A final, but vital finding was that the role of farmers' cooperatives in scheme management is crucial. Most particularly in the management of water and of credit for buying inputs at the beginning of the season. This has implications for the management of inputs in the ICM. "One problem here," explains Kebbeh, "is that we have mostly targeted individual farmers with recommendations, when some of the decisions required have to be made collectively." For example, there are specific recommendations for farmers to drain their fields at certain times for fertilizer application and prior to harvest. But, water management decisions are often out of the individual's control, resting with the cooperative. "One implication of this finding," continues Kebbeh, "is that research and technology development efforts that target only individual producers for recommendations involving input use and management decisions may be misguided."

The way forward... making research results matter

Miézan is delighted at progress to date and prospects. "We have been working towards something like this for ten years," he says, "and now we are on the brink of helping to improve the livelihoods of more farmers than most researchers ever dream of doing." He is talking about the team's bold plans for 2001.

Kebbeh: "With the successes of the last two years behind us—80 farmers in 1999, and 150 in 2000—we feel the time is right to think big!" But, how big is 'big'?

The one female farmer at Sinthiane achieved higher rice production on both her own managed plots and on the ICM plot than her nine fellow participants—all males!

Miézan: "In January 2001, we were invited to present our ideas at a meeting with CIRIZ [a farmers' cooperative in Senegal representing several hundred farmers] and SAED. We shared with them our results on ICM, the ICM poster," (*see* Box 'The printed "word"') "and a questionnaire." The link with extension is vital, "if we expect to reach hundreds of farmers with this, we can forget about personal WARDA involvement with each and every farmer! It is the field extension agents who will do the bulk of the work."

But even hundreds of farmers in northern Senegal isn't enough for Kebbeh. "We have developed a partnership with a major regional NGO, the West African Rural Foundation," he says, "with whom we are preparing a proposal for scaling up the ICM work." The proposal addresses the problem of transferring the ICM technology experience to farmers in four or five countries. "In preparing the document, we are also seeking ideas from the national programs in the target countries and the Food and Agriculture Organization of the United Nations (FAO)," explains Kebbeh.

The proposal will be considered further at a regional workshop in April 2001. The national agricultural research and extension systems, along with key NGOs and farmers' organizations from the target countries will be in attendance. "In addition, target donors—the FAO, the World Bank, and the European Union—will be there," says Miézan. “In fact, it is the FAO that is funding the workshop.”

“The workshop,” explains Kebbeh, “will review and validate the project document.” That is, the participants will all (hopefully) agree to be bound to the wording, the work plan, and responsibilities inherent in the project’s implementation. “The final document will be submitted for funding,” says Kebbeh, “hopefully by one of the donors who has shown an interest by attending the workshop in the first place.”

Ever upwards—improving the improved

“The potential yield of existing rice cultivars in the Sahel is over 9 tonnes per hectare,” explains Stephan Häfele, now WARDA’s agronomist for irrigated systems. “So, even if we achieve a regional increase to an average of 6 or even 7 tonnes, we are still looking at a yield gap that can be made even smaller.”

He continues: “Compared to the old ‘blanket’ recommendations for fertilizer and herbicide, the newer recommendations that we have helped develop along with our national partners are already a vast improvement—more geared to the area of interest.” However (and as we stated in the *Annual Report 1998*, page 17), this is still a long way from the precision farming (fertilizer dose determined on a square-meter basis) of countries such as the United States. “As time goes by, and instruments for measuring soil fertility status become cheaper, it should be possible for first extension agents, then later farmers’ cooperatives to do field-specific soil testing, and make fertilizer recommendations on the basis of the results.” Meanwhile, the current ‘target’ areas are sufficiently large, that there is enough work to keep Häfele and his colleagues busy for a few years yet on intermediate steps.

And there are other areas where progress can continue. “The irrigated rice field is complex,” explains Program Leader Kouamé Miézan. “Optimum management of the crop requires quantification. Farmers’ management options are dynamic, and any changes to the schedule may well affect the timing of future management interventions.” The work of Mohamed Kebbeh on the socio-economic aspects of adoption feeds back into the cycle of changes. “Reasons for non-adoption of particular options are especially useful in this respect,” says Miézan. To maximize the value of this kind of feedback, computer-based modeling remains high on the Sahel team’s agenda.

Another area of further development is the rice varieties grown. In addition to being Program Leader, Miézan is also WARDA’s irrigated-rice breeder. “The variety is crucial to the whole management system,” he explains. The pivotal position of a variety is shown in the fact that varieties are ICM-specific—choice of appropriate variety is crucial to the optimum output of the whole management system. “For example, why would you use a nutrient-dependent variety in a system where farmers do not have access to fertilizer, or why use a variety that is not responsive to fertilizer in a system where fertilizer is used? However, as the farming system becomes more profitable, and the farmer can increase his or her use of inputs, so we can look at different types of varieties. Contrary to ‘popular’ belief, we are not trying to adapt the system to the variety, rather we want to develop varieties adapted to the system. For example, where salinity is a problem, we require a salinity-tolerant variety, but the whole ICM package for that environment is based on the sum of resources available to the farmer and not just the variety.” Thus, once the farming system itself is characterized, an ICM basket is developed to optimize the output of the system—one component of that is selecting the variety best suited to the system, that is, one which contributes to the ICM goal of optimizing the system. On-going variety work in the Sahel is targeting increased nutrient-use efficiency and weed-competitivity.

“Once we start looking at resource-use efficiency,” Miézan continues, “we have to consider water.” Water management has implications for many other crop management interventions—fertilizer application, weed control and harvesting to name a few. What’s more, “water management at the scheme level has direct implications for the farmer,” explains Wilfried Hundertmark, former Water and Irrigation Management Specialist seconded from the International Water Management Institute (IWMI) to WARDA Headquarters. “Decisions made at the scheme level can equally cause water shortages or flooding at inappropriate times for any particular rice crop.” IWMI has now seconded an Irrigation Management Economist to the WARDA Sahel Station, so the issue of water is climbing in the Program agenda. It should not be too long before we see refinements to the water management components in the ICM.

Remaining challenges

"But we're not there yet," Kebbeh continues. "There are still major organizational issues to be resolved, like the 'simple' organization of so many partners and other stakeholders." The idea of involving all the potential partners in the project formulation stage is to increase their commitment to the final project and ensure joint ownership. "The project plans to build on the current (positive) trend of increased involvement of national partners," says Miézan, "namely, the research and extension services of the target countries." As we said before, the extension agents will be key to the success of the program.

Then, of course, there are the logistics of mobilizing so many extension personnel, and determining how best to reach the farmers. "Local language may well play a key role here," explains WARDA Information Officer Guy Manners. "We are looking into partnerships with NGOs who work specifically on literacy in local language groups, since it is not only verbal communication that counts, but also the little 'reminders' in the form of the ICM poster."

Another area of concern is measuring impact. "We want impact... the donors want impact," explains Kebbeh, "so we have to devise some mechanism of monitoring it." Impact takes the form of increased yields and farmers' income, but also in measuring just what components of the package farmers feel they 'can' adopt and do adopt. "Our current thinking," Kebbeh continues, "is to select five key sites—one in each country—and to monitor about 100 farmers per site. That would give us some 500 farmers—a fair number to measure our 'success' by. And the socio-economic aspect won't be ignored at this stage either. We still want to know which components are most appealing to the farmers and why."

"We mustn't forget," Director General Kanayo F. Nwanze states pointedly, "we are not talking pure extension here. This is still at least partly strategic research at the farm level. From our experience to date, and that of others, we believe that we can disseminate this ICM technology on a wide scale, but we don't know for sure. This whole thing is one big research project to see if we can do it. And if we can? Well, then that opens up a whole lot of possibilities, not only for us, but for agricultural research throughout the region, and even beyond."

Big Problems with a Little Fly: African Rice Gall Midge

AS ITS name might imply, African rice gall midge looks more like a mosquito than a serious plant pest; but, this little bug is an important pest of lowland rice in at least four of WARDA's member states, and has been recorded in a further 16 Sub-Saharan African countries. The larva bores into a rice tiller and eats away its host from the inside. Infestation in a field of a susceptible variety can result in complete yield loss. WARDA has been working on gall midge for some years, and now has some methods for managing it that can be combined for greater effect.

Gall-midge adult: It's only a little fly, but its appetite for rice tillers can lead to total crop loss!

Gall midge has been known as a pest of rice for a long time; however, it was not until the late 1970s that serious damage was recorded in West Africa, and that was in southern Burkina Faso. In 1988, extensive outbreaks occurred over 50,000 hectares of lowland rice in southeast Nigeria. It is now a serious problem in both these countries, and also in Mali and Sierra Leone. In addition, it has been recorded from a further 11 West and Central African countries, and 5 other Sub-Saharan African countries (*see* map, Figure 5). Yield loss assessments in fields with up to 30% tiller infestation suggest that for each 1% increase in tiller infestation, a farmer can expect to lose 2–3% grain yield. Heavily infested fields may produce no grain at all. Thus, the potential for devastation is already great, and is most likely increasing.

Early research by WARDA, the International Institute for Tropical Agriculture (IITA) and their partners concentrated on the basic biology and ecology of the pest. It was not until 1982 that African rice gall midge (*Orseolia oryzivora*) was recognized as being distinct from Asian rice gall midge (*O. oryzae*) of South and Southeast Asia. In 1993, entomologist Charles Williams of the Centre for Agriculture and Biosciences International (CABI, UK) was seconded to WARDA, based at IITA headquarters (Ibadan, Nigeria), to work on African rice gall midge in a project funded by the UK Department for International Development (DFID). The DFID project ran through 1996, and covered the study of pest distribution and economic importance, ecology, alternative hosts and cultural practices, identification

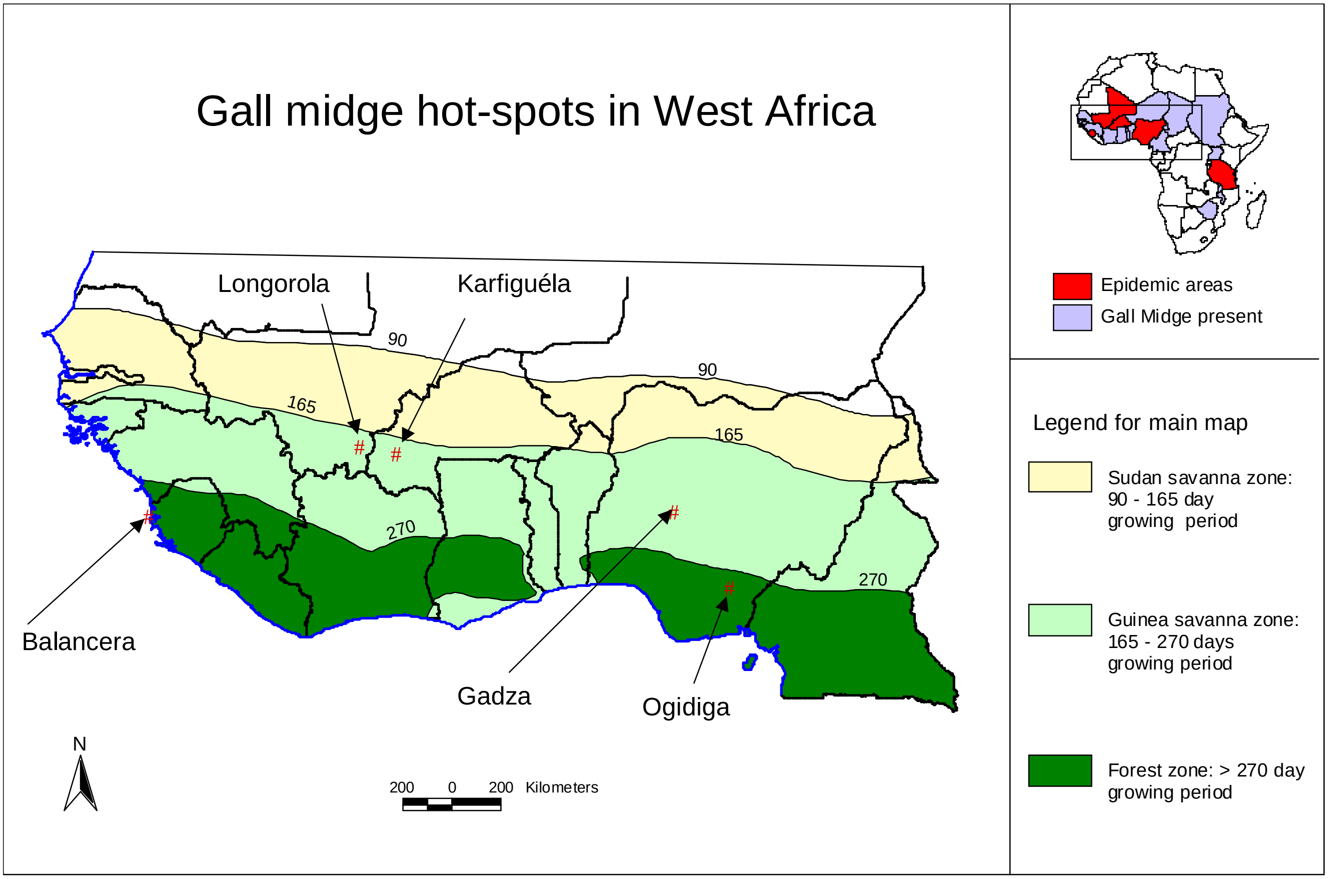


Figure 5. Map of the distribution of African rice gall midge

of natural enemies of gall midge, and screening of rice varieties to assess their resistance to the pest. The work continues today under the supervision of staff entomologist Francis Nwilene, who first came to WARDA (headquarters this time) as a Visiting Scientist in 1998.

Life cycle

A female gall midge lays its eggs scattered on leaves and leaf sheaths of rice. Eggs hatch in 2 to 5 days. The tiny, legless larva crawls onto a rice shoot (tiller) and makes its way (down) between the leaf sheaths to the growing point. After it has shed its first skin, the larva burrows its way into the tiller. Water droplets are needed on the plant surface to allow the larvae to move and penetrate the tiller—if the plant is dry, any larva that hatches will most likely die. The presence of the larva at the growing point causes the plant to produce an oval white gall, in which the larva feeds and develops for 10 to 20 days. When fully grown, the larva becomes a pupa—at this stage the insect is about 5 mm long, it does not feed; it does, however, darken from whitish to dark brown as it develops.

Galls on young plants shortly after transplanting

Toward the end of the pupal stage (usually 3–5 days), the gall elongates rapidly to form a hollow tube of about 3 mm diameter, tapering at the end. At this time, the gall becomes visible as it projects beyond the tiller. The gall's final length is determined by as yet unknown factors, but it may be as long as 50 cm. The pupa wriggles up the gall and cuts an exit hole near the tip using spines on its head. Finally, the pupal skin splits and the adult midge flies away leaving the pupal case protruding from the hole. After emergence of the midge, the gall dies back slowly over a few weeks.

To control a pest...

The adage "beat that big, bad bug with the bug-spray" is not so easy if you're a subsistence farmer. You simply don't have the financial resources to invest in expensive chemicals, or you may not have time to spray the crop even if you have the money to do so. What's more, insecticides are frowned upon by those who pay for development these days, as environmental contaminants and altogether undesirable! So, we have to find another way—or several ways—to "beat the bug."

The cultural way

Cultural, or farm-management, practices are often a cheap and easy entry point for farmers to reduce their risks from insect attack and damage.

For example, when farmers don't all grow their rice at the same time, they make life easy for the gall midge by providing it with a succession of suitable habitats. This allows gall-midge populations to build up through the whole growing season, with most damage being inflicted on the last-sown fields. The converse of this acts as a population control: synchronized and early planting over an area doesn't give the midges a good start to the season, and then gives them only a very short season to multiply in. Unfortunately, the diversity of rice farmers in any given area means that it may not be particularly easy for them to do all their planting at the same time.

African rice gall midge is specific to rice (and its close relatives), so it has to make use of whatever rice it can find during the off-season in order to survive. Crop residues (what's left after harvest of the grain), ratoons (tillers that sprout from rice stubble) and volunteers (self-seeded rice plants that grow up from shed or spilt seeds) all make perfectly good places for midges to survive and multiply. Thus, destruction of crop residues, and careful clearing away of ratoons and volunteers deprives the pest of this alternative and consequently helps limit the population.

A close relative of rice—*Oryza longistaminata*—is also one of the commonest weeds in and around rice fields. The added advantage of this weed to gall midge is the fact that it is perennial, living for more than one season. Gall midge can survive the dry season in the underground parts (rhizomes) of *Oryza longistaminata* ready for an early start to the following rice-growing season. Careful weeding to remove *Oryza longistaminata* plants and their rhizomes should help reduce the gall-midge population that can survive the dry season.

Useful as such cultural practices are, it is often difficult for farmers to find the labor to have the activities carried out at the appropriate time. We must, therefore, seek yet further methods to control the bug.

The search for resistant rice plants

Since resource-poor farmers have problems both with managing labor requirements and with acquiring resources, their ideal solution to any rice problem is to have a variety for which the problem is not a problem. In terms of pests and diseases, we therefore need to find a plant that either *resists* the offending organism, or else *tolerates* the presence of the pest and produces 'normally' despite being infested.

Early work comprised screening of varieties for their resistance to African rice gall midge by teams led by M.S. Alam at IITA and Mark Ukwungwu at the National Cereals Research Institute (NCRI), Nigeria. In 1982, some 90 Asian varieties known to be resistant to Asian gall midge were screened, and only six suffered less than 2% infestation from the African species. The screening work finally yielded two useful Asian varieties. The first of these was Cisadane, a variety from Indonesia introduced in nurseries distributed by the International Rice Research Institute (IRRI). Cisadane *tolerates* gall-midge infestation and was by far the best-yielding variety at infestation levels of up to 30%, in trials in southeast Nigeria. The variety was released in Nigeria as FARO 51 in 1998, for the rice areas with endemic gall midge. On the down-side, Cisadane is susceptible to iron toxicity—another common problem in lowland rice in West and Central Africa—this limits its value for wider use. Variety BW 348-1 from Sri Lanka is also tolerant of gall midge, but has the advantage of also being tolerant of iron-toxic soils. It is currently undergoing field testing in both Nigeria and Burkina Faso.

Galls on rhizome of *Oryza longistaminata*

Meanwhile, a 'traditional' variety from The Gambia, TOS 14519, showed moderate resistance to African gall midge, but has poor yield. It is, therefore, not suitable for direct release, but is being used as a source of resistance in the breeding program. However, to date no high-yielding variety that is resistant to African rice gall midge has been found among the 'Asian' rices (*Oryza sativa*).

"With the paucity of material available in Asian rice, it was clear that the time had come to look elsewhere within Africa," explains WARDA entomologist Francis Nwilene. With the advent of the NERICAs and the technology to generate interspecific progeny more and more rapidly, WARDA switched its search for gall-midge resistance to the African rice species (*Oryza glaberrima*). The results were promising: at least four varieties have been identified that are highly resistant to gall midge. "Of course," explains Nwilene, "these are all typical *glaberrimas*, susceptible to lodging and grain-shattering at maturity. However, they are ideal donors for the breeding program, since they express much higher resistance than anything found so far in the *sativas*."

Progress is being made, but WARDA still has one source 'up its sleeve.' Deputy Director for Research, Monty Jones, explains: "The NERICAs were specifically bred for the upland ecology, but we were so impressed with their performance that we decided just to test them under rainfed lowland conditions." After the initial 'lowland adaptation' trials, some 102 upland NERICAs were screened against gall midge. One of these lines showed moderate resistance to gall midge—this augers well for the possibility of generating gall-midge-resistant NERICAs from lowland-adapted *sativas* and resistant *glaberrimas*.

But not all African rice gall midges are the same

Nwilene takes up the story again, "the screening work [*see* Box] also revealed that resistance or tolerance to gall midge is not stable across sites." The five major pockets with serious gall-midge problems were all used as screening sites. "Varieties that performed well at Ogidiga (southeast Nigeria) did not do so at Gadza (central Nigeria), and those that performed well at Longorola (Mali) did not do so at Balancera (Sierra Leone)." In fact, the behavior of the resistant and tolerant varieties divides the sites into two groups: one resistance is stable among southeast Nigeria, Burkina Faso and Sierra Leone, and the other between central Nigeria and Mali. This difference seems to reflect elevation, with the first three site being low-lying (less than 11 m above sea level) and the remaining two higher (200 to 400 m).

When an insect of the same species can attack a plant that is resistant to that species at another location, scientists say that the insect occurs in 'biotypes,' that is, there are differences between the insect populations that are manifest in the resistance reaction of the host plant. Thus, it seems clear that there are at least two biotypes of African rice gall midge in West and Central Africa, and more may be found in other parts of the region. The UK Department for International Development (DFID) has recently started to fund work to classify the gall-midge biotypes by means of molecular fingerprinting.

Useful 'friendly' bugs

Another avenue of research is to tap into nature's own pest-management brigade.

Modified screening methodology

"One major advantage of doing all this screening work is that we have been able to improve our screening techniques over time," says Entomologist Francis Nwilene. The early work was carried out using conventional 'spreader rows'—that is, rows of a highly susceptible variety grown around the plots of the plants being screened; newly-hatched larvae were deposited appropriately on the susceptible 'spreader' plants. However, such a system is open to the vagaries of chance and it is just possible for a healthy line to be simply uninfested rather than resistant or tolerant to the pest. The new technique involves direct introduction of young larvae to all test plants, and replication of every test entry. This method should be more efficient, and ultimately cheaper than the old one.

There are very few organisms on the planet that have no enemies besides human-beings, and African rice gall midge is no exception. Natural enemies generally fall into two categories—predators and parasites. Predators are not a serious problem for gall midges, as only the eggs and very young larvae are exposed on the outside of the plant and therefore available as predator food. However, a range of insect-eating insects and spiders will happily munch on gall-midge eggs and larvae should the opportunity arise.

Many plant-parasitic bugs have even smaller species that parasitize them. Most of these are what are termed by scientists 'parasitoids.' Parasitoids are merely parasites that develop in or on their host without killing it until they are mature. Our research identified two major parasitoids attacking African rice gall midge, both wasps. The first of these is a 'gregarious endoparasitoid' known as *Platygaster diplosisae*. It lays its eggs within a gall-midge egg. Several *Platygaster* larvae then hatch (within a single midge egg) to eat away the developing gall midge from inside—the *Platygasters* develop within the egg and larval gall midge. The adults then emerge from the fully-grown corpse of the gall-midge larva. Thus, the parasitoid essentially does to the gall midge what the gall-midge larva does to the rice plant!

The second parasitoid is a 'solitary ectoparasitoid' known as *Aprostocetus procera*. The female *Aprostocetus* paralyzes the pupa and then lays her egg close by. The single larva hatched from the *Aprostocetus* egg then feeds on the paralyzed gall-midge pupa. Though neither of the parasitoids prevent the stem-boring activities of the gall-midge larva that inflict the damage on the rice plant, they do have a direct impact on the gall-midge population as a whole.

Both parasitoids are indigenous to Africa, but are apparently ineffective in controlling gall-midge numbers under 'normal' circumstances. They tend to arrive in gall-midge-infested rice fields late in the season, by which time the gall-midge population has already reached damaging levels. Further research, therefore, focused on the biology of these tiny insects as a means of finding ways of 'helping them to help themselves' to gall-midge hosts and thereby aid the farmer.

We discovered that both parasitoids have the same alternative host, a cousin gall midge (*Orseolia bonzii*) that lives on the grass *Paspalum scrobiculatum*—it is consequently known as paspalum gall midge. Now, *Paspalum* itself is a weed and is usually cleared by farmers during their weeding operations. But what if we were to encourage rather than cut *Paspalum*? We have recently started a project to find out. We hope that by maintaining the grass near to rice fields in the non-rice-growing season, we will maintain the population of paspalum gall midge. That, we hope, will enable the two parasitoids to maintain numbers right beside the rice fields, so that they are ready to attack the rice gall midge as soon as it arrives early in the rice-growing season.

Dissected gall with *Platygaster* adults beside corpse of full-grown gall-midge larva

"Another interesting avenue of research has arisen from the parasitoid work," says Nwilene. It seems that any rice plant attacked by a gall midge releases a chemical that attracts the parasitoids to the plant. It may be too late by then for *Platygaster* to get at that particular gall-midge larva, but at least it is likely to find other gall-midge eggs and recently hatched larvae on adjacent plants. "If we can obtain the resources," continues Nwilene, "we will try to identify the chemical, with all the potential spin-offs that that knowledge would offer." If we know what attracts the parasitoids, we can use it early in the season to attract the helpful insects before the gall midges do too much damage.

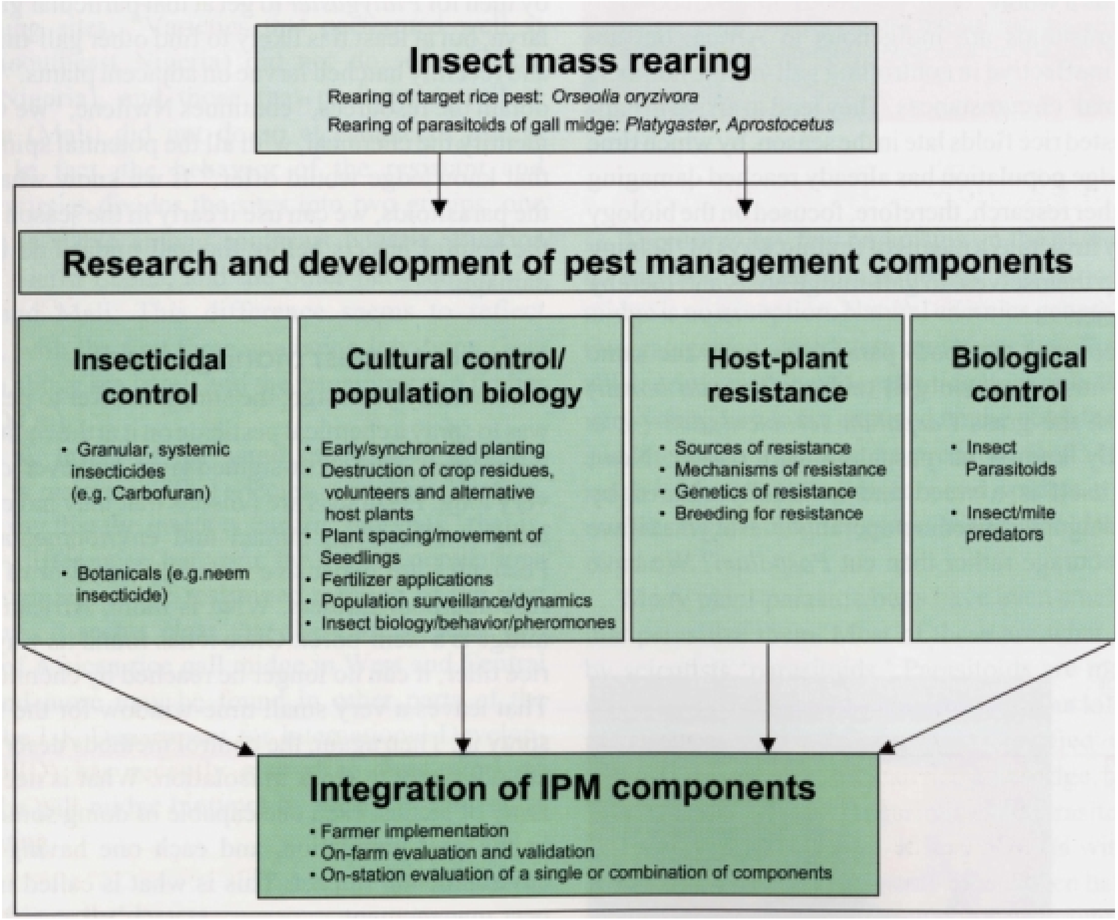
Integrated pest management

Not so many years ago, the simple answer to pest control was to spray a chemical pesticide on it at the right time and kill the pest. That short-sighted view, however, didn't last very long. Pesticides are poisons that may have direct or indirect effects on human and environmental health. Pesticides are expensive—usually way out of reach of resource-poor farmers. What is more, African rice gall midge is a stem-borer. Once it has found its way inside a rice tiller, it can no longer be reached by chemical spray. That leaves a very small time-window for the farmer to spray in. Then again, the control methods described here are not likely to work in isolation. What is needed is an array of tactics, each one capable of doing some damage to the pest population, and each one having minimal environmental impact. This is what is called integrated pest management.

To date, our armory consists of a couple of tolerant varieties and some crop-management options to minimize off-season survival and seasonal population growth. In the short term, a combination of Cisadane or BW 348-1 with whichever of the recommended cultural practices the farmer can handle will be the best bet for minimizing damage. In the medium term, we have prospects for truly resistant NERICA varieties and management techniques for natural parasitoids. The biotype 'problem' will feed into the breeding program, so that resistance can either be targeted or else 'pyramided' (resistance to all biotypes bred into one variety).

"All in all," enthuses Monty Jones, "we are looking at an exciting time ahead for both entomologists and breeders. Not to mention the prospects for rice farmers in gall-midge infestated areas."

Major elements of integrated management of gall midge



Rice Yellow Mottle Virus

RICE YELLOW mottle virus is the most problematic disease affecting irrigated rice in West and Central Africa; it also affects rice cultivated in rainfed lowlands. When it first appeared in the huge *Office du Niger* irrigation area of central Mali, the farmers felt that they only had their god to turn to, and prayed for deliverance. WARDA and its partners have invested a lot of time and funds in the search for resistant rice varieties and in other aspects of the disease's biology with a view to providing a solution for the region's farmers.

What... where... how bad... and how?

What? Rice yellow mottle virus—usually known by its abbreviation, RYMV—as its name suggests, is a plant virus disease. It is endemic to Africa, having first been discovered in Kenya in 1966. It gains entry into rice plants through injuries, which may be inflicted by insects (which also act as vectors) or mechanically during the course of crop cultivation, for example damage to plants during hoe-weeding.

Where? RYMV was first recorded in West Africa in Sierra Leone in 1975. By 1990, it had been recorded in all West and Central African states, except Mauritania. It had also shown up in Madagascar and Tanzania. Over the last 20 years or so, it has become a major problem in irrigated rice systems, especially in Burkina Faso, Côte d'Ivoire, Mali and Niger, and in lowlands in Burkina Faso, Côte d'Ivoire, Senegal and Sierra Leone. It will, however, attack rice in any lowland situation.

How bad? RYMV can be devastating. Major field losses have been measured at 64–100% in Mali, and at 58–68% in Niger. That's a large proportion of a rice crop, and more than most farmers can afford. It's no wonder that farmers who suffered in the catastrophic epidemic that affected 50,000 ha of the *Office du Niger* (Mali) in the early 1990s prayed for deliverance from the curse of the disease! However, RYMV is unpredictable in its appearance—for example, the irrigated rice scheme at Karfiguela, near Banfora, Burkina Faso, suffered heavy symptoms in 1990, and yield losses of between 0.4 and 1.6 tonnes per hectare were recorded, but by 1993 the disease

A rice field devastated by RYMV, Karfiguela, Burkina Faso, August 1990 was restricted to a few small patches in a few farmers' fields. WARDA's Plant Pathologist Yacouba Séré is under no delusion about the threat that RYMV poses: "RYMV has the potential to devastate lowland rice anywhere in Africa," he says. "And crop losses seem to be higher in the large monocrop irrigation schemes in the Sahel than in the smaller schemes in the humid zone." If we take that as our baseline, then there is in excess of 3 million ha of lowland and irrigated rice potentially at risk from RYMV in Sub-Saharan Africa.

How? There are two aspects to the "how" question. First, how does the disease 'get a hold,' or what puts a rice field at risk from RYMV attack? Second, how does the disease affect the plant and cause yield loss? We get the clue as to how the disease was encouraged by looking at the catastrophic epidemic of the *Office du Niger*. Séré again: "RYMV came almost as an immediate 'result' of changes in management of the irrigated rice crop. In particular, the change from direct seeding to transplanting." The act of uprooting the rice seedlings and transplanting them inevitably inflicts some damage on the roots. If there is any RYMV in the field into which the rice is transplanted, the virus can enter the plants via the injured roots. Séré continues: "But then the disease was able to spread rapidly because 70 to 90% of the area in each country was planted with the same high-yielding varieties—varieties that are unfortunately susceptible to RYMV." So, when RYMV was not a problem, the fact that the popular varieties were susceptible to it was of no consequence. However, as soon as transplanting was introduced, giving RYMV a foot-hold, the susceptibility of the varieties was the farmers' undoing!

"There are four principal characteristics of RYMV symptoms on a rice plant," explains Séré, "and these give an indication of how yield-loss is effected: chlorosis of the leaves, stunting, reduced panicle exsertion, and panicle sterility." Chlorosis in plants is a reduction in green pigment. Since the green pigment in plant leaves is the all-important energy-capturing chlorophyll, chlorosis results in reduced photosynthesis, and therefore reduced plant growth. Stunting refers to severely reduced plant height—infected rice plants are simply much shorter than healthy

Healthy (background) and RYMV-infected (foreground) rice. Note the paleness of the leaves (chlorosis) and short stature of the plants (stunting)

The panicles of infected plants (left) do not exsert properly

There's no food inside sterile grains!

ones. Panicles are the grain-bearing parts of the plant and therefore essential to good yield. In RYMV-infested plants, the panicles often do not grow normally. What is more, many of the grains on an infested panicle are sterile—that is, either the grains are not formed or else they are empty.

With such potential to wreak havoc in lowland rice fields, and such unpredictability, RYMV was an obvious target for WARDA research. With WARDA taking the lead, the research takes on a regional perspective, and the individually affected countries are not working in isolation.

Groundwork and developing a research strategy for RYMV

WARDA's first experiences with RYMV were not alone. "Before WARDA joined the Consultative Group on International Agricultural Research (CGIAR) in 1987," explains WARDA Deputy Director for Research Monty Jones, "the International Institute of Tropical Agriculture (IITA) in Ibadan, Nigeria, also had a mandate for rice in West Africa." Thus, region-wide surveys for RYMV in 1984 were conducted jointly by WARDA and IITA. It was these surveys that detected the disease in the majority of West African countries. However, it was a few more years before RYMV came to the fore of the WARDA research agenda.

In the early 1990s, Yacouba Séré was working for his national program in Burkina Faso, but was also a member of the newly formed Integrated Pest Management (IPM) Task Force of WARDA. "In February 1992, we had our first meeting," he explains, "at which we identified regional priorities for disease, pest and weed research. RYMV and blast were identified as top priorities."

In September 1995, several donors sponsored a regional symposium on the disease to review the state of the art, and determine research priorities. Among others, representatives from the Malian and Nigerien national programs, together with representatives from the *Office du Niger* irrigation scheme, made it clear that RYMV was their Number One rice research priority. The findings of the symposium were taken by WARDA and its IPM Task Force to develop the first RYMV research strategy for the region. "A project proposal based on this strategy was developed and then accepted by the UK Department for International Development (DFID)," explains Séré, "and much of the on-going work has been funded by DFID ever since." The research strategy that was developed in the mid-1990s remains relevant even today:

- Rice varieties resistant or tolerant to RYMV need to be identified to replace susceptible varieties grown by the majority of farmers
- Resistant rices need to be identified, even if not suitable for release to farmers, for use in the breeding program for RYMV resistance, and their resistance needs to be characterized; then, new resistant varieties can be bred from this material
- Strategic research concentrates on filling in the gaps in existing knowledge of the disease, especially in disease epidemiology, with a view to developing integrated management of RYMV in the lowlands of West Africa.

The importance of screening

The three countries that are the focus of the DFID-funded screening project share a common problem: most of their irrigated-rice farmers grow varieties that have proven highly susceptible to the onslaught of the spreading RYMV epidemic—Bouaké 189 in Côte d'Ivoire, BG90-2 in Mali, and IR 1529-680-3 in Niger.

Screening for resistance to RYMV was actually started in the mid-1980s by IITA. Owing to the ferocity of the virus epidemics, and the urgent need to find resistant material, large nurseries were established and distributed through the International Network for Genetic Evaluation of Rice in Africa (INGER-Africa)—formerly operated through IITA by the International Rice Research Institute (IRRI), but relocated to and operated by WARDA in 1997.

Diagnosing the disease

Symptoms are not always indicative of RYMV, so researchers require a simple test to determine whether the virus is present in plant tissues.

The fact that virus particles elicit an immune response from animals and plants is used by plant pathologists to aid the identification of virus diseases. Antibodies can be produced by inoculation of the virus into a suitable host (often rabbit). These antibodies can be isolated, purified, concentrated and then used as a sensitive test for the virus in plant tissue. 'Polyclonal' antibodies to RYMV have been developed at the WARDA pathology laboratory. These antibodies attach themselves to the virus's protein coat, they are easy to produce, and are not strongly pathotype-specific. These antibodies have been made available to WARDA's partners in those countries that need a rapid tool for diagnosing RYMV.

Inauguration of the screen house constructed in Mali under the DFID-funded screening project

In order to ensure high disease pressure without the risk of starting an epidemic, screening for disease resistance is done in isolation, in what is known as a screen house. By this method, the test plants are not left to the vagaries of natural disease spread, which vary in space and time, but are artificially subjected to high disease pressure. At the same time, the virus is confined within the screen house and prevented from starting a disease outbreak in rice fields in the vicinity. The screen houses are also used for the uninoculated, or control, plants, to keep them free from possible outside infection.

At first, screen houses were only available at WARDA, and 'hot-spot' screening by the national programs depended on natural disease spread. However, the DFID project established screening facilities in Mali and Niger. These will improve the screening efficiency, especially as more and more breeding material needs to be tested.

Pathotypes: variations on a theme

"We did the initial screening against RYMV in the screen house at WARDA's Main Research Center at M'bé," continues Séré. "We used an isolate of the virus from Gagnoa [south-central Côte d'Ivoire] and identified a good number of resistant and tolerant lines." The trouble was that when these lines were taken to other sites in Côte d'Ivoire for field testing, many of them were no longer tolerant! "This is why RYMV is the most problematic disease of irrigated rice in West Africa," says Séré. "The virus is highly variable—the viruses in one location are not necessarily the same as those in another location." The different types of RYMV are known as pathotypes. This makes the whole issue of rice resistance to RYMV rather complicated, since a variety that is resistant in one location to one pathotype may be susceptible in another location where there is a different pathotype.

A highly virulent pathotype is defined as one that attacks many of the differential varieties. Conversely, a pathotype with low virulence attacks only a few varieties (*see* Table 1). The virus isolate from Gagnoa, used in the early screening trials, had low virulence, and so the selected lines were attacked by the more virulent pathotypes of RYMV in the field at sites like Danané and Odienné.

Table 1. Virulence of two RYMV pathotypes on the differential set of varieties.

Differential	Reaction with pathotype†	
	Hypervirulent (from Odienné)	Hypovirulent (from Korhogo)
Gigante (Tete)	–	–
Bouaké 189	+	+
Faro 11	+	–
Morobérékan	+	–
Lac 23	+	–
ITA 305	+	–
PNA 647 F4-56	+	–
H 232-44-1-1	+	–

† + = symptoms, – = no symptoms.

Another source of pathotype variation

A rice variety that is grown at a site where it is resistant to the local pathotype may 'lose' its resistance if a new pathotype spreads into the area. But this may not be the only source of variation. Pathologist Yacouba Séré explains: "RYMV has its genetic code on a single strand of RNA, therefore any mutation is likely to be expressed in the virus makeup." Most organisms have two strands of DNA, so that mutation in one is likely to be masked (that is, prevented from being expressed) by the dominant gene for the same character on the other member of the pair. "Therefore," continues Séré, "there is potential for pathotypes to change by mutation." This has not yet been proved in the field, but WARDA has started to study the stability of the virus population structure at certain sites.

"With individual variation among pathotypes and varieties," explains Séré, "we end up with a matrix, or grid, of pathotype versus variety in terms of which pathotypes attack which varieties or, conversely, which varieties are susceptible to which pathotypes." Thus, a set of varieties may be used to differentiate a range of pathotypes—this is then known as a set of 'differential varieties.'

"At present we have a differential set of eight varieties for RYMV pathotype characterization in West and Central Africa," says Séré, "but this is being refined in collaboration with our NARS partners." 'New' virus isolates are collected in each country and then tested (in the same country) on a set of 15 to 20 varieties—the eight differentials are used in all the sets as a cross-reference point. "In Côte d'Ivoire," Séré continues, "we currently identify six pathotypes on the eight differential rice varieties."

Differences among virus pathotypes must be detectable at the molecular level. Our partners at the *Institut de recherche pour le développement* (IRD, France) and the International Laboratory for Tropical Agricultural Biotechnology (ILTAB, USA) have been working on sequencing of the genetic code of several RYMV isolates. This is with a view to developing pathotype-specific tests for use in outbreak areas.

First fruits of the search for resistance

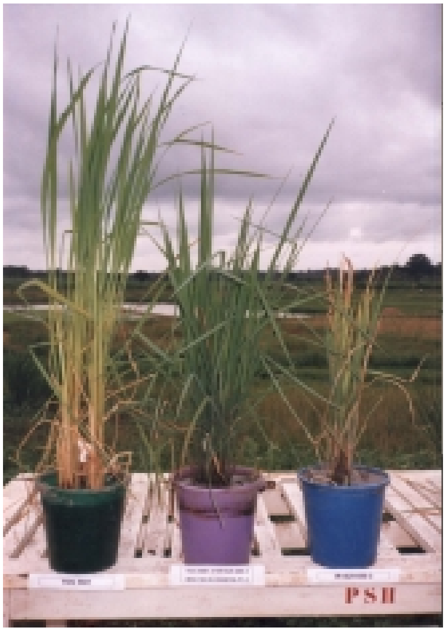
Fifteen, or so, years of screening have not been without some success: resistant or tolerant material (*see* Box 'Resistance vs tolerance,' page 33) has been identified in the three main rice types.

- Many *Oryza glaberrima* (native African rices)—but these are susceptible to lodging (falling over) and grain-shattering, and therefore low yielding.
- Many *O. sativa* subspecies *japonica* (traditional rainfed or 'upland' rices)—potentially suitable for direct-seeded rainfed lowlands, but not adapted to irrigated conditions.
- One *O. sativa* subspecies *indica* (traditional irrigated or 'lowland' rice) is highly resistant to RYMV—Gigante, a traditional cultivar from Mozambique; it is susceptible to blast and low yielding.
- A further 11 varieties that are resistant or tolerant to the Gagnoa virus isolate have been identified since 1998.

"In plant breeding and selection, 'short term' does not necessarily fit everybody's definition of the phrase," says Séré. "In 1999, we had these 11 resistant/tolerant varieties in hot-spot trials in three countries. Two or three of these gave yields close to those of the released varieties in the field with no disease pressure." The implication is that, since these plants are tolerant to RYMV, they should yield better than the released susceptible varieties once the disease strikes—they are to be tested on farmers' fields in Côte d'Ivoire, Mali and Niger in 2001. "In addition," continues Séré, "we have recently identified at least four *japonicas* that have *indica* grain type"—when direct-seeded with close plant-spacing, these rices behave somewhat like lowland-adapted *indicas*—"and that give yields under virus pressure that are comparable with the yields of the popular varieties in the absence of RYMV."

Breeding for resistance

"We had interesting resistant and tolerant material of *glaberrima*, *japonica* and the *indica* Gigante by 1996," explains WARDA Irrigated Rice Program Leader and Breeder Kouamé Miézan, "so we started targeting intra- and inter-specific crosses at developing RYMV-resistant material. In particular, popular but susceptible cultivars, such as IR 1529-680-3, BG90-2, Bouaké 189 and IR64, were crossed with Gigante, and also with resistant *glaberrimas*." Screening against RYMV inoculum in the screen house has shown that both types of crosses have successfully transferred resistance to RYMV into the popular varieties.



Like other NERICAs, the cross (center) between *glaberrima* TOG 5681 and popular variety IR 1529-680-3 of Niger combines the best of its parents—in this case including the RYMV-resistance of TOG 5681

"Several years on, we have even more components for the breeding program," says Miézan. "We have plants that are resistant to one pathotype of RYMV, and others that are resistant to several pathotypes. We also have the means of differentiating the resistant lines from those that are merely tolerant" (*see* Box 'Resistance vs tolerance'). But, breeding is a slow process—until recently it has taken breeders anything up to 10 years to develop new varieties." Enter molecular biology.

Resistance v tolerance

A crop variety is resistant to a disease if that disease has a less damaging effect on the resistant variety than it does on other (susceptible) varieties. The resistance may be the result of the disease being less able to infect the plant (i.e. enter its tissues), multiply or move within a plant of the variety, or it may be due to the variety's ability to grow and yield better than susceptible varieties despite being infected. The latter form of resistance is known as 'tolerance' (*see* Table 2).

Table 2. Effects of disease pressure on yields (g/m^2) of rice varieties susceptible, tolerant and highly tolerant to RYMV. Note how the tolerant varieties out-yield the susceptible one at high disease pressure; the highly tolerant variety also out-yields the susceptible one at low disease pressure.

Variety	Reaction to RYMV	Disease (RYMV) pressure		
		None	Low	High
Bouaké 189	Susceptible	590	164	38
WITA 11	Tolerant	294	168	107
IR 47686	Highly tolerant	274	268	136

The trouble with tolerance

The problem with 'field' screening is that symptoms do not tell the whole story. As an additional level of assessment, plants classified as resistant or tolerant on symptoms were subjected to laboratory-based pathological tests, to look for the presence of virus particles within the plants. "Once we were in the laboratory," explains Pathologist Yacouba Séré, "we found that not all the resistant material was the same. Some of the lines that had no or few symptoms in the screen house had very little virus inside them and could rightly be classified as resistant. However, other lines that looked just the same as the resistant ones in the screen house were in fact full of virus particles. What is more, if we let the plants grow to maturity in the screen house, we discovered that those in the latter group in fact gave reduced yield." These plants can fairly be termed tolerant, but Séré sees little future for this group: "the plants in these groups may be tolerant, but they provide a source of virus inoculum ready to infect adjacent plants or neighboring fields. Since one of our goals is to reduce disease pressure in the field, I do not want such plants around, and neither should a conscientious farmer!"

In last year's Report, we mentioned that our partners at the IRD had identified a gene that confers RYMV resistance in both *Oryza glaberrima* and *O. sativa*, and molecular markers associated with it (*see* 'Molecular Biology Facilities at WARDA,' *WARDA Annual Report 1999*, especially page 20). WARDA Molecular Biologist Marie-Noëlle Ndjiondjop takes up the story: "with a desirable gene and appropriate markers to follow its inheritance by the offspring of a cross, we have the means to conduct marker-assisted selection for RYMV resistance." The great advantages of marker-assisted breeding are, first, that the material does not have to be screened in the field or in the screen house in the early generations and, second, that the markers can be detected in young plants, so time and space is not taken up with growing large numbers of plants every season—only those with the required gene need be grown to maturity for their seed. "When we combine this with other tools, such as double-haploid breeding," continues Ndjiondjop, "we can speed up the production of useful lines considerably."

But the breeding does not stop there. "A variety with a single gene for resistance is still very vulnerable," explains Miézan. "If the local virus pathotype should mutate, or another pathotype arrive in the area, the variety's resistance could very well break down. In the worst scenarios, the disease resistance of upcoming varieties has been known to break down even before the variety is released. Then we are back to square one and years of work are effectively wasted!" This is why WARDA talks about 'durable' resistance—the aim of the breeding program is to combine several genes for resistance into varieties, so that they are fore-armed against mutations and invasions of new pathotypes. Ndjiondjop again: "once we know the type of resistance operating in a particular variety or line, and the genetics of its inheritance, then the same tools that make it possible to transfer one gene can be used to speed the process for combining resistance genes."

Meanwhile, the John Innes Centre in the UK has developed transgenic resistance from the coat protein of the RYMV particle itself. This transgene has been successfully incorporated into popular varieties Bouaké 189 and BG90-2, which will be available for testing in the region once biosafety regulations are in place (*see* Box 'Transgenics and biosafety').

Epidemiology—the how and why of disease epidemics

"We do not want to be limited to using just resistant plants," says Séré. "After all, we've been screening for over 15 years, and there are still no highly resistant varieties in farmers' fields!"

"One thing that became perfectly clear at the 1995 symposium," he continues, "was that we knew so very little about the epidemiology of the disease, and there were so many questions to be answered." Thus, elucidating the components of RYMV epidemiology was, and continues to be, one of the principal foci of the WARDA research on RYMV.

Transgenics and biosafety

The transgenic rices developed by the John Innes Centre in the UK are 'genetically modified organisms' (GMOs). As such they need special treatment. "There are genuine concerns around the world about the potential effects of GMOs on the 'natural' environment," explains Pathologist Yacouba Séré. The UK-based Gatsby Foundation not only funded the original research on RYMV at John Innes Centre, but have also been supporting WARDA's efforts to ensure proper handling and regulation of the plants should they come to West Africa.

"Gatsby are funding the construction of a containment facility at our M'bé site," continues Séré. The idea of this construction is to enable the testing of the new material in an appropriate climate and with the local pathogens with minimal risk of their escape. The containment facility will effectively isolate the transgenic material from the surrounding vegetation. Not only is it located at some distance from the nearest experimental fields, but it is in itself a barrier to pollen flow—it is the fear of pollen flow from transgenics to cultivated and wild species, and the consequent 'escape' of the transgenes that environmental groups are so worried about. "Thus, we will be able to test the material to ensure that it is stable against the virus pathotypes here, and also has no undesirable effects once exposed to the prevailing climate, while safeguarding the surrounding environment from possible contamination," says Séré.

"In addition," he continues, "we have been working with our member states on the whole issue of biosafety." First, the state governments need to know what the GMO issue is all about, and then they need appropriate regulations. "And it is no good having a biosafety regulation in only one or a few countries," says Séré. "Farmers can cross international borders as easily as anyone else, and cross-border trade in seeds is a well-known phenomenon in the region." WARDA has been actively involved in the development of biosafety legislation in Côte d'Ivoire and this has regional implications: it could serve as a template for regional guidelines, as well as being promoted among other member states' policy-makers as the basis for national legislation region-wide. "Without blanket application of biosafety regulations for the exploitation, diffusion and marketing of transgenic crop plants, we will not consider introducing such plants into individual countries of the region," explains Director General Kanayo F. Nwanze.

An important early finding was that RYMV is 'inoculum dependent.' That is, the more virus there is in the environment, the worse the disease affects the crop. Thus, if we have a field of a susceptible variety, the worse the disease pressure, the more virus (inoculum) is produced—a vicious spiral.

"What we want, therefore," says Séré, "are options for reducing disease pressure in the field. Planting resistant varieties is just one of these options."

A first question that anyone interested in crop pest control is likely to ask is: "where does the organism spend the off-season?" In the case of RYMV, rice is not cultivated in the fields continuously for 12 months each year, so the virus has to live somewhere else when there's no rice in the fields. Three groups of alternative hosts have been identified for RYMV: crop residues, volunteer rice plants, and weeds. Crop residues are the bits left after harvest of the grain, they include roots, stems and straw. RYMV can survive on any or all of these—simple destruction of crop residues after harvest should, however, remove this option. Volunteers are rice plants that grow up during the off-season from grain scattered or spilled at harvest time. These are a little more problematic than residues, in that they have to be dealt with some time after the harvest of the crop, which puts an extra demand on the farmers' time. However, removal of volunteers could be combined with a post-harvest weeding, that would also deal with the third reservoir of off-season virus inoculum.

Once we know where the virus spends the off-season, the next question is: how is it transmitted? "The essential aspect of the epidemiology of RYMV," explains Séré, "is the role of mechanical injury of plants—*any* mechanical injury in the presence of virus particles." In addition to root damage during transplanting, rice plants are especially prone to damage during weeding operations when farmers use hoes—if an infected rice plant is damaged during weeding, virus is deposited on the hoe. If a healthy plant is then damaged with the same hoe, the virus is immediately available to enter via the fresh wound. The virus can also survive in irrigation water, so any damage inflicted on a plant in a flooded field is prone to virus infection from contact with contaminated water. Then, of course, there is the whole issue of insect vectors.

'Inoculum dependence': gradation of RYMV symptoms from uninoculated (left) through spot-inoculated and single-leaf inoculated, to fully inoculated plants of Bouaké 189

WARDA Entomologist Francis Nwilene takes up the story: "It has been known since 1974 that insect vectors transmit RYMV mechanically. That is, they feed on an infected plant, collect virus particles, and then pass them on to the next plant that they feed on—the virus does not undergo any changes within the insect itself, but simply uses it as a vehicle." Some 12 insect species are known to transmit RYMV between rice plants, and from rice plants to alternative (weed) hosts, including beetles and grasshoppers that bite the plants, and leaf-sucking bugs. Another avenue for controlling the disease is therefore to control the vectors—this has been a focus of WARDA's entomology work in 2000 (*see* Box 'Controlling the vectors of disease').

Integrated management of RYMV and the future

Like so many problems that affect growing crops, there is no single method of approaching RYMV that is going to rid the region's rice of this insidious disease. Instead, we

Controlling the vectors of disease

With the exception of insect vectors, all the mechanisms for virus infection require the presence of the virus either in the field to which rice is transplanted, or else in the nursery. Entomologist Francis Nwilene: "if a field is completely cleared of virus during the off-season—for example, by destruction of all crop debris, ratoons, volunteers and alternative hosts—then the *only* source of RYMV lie outside the field, and it is only the insects that can bring it to the crop. Thus, there is justification for looking at methods for controlling these insects."

Like the disease itself, there is no single control measure that does a satisfactory job. "We have left the route of host-plant resistance to the breeders and pathologist," explains Nwilene, "and have concentrated on cultural methods and bio-pesticides." The logic behind the plant-resistance decision lie in the extensive screening that has been done, which will select for insect-resistant types as much as for purely virus-resistant types.

Among the cultural practices, water management can play a key role in the dry (off-) season. "During the dry season," explains Nwilene, "the vectors tend to leave the uplands, as the air is too dry for them, and their food supplies are dying out." If the lowlands are also drained at that time, the humidity there will also be reduced, and the food supply there will also be diminished, with consequent impact on the vector population in the lead-up to the cropping season.

"One positive trend," Nwilene continues, "is the move towards direct seeding." This trend is driven by labor costs, but it has two advantages in the fight against RYMV. First, there is no transplantation-induced root damage. Second, the populations of vectors spends the whole season in an interactive phase with its natural enemies (predators, parasites)—there is no relocation of vectors with seedlings, and a certain level of natural control is achieved.

However, it is the potential role of bio-pesticides that attracted Nwilene's attention in the last season. "We compared the effects of extracts from neem and pawpaw with commercial insecticide Decis," he explains. "I'm delighted to report that neem oil was not only more effective in controlling all three groups of vectors (beetles, grasshoppers and leaf-sucking bugs) than pawpaw extract was, but also even better than Decis! What is more, the preliminary results suggest that the neem oil had less of an impact on the vectors' natural enemies than either of the other two insecticides." Research into this potential role for neem oils is continuing in the 2001 wet season.

need to combine elements to provide adequate relief. As is often the case when dealing with resource-poor farmers, the researchers' first line of approach is through the development of resistant varieties—WARDA and its partners have come a long way with this work, but there is still much to do, as explained above. This, however, is backed up with other interventions—using appropriate cultural practices to minimize the spread of the disease, removing alternative hosts where virus populations can survive or build up over the off-season, and managing insect vectors. "In 2001," explains Séré, "we will begin to look at the role of overall crop management, including fertilizer, in the epidemiology of the disease, and that may provide yet another entry into RYMV population control."

Also in 2001, WARDA is expecting to begin collaboration with the University of Leuven, Belgium on a project to enhance the sustainability of rice production in RYMV hot-spot locations. This will involve training of national-program advisers and farmers on virus management. In addition, the project aims to develop new tools for identifying the virus—within rice plants and insect vectors, and in the field—and others for monitoring the disease in the field (in relation to climate).

Another approach in the RYMV work is through WARDA's Interspecific Hybridization Project. Specific areas of interest are identification of the types of resistance present in the three basic rice groups—*Oryza glaberrima*, *O. sativa* subspecies *indica*, and *O. sativa* subspecies *japonica*; continued study of RYMV variability in West, Central and East Africa; and, further strengthening of the collaboration with national programs on screening of new material. This latter element will involve the production of further targeted crosses between popular local *O. sativa* varieties and *O. glaberrima*, which will be screened and further advanced at WARDA. However, it will not be the final products of breeding that are sent to national programs from screening against the most virulent local isolates in screen houses. This will enable national breeders to select for adaptation to local conditions in addition to RYMV resistance.

Capacity building for national partners

From the beginning, WARDA's work on RYMV has been conducted through partnerships. The whole issue of multilocation screening of varieties brings a need for partnership in itself. However, as the screening progressed, and especially with the advent of the DFID *in-situ* screening project, it was necessary to upgrade the capacities of some of our partners—to train the national-program technicians to actually conduct the screening in the screen houses. In addition, the development of the polyclonal antibodies for detecting RYMV in plant tissue meant that we had to train laboratory technicians in collaborating countries in their use.

By providing training to our partners, we are not only providing a service to the countries concerned, but rather to the whole region. The information produced from the *in-situ* screening work feeds into the whole RYMV research process, which will ultimately benefit lowland-rice farmers in RYMV-endemic areas throughout Sub-Saharan Africa.

Then again, we are not only interested in today's research-workers. We are also providing input into the training of tomorrow's pathologists. After all, rice systems and RYMV itself are biological entities—the virus will eventually adapt to whatever control measures we put in place, or else another disease could come along to fill the niche of RYMV should we ever come close to eradicating it. Thus, we need an upcoming cadre of pathologists ready to tackle tomorrow's plant-disease problems. Linkages have been established with universities in Côte d'Ivoire and Mali for basic methodologies for screening and scoring, plus research topics such as the variation in pathogenicity (virulence) of Ivorian isolates of RYMV.

"We are at a very exciting stage with the RYMV work," says WARDA's Director General Kanayo F. Nwanze. "We have nearly reached our short-term goal of seeing improved virus-resistant rice in the fields of farmers in those areas where the disease is endemic, and we have identified certain components to initiate integrated management of the disease at farm level. The next few years will see an increase in the amount of resistant material available, and some of this will not only have durable resistance, but also be attractive to farmers in other ways, such as plant and grain types and cycle length. We trust that never again will farmers be thrown into despair by the site of their fields devastated by RYMV."

Using Computers to Design Weed-Competitive Rice Plants for the Sahel

WEEDS ARE a major factor in reducing rice yields in West and Central Africa. Now that new rice plant types are available through the interspecific breeding activities, WARDA has adapted a weed-competition model to learn more about what makes rice plants good competitors.

Total rice consumption in the Sahel has grown tremendously in recent decades as a result of population growth and increased per-capita consumption, especially in urban centers. Senegal has the largest share of rice consumption among the Sahelian countries, and about 75% of the rice consumed there is imported. Major investments have been made to help meet demand, yet yields remain relatively low (about 4 tonnes/ha). Inadequate weed management is one of the most important factors reducing rice yields in Senegal (*see*, for example, point 5 of Figure 1, page 00: not weeding a field of a popular improved variety results in 50% yield loss).

Relatively good soil, intense sunlight, high temperatures throughout most of the year, and the assured availability of water from irrigation, create ideal conditions for weeds to grow in abundance. As irrigated rice in the Sahel is mostly direct-seeded rather than transplanted, weeds and rice start competing as seedlings and yield losses tend to be greater than in transplanted systems. Studies conducted by WARDA on farmers' fields in 1998 demonstrated that the benefits from improved weed control were in the order of 1 t/ha, or almost 25% above farmers' practice (*see* 'Soil Nutrients and Fertilization in Irrigated Rice in the Sahel,' *Annual Report 1998*, pages 16–22). Yet, farmers tend to wait until weeds are clearly visible and competing with rice before they control them. When herbicides are applied late, weed control is less effective as the weeds become less sensitive to herbicides as they grow. The extended periods of competition—both before weed control and afterwards because of reduced efficiency of control measures—cause increased crop losses.

Rice cultivars that are more competitive with weeds would be appropriate in all the rice ecologies of the region, including the Sahel irrigated systems. Access to the *Oryza glaberrima* gene-pool through the development of progeny of interspecific hybrids (the NERICA rices) has increased the scope for the development of low-management (low input) rice plant types. "One of the most important features of the NERICAs," explains WARDA Deputy Director for Research Monty Jones, "is the weed competitiveness that they have inherited from the *Oryza glaberrima* parent. In fact, that was one of the main targets of the whole interspecific breeding program." Studies have shown that, compared with traditional *Oryza sativa* varieties, *O. glaberrima* produces more biomass and tillers, has higher leaf indices (for definitions of indices, *see* Box), and puts more of its increasing biomass into leaves in the earlier stages of growth. Subsequently,

Plant growth indices used in INTERCOM

This story refers to three indices related to plant growth characteristics, and that are used in WARDA's weed-competitiveness studies and in the INTERCOM model adapted for Sahel irrigated systems.

Leaf Area Index, LAI is the total leaf area of a plant divided by the amount of ground it occupies; it is therefore a direct function of plant-spacing in the field. LAI was already known to be a good indicator of weed-competitiveness before WARDA started these studies.

Specific Leaf Area, SLA is leaf area per unit leaf weight. Thus, a thin leaf has a high SLA, and a thick leaf has a lower SLA. A thin leaf (high SLA) presents a bigger area to absorb sunlight than a thicker leaf (low SLA) of the same weight does. So, for the same weight, a thin-leaved plant provides more shading to smother weeds than a thick-leaved one does. This index is measured (or simulated) for each leaf on the plant for the purposes of INTERCOM modeling. Like LAI, SLA was known to be a good indicator of weed-competitiveness before these studies commenced.

Relative Growth Rate of Leaves, RGRL is the daily growth rate of a plants' leaves expressed as a percentage, in the early growth stages (until LAI = 1).

it was shown that, in a wider range of cultivars, leaf indices and tillering capacity were predictive of weed-competitiveness. The early NERICA lines were better adapted to upland conditions, but recent developments have generated plant material likely to be suited to lowland conditions. With these materials now available, it is appropriate to examine the impact that different plant types could have on losses due to weed competition.

Mathematical crop simulation models can be valuable in giving us better insight into the complex mechanisms of crop–weed interactions. Furthermore, these models can be used as a tool to guide plant breeders in the design and evaluation of new plants.

"Our starting point," explains Weed Scientist David Johnson, "was INTERCOM, a computer model—developed by the International Rice Research Institute (IRRI) and Wageningen Agricultural University—that uses ecological and physiological parameters to simulate competition between a crop and weeds in the field." The model was already in use at WARDA headquarters, and being adapted for upland rice (*see* 'Donor Country Profile: Canada,' in this Report, page 47). "What was needed," Johnson continues, "was to reconfigure the model for Sahelian irrigated rice conditions with suitable varieties and weeds, so that we could then manipulate the plant type as required."

In the second half of 1999, Dutch MSc student Petra Hogervorst, visited the Sahel Station from Wageningen Agricultural University. Her task was to collect the data necessary to configure INTERCOM for irrigated rice in the Sahel. To study the effect of weed competition on rice growth, rice and weeds were grown in mixed populations at different densities of weed infestation. The rice variety used was the now-popular Sahel 108 (*see* Box 'Sahel 108 and other Sahel rice varieties,' page 11), while two common weeds were chosen to represent the main weed groups that infest irrigated rice fields in the Sahel—*Echinochloa colona* for the typical grass weeds, and *Cyperus difformis* for the perennial sedges. Hogervorst determined growth and development parameters of the two weed species and the rice variety—including plant height and the leaf indices. The data were then 'plugged' into INTERCOM to provide the model for rice–weed competition in irrigated systems in the Sahel.

In order to validate the newly-configured model, rice–weed competition experiments were conducted in farmers' fields in the Senegal River delta (actually within a 1-km radius of WARDA's Sahel Station, at N'diaye, Senegal) in the 1999 wet season and the 2000 dry season. These experiments were conducted by Senegalese MSc student Daouda M'Bodj, from the *Ecole nationale des cadres ruraux de Bambey* (ENCR). The experimental treatments consisted of different periods of competition to which the rice crop was exposed to identify critical periods of competition. More precisely, weeds were allowed to grow from the day the rice was sown for a certain period

Souleymane Diallo (ISRA, far right), Marco Wopereis (WARDA, center right) and Yaya Sané (WARDA, far left) discuss weed-rice competition trials with Daouda M'Bodj at WARDA's Sahel Station, N'diaye, Senegal

(14, 28, 42, 56, 70 days), after which the field was kept free of weeds by hand-weeding. In addition, two 'controls' were maintained: one that was kept weed-free throughout the growing season, and one that was not weeded at all. The experiments were conducted on five farmers' fields in the wet season, and on seven farmers' fields in the dry season. Again, fields were direct-seeded with pre-germinated seed of Sahel 108.

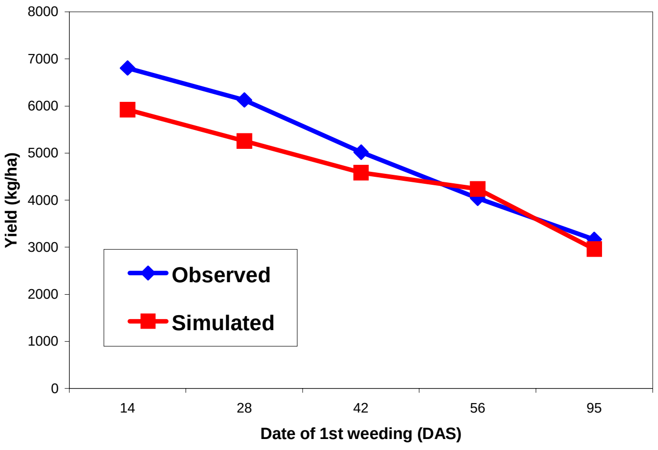
When the field data were plotted in comparison with the data simulated by the model, the two lines were very close together (Figure 6). Thus, INTERCOM is able to predict the essential features of rice–weed competition in the Sahelian context. With no weed control, yields dropped to 3.2 t/ha, or 50% of those kept weed-free from 14 days after sowing. As the date of first weeding is delayed, there is a steady decline in yield; in other words, the later weeding is started in the cropping cycle the greater the yield loss. This serves to illustrate the importance of early weeding. Increasing periods of weed competition also decreased the numbers of tillers and panicles per unit area. Deviations between simulated and observed yields occurred where weeding started earlier in the crop cycle—early weeding had a greater influence on crop performance than the model predicted. The accurate simulation of the field-trial results validated the use of the model for the subsequent modeling studies.

Modeling

INTERCOM was then used to analyze how the rice crop would have reacted had a different rice plant type been grown. "This is the beauty of modeling!" enthuses Agronomist Marco Wopereis. "It allows experimenting using the computer—once the model is properly validated." The objectives were to obtain a better understanding of weed competition in irrigated rice cropping systems in the Senegal River valley through the use of a computer model and to evaluate how new plant types would be affected by competition from weeds.

"We know that *Oryza glaberrima* competes better with weeds than does *O. sativa*," says Wopereis. "Given what we know about the *O. glaberrima* plant type, and

Figure 6. Validation of the calibrated INTERCOM model: Effect of weed competition on rice yield (actual data from wet season 1999 v INTERCOM-simulated data)



Note: 95 DAS (days after sowing) = no weeding.

our theories of what factors influence weed-competitiveness, plant height and the leaf indices were the obvious targets for manipulation within INTERCOM to assess the value of different plant types."

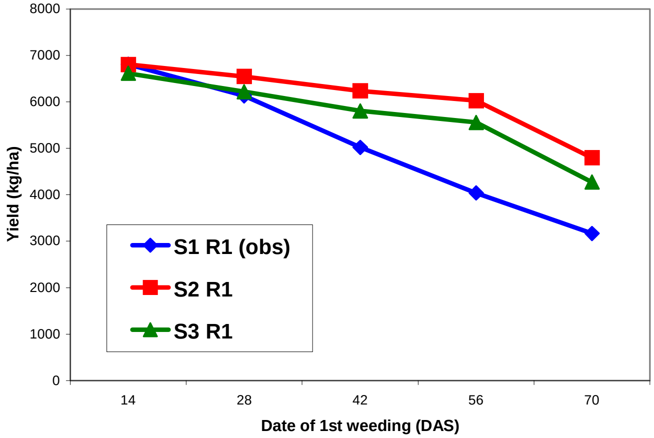
"Higher values of specific leaf area (SLA) [*see* Box, page 40] enable a plant to produce a greater leaf area with a given biomass," continues Wopereis, "and this is an advantage during the early stages of growth when competition for light is important." However, high values of SLA become a disadvantage later in the crop's development as plants 'over-produce' leaves. Once there are about four layers of leaves (i.e. LAI reaches 4), about 95% of solar radiation is intercepted by leaves. After that, having more leaves does not help! So, the ideal situation is to have high SLA early in the growth cycle, but low SLA later on.

Results—what INTERCOM tells us

When we compare only SLA differences between the three plant types, the model predicts that both the *glaberrima* and the intermediate plant types are more weed-competitive than the *sativa* type (Figure 7), with the difference becoming more marked as first weeding is delayed later in the season. If we then modify the *glaberrima* and 'interspecific' types so that they have faster-growing leaves in the early growth phase (Figure 8), the improvement in weed-competitiveness is even more marked—the interspecific giving yields 70% higher than Sahel 108 when left unweeded for the first 70 days after seeding.

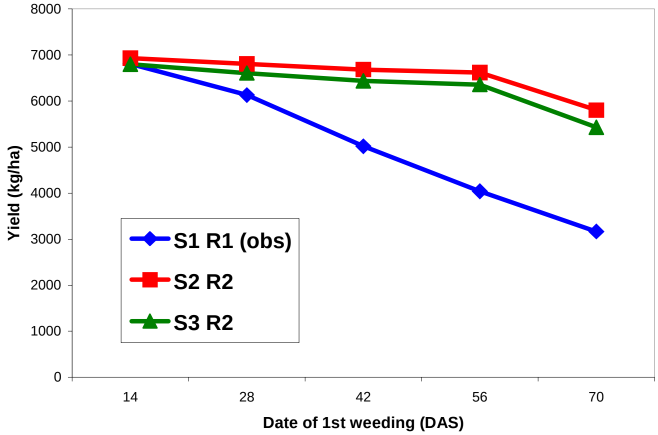
Finally, we compared the three plant types (as represented by SLA figures) at low plant density typical of farmers' fields in the Senegal River valley and delta (Figure 9). Such low plant density may be a result of low seeding rate, or poor germination or crop establishment. All three plant types suffer serious yield losses from competition with weeds, mainly as a result of the rice crop being unable to close the canopy and shade the weeds from the sunlight. Once again, however, when first weeding was delayed, the interspecific (S3) and *glaberrima* (S2) plant types gave more yield than the *sativa* type.

Figure 7. Simulated effect of SLA on yield, as a direct result of its effect on weed competitiveness



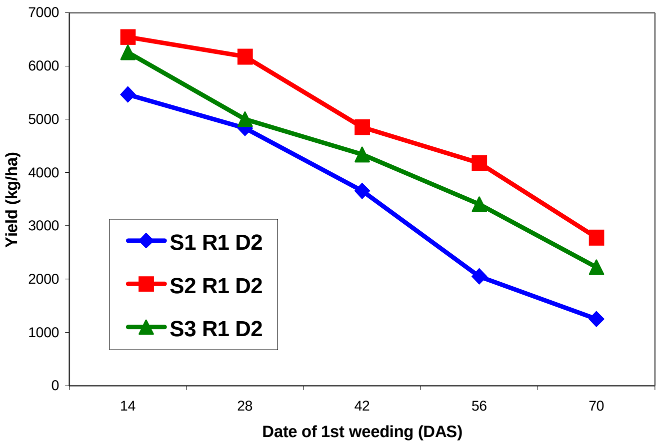
Notes: S1, S2, S3 = SLA type: *O. sativa* (Sahel 108), *O. glaberrima*, interspecific; R1 = RGRL of *O. sativa* (Sahel 108) type.

Figure 8. Simulated combined effect of SLA and increased RGRL on yield, as a direct result of their effect on weed competitiveness



Notes: As Fig. 2; R2 = RGRL of hypothetical plant type with high RGRL.

Figure 9. Simulated effect of reduced plant stand (120 plants/m²) on yield (as a direct result of its effect on weed competitiveness) of 3 plant types: note almost uniform yield reduction regardless of plant type.



Notes: As Fig. 2; D2 = planting density of 120 plants/m².

"When we tested the effect of plant height," says Wopereis, "the results were not spectacular." The simulated plant that was 10% taller than 'normal' was not significantly more weed-competitive than the 'normal' height plant.

Conclusions—the value of modeling

The simulations showed the importance of weed competitiveness in fields with heavy weed infestation. INTERCOM can be used to predict what an increase in leaf indices or other parameters (compared to a 'standard' variety like Sahel 108) would mean given a certain weed pressure in the farmer's field. Thus, those parameters that directly affect weed-competitiveness and yield can be targeted in breeding activities.

"The indices are relatively easy to measure—and that is the exciting bit!" enthuses Wopereis. "However, they change with location and sowing date as a result of climatic factors (mainly minimum air temperature)." WARDA has started to measure these parameters in 'rice-garden trials' to obtain year-round figures for these important traits.

Johnson is also happy: "Our study showed the strength of modeling in testing new plant types," he says. "It allowed quantification of yield gains from improved crop management"—better quality seed, higher seeding density, timing of weeding—"and from better plant types. To do such analyses experimentally would be almost impossible."

Donor Country Profile: Canada

OUR RELATIONSHIP with Canada might be fairly termed as a ‘mixed bag’ of activities, especially in terms of restricted (special project) funding. What we appreciate most is the consistently high level of unrestricted (core) support at a time when so many donors are confining their money to specific projects with short life-spans.

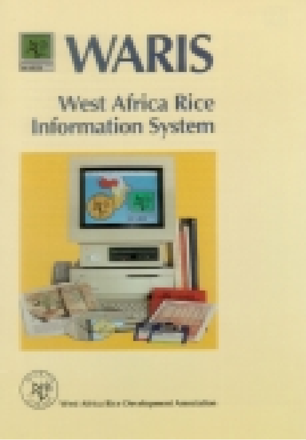
The funding that WARDA receives from Canada comes via two routes. The first is direct from the Canadian International Development Agency (CIDA) and the second via the International Development Research Centre (IDRC). IDRC is a public corporation created and funded by the Canadian Government to help communities in the developing world find solutions to social, economic and environmental problems through research.

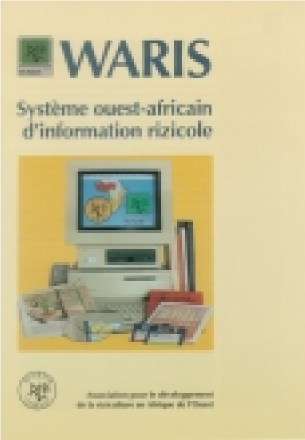
Canada’s contributions to WARDA from 1988 to 2000 are shown in Figure 10—we are particularly grateful for the consistent donations to our unrestricted core budget, averaging over US$0.55 million a year.

Library and information services

In 1990, IDRC agreed to provide funds for the upgrading of WARDA’s library and documentation service. Information has always been one of the ‘pillars’ of IDRC and an area in which they promote growth in developing countries and the institutions that serve them. When the project started, the library had only four full-time staff—a documentalist, a junior librarian, a bilingual secretary and a library clerk. By the end of 1994 (when the project finished), a production assistant and a messenger had been added to the team, and an assistant documentalist was being recruited. Although these recruitments were not funded by the IDRC, the project provided the impetus to put information onto a higher plain.

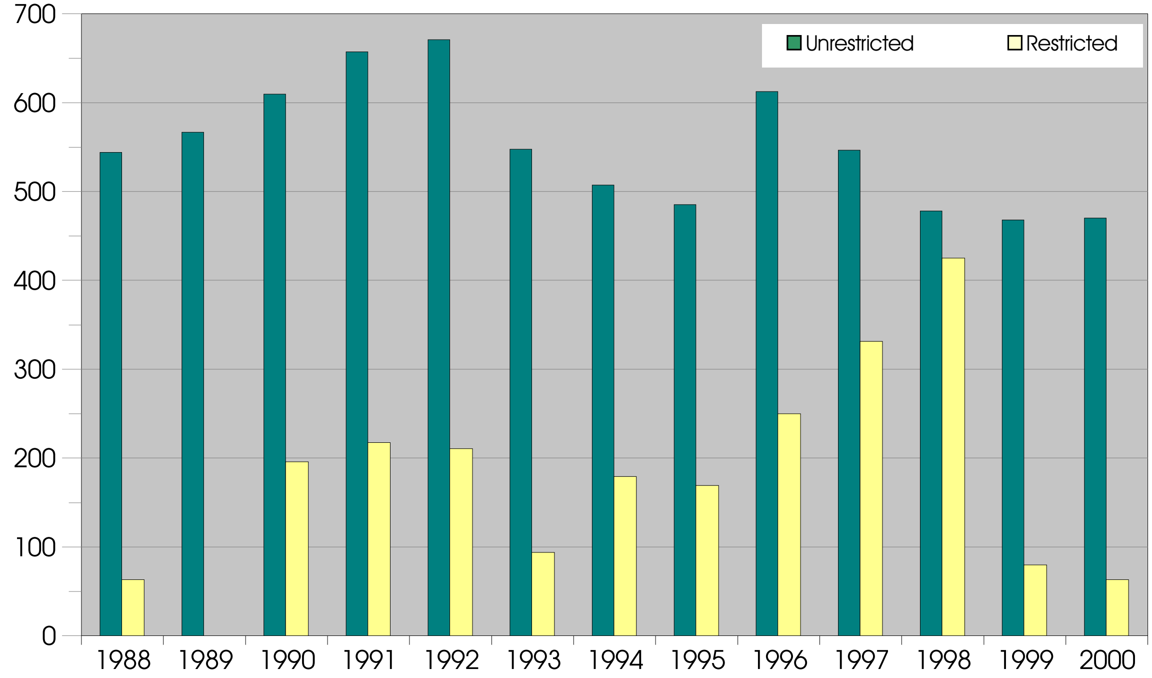
The project was titled ‘West Africa Rice Information Service (WARIS)’ and the development or enhancement of WARDA’s capacity to operate a modern information system was a key element of the activities. During the lifetime of the project, although independent of it, a new building was constructed specifically for the Library and Documentation Center at WARDA’s Headquarters, and was occupied in January 1993. The four-year period also saw major upgrades in information and related technology, the project contributing 1 computer, 2 printers, 1 CD-reader, 2 photocopiers and a microfiche-reader.





Leaflets on WARIS (English and French)

Figure 10. Canadian funding to WARDA, 1998–2000.



The project provided funds for the WARDA Documentalist Alassane Diallo to visit the libraries of the International Rice Research Institute (IRRI) in the Philippines, the *Centre de coopération internationale en recherche agronomique pour le développement* (CIRAD) and the International Complex for Research and Higher Education in Agriculture (AGROPOLIS) in France, and other information services in those countries. "Those contacts were instrumental in upgrading WARDA's information delivery service," he explains.

'Standard' information services were promoted and expanded during the project, comprising selective dissemination of information (SDI, 20 profiles by end 1994), literature searches (135 main searches in 1994, compared with 40 in 1990), *Current Contents at WARDA* (200 copies per month in 1994, compared with 46 in 1991), and document delivery to WARDA and NARS scientists (on demand). The project was also around to help WARDA in the early days of the electronic information age. Over the four years, WARDA developed various in-house bibliographic databases, and started its collection of CD and other electronic databases from outside. Capacity-building funds enabled nine personnel from the national agricultural research systems (NARS) plus a secretary from WARDA's Sahel Station to be trained, 'on the job,' in information management, and the project provided funds for the WARDA Documentalist to make follow-up visits to Benin, Congo, The Gambia, Sierra Leone, and Abidjan and Bouaké (Côte d'Ivoire) to monitor the progress of former trainees. These visits and other contacts also provided a means of increasing WARDA's collection of 'gray literature'—mostly unpublished research reports from NARS and theses. Some 1249 titles were collected in 1994, compared with only 15 in 1991. "All this contributed to 'breaking' the isolation of the NARS scientists of the region," says Diallo.

In that period, WARDA library staff were also able to produce a directory of rice researchers active in West Africa, and bibliographies on the increasingly important *Oryza glaberrima* and rice yellow mottle virus.

IDRC provided vital funds at a strategic moment in WARDA's development. Today, WARDA's library is housed in a new purpose-built Information and Documentation Center, and is part of the department of the same name. However, the legacy of IDRC's input is not forgotten. WARIS lives on providing relevant rice information to NARS researchers throughout the region and beyond—it forms the basis of WARDA's drive to be the hub of an information system on rice for the whole of Sub-Saharan Africa.

Human Health Consortium

From 1994, IDRC payed a double role in the activities of the WARDA-hosted Human Health Consortium. Up to 1998, the Consortium received direct funding from IDRC. In addition, the office of IDRC based in Côte d'Ivoire was one of the partners in the research. Aspects of the Consortium's work were reported earlier—malaria research in the 1996 Report and schistosomiasis research in 1999.

In particular, IDRC was a key proponent of the intersectoral, multidisciplinary research methodology, developing the original protocol and actively seeking funding for the Consortium. They provided guidance in developing the work plans for the socio-cultural aspects of environmental and health appraisals, plus six months of consultancy time to develop the social-science components of the research agenda. Finally, IDRC participated in the institutional review of the research approaches.

Crop modeling

In 1997, we initiated a collaborative project with Laval University, Quebec, aimed at alleviating food insecurity in developing countries through the development of rice plant types that are competitive against weeds while remaining high yielding. The project was funded by the CGIAR–Canada Linkage Fund (CCLF), and lasted three years.

The overall goal of the project was to develop interspecific plant types for resource-poor upland-rice farmers, drawing superior weed competitiveness and drought resistance from *Oryza glaberrima* parents and a high-input-responsive yield potential from *O. sativa*. In the shorter term, the project aimed to assist breeders exploit the rich genetic diversity recently made available through the NERICA technology, by developing detailed plant-type concepts for weed-competitive, drought-resistant, high-yielding rices. An interdisciplinary systems approach was followed, involving a rice breeder, a weed scientist and a natural-resource management specialist at WARDA, and a weed scientist and a weed-and-crop-competition modeler at Laval University. A Postdoctoral Fellow position nominated by Laval University was out-posted to WARDA, and was filled successively by Folkard Asch (1997–1999) and Frank Abamu (1999–2000).

The project used as its starting point a crop–weed competition model developed by IRRI and Wageningen Agricultural University (INTERCOM). Rice and weed trials were established over several planting dates to generate cultivar-specific data for the model. Data from one date were used to 'parameterize' the model (that is, reconfigure the model specifically for rice), then data from a later date were used to verify that it worked. When the timings of plant growth stages (phenology) were fixed, the adapted INTERCOM accurately predicted both total plant production and grain yield in both weed-free and weedy scenarios.

Vegetative and reproductive growth stages of five weeds were well predicted. Plant height was simulated very accurately in four of the weeds, but that of *Sphenochlea zeylanica* (a common weed of lowland rice that is fast-growing and small) did not follow the logistic pattern assumed for rice and weed species in the model. Further experimentation is required to explain this observation. More work is also needed to quantify other morphological and physiological aspects. However, the competitiveness of both rice and weeds was well explained by the model (*see* Figure 11).

A user-friendly manual was developed for application of the modified INTERCOM model for plant-type design for improved competitiveness against weeds. The guide facilitates applying the model for sensitivity analyses against specific stresses or agronomic issues, such as climate, planting time and planting density. It was specifically prepared for partners in national programs, who may be less familiar with details of ecophysiological principles that were used to the model's development—it is structured so that users do not need detailed understanding of the physiological, ecological or mathematical principles used to develop the model.

An array of 27 hypothetical rice ideotypes was generated by the adapted INTERCOM, combining morphological and physiological parameters of *O. glaberrima* (CG14) and *O. sativa* (WAB56-104). The best prototype was one with 20% faster leaf growth rate, which gave 139% of the yield of the *O. sativa*. This suggests that breeders should add leaf growth rate to their criteria when selecting for

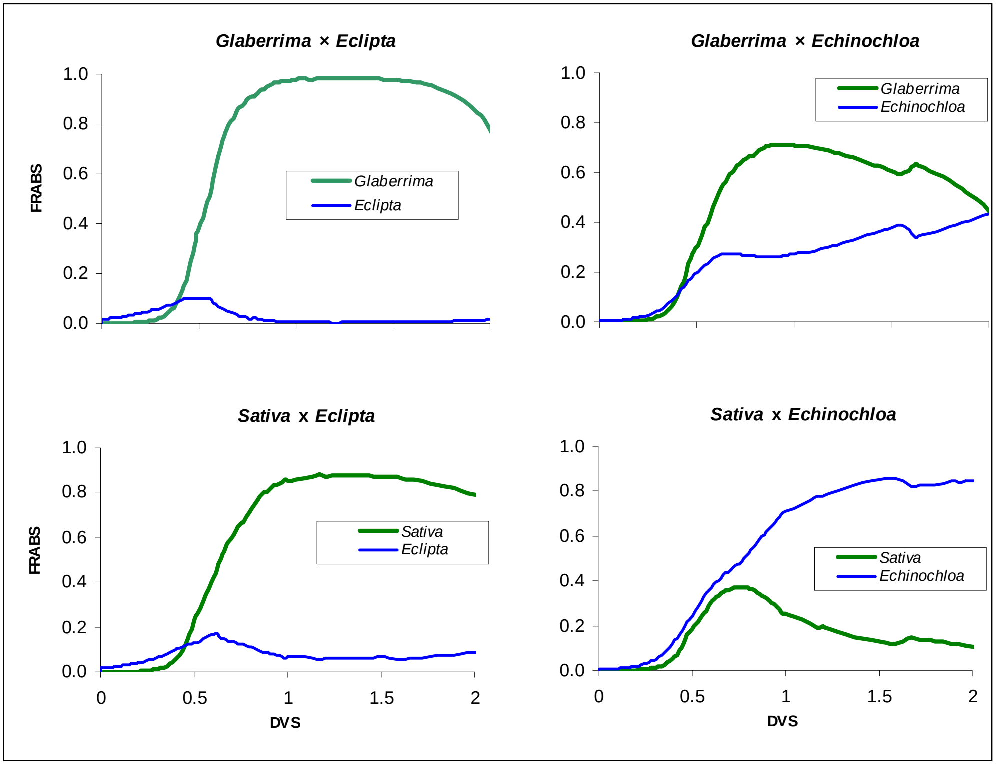


Figure 11. Fraction of incoming radiation (FRABS) interception by rice cultivars of *O. glaberrima* (CG14) and *O. sativa* (WAB56-104) during competition with a broad-leaf weed (*Eclipta prostrata*) and grassy weed (*Echinochloa crus-pavonis*). DVS = rice developmental stage, where 0 = emergence, 1 = flowering, 2 = maturity. Simulation was performed with the adapted INTERCOM model. These results show the effectiveness of the *O. glaberrima* variety in smothering weeds, by intercepting most of the incoming light.

weed competitiveness. Adjusting the phenology with a view to making the rice grow faster resulted in a less-competitive plant type.

Taking the thresher–cleaner to Burkina Faso and Mali

Following the success of the thresher–cleaner (ASI) produced by WARDA and partners in Senegal (*see* Box, page 50), IDRC provided funding for two years (1998 and 1999) for WARDA to work with similar partners in Burkina Faso and Mali to assess the thresher–cleaner's potential there.

Specifically, the project aimed to: (1) evaluate the capacity of local workshops to produce the thresher–cleaner using locally available materials; (2) assess potential benefits to service-providers and farmers; and, (3) assess likely shifts in labor demand with adoption of the thresher–cleaner, particularly the effect on women and laborers who sift straw for paddy, and winnow and clean rice.

Prototype thresher–cleaners were successfully produced from locally available materials, first in Niono (Mali) during the 1998 wet season and then in Bobo Dioulasso (Burkina Faso) during the 1999 dry season. Construction took place in sparsely equipped workshops, representative for the working conditions of the agricultural machinery industry in the region. WARDA trained four agricultural machinery manufacturers in Mali and three in Burkina Faso. Technical drawings of the machine were compiled in collaboration with the University of Saint Louis in Senegal in January 1999, and sent to all partners involved in the project.

The machines were tested during the 1998 wet-season and 1999 dry-season harvests in Mali. Testing in Burkina Faso started in October 1999. Surveys were conducted among groups of stakeholders—rice producers, people who thresh, winnow or glean manually, local artisans and operators/owners of mechanical threshers—to find out their perceptions of the machine. All respondents considered the thresher–cleaner a major improvement over threshers currently in use. Where the thresher–cleaner was not replacing family labor, such as among women involved in winnowing and gleaning for cash or paddy fees, the primary concern was that introduction of the equipment will diminish demand for manual labor. During the second half of 1999, a total of 10 thresher–cleaners was produced in Mali by local manufacturers trained within the project.

Support to Key Sites in Côte d'Ivoire

In 1998 and 1999, CIDA provided funds through the *Fonds De Contrepartie Ivoiro-Canadien* (FDCIC) towards agronomy and breeding activities in WARDA's Key Sites in Côte d'Ivoire. The Key Sites are used by WARDA for research that needs to be conducted in ecologies other than those available at its main research stations. At that time (and up to 2000), WARDA operated five Key Sites within Côte d'Ivoire, in addition to the Main Research Station at M'bé, north of Bouaké in the southern guinea savanna zone:

- Bouaké peri-urban areas, in the center of Côte d'Ivoire, in the transition zone between the forest and the savanna; it has a bimodal annual rainfall regime, with a total of about 1100 mm rain;
- Korhogo, in the north of the country, is in the northern guinea savanna zone; it has a relatively cool dry season and rainfall of 1300 mm per year;
- Boundiali, is also in the northern guinea savanna zone; it receives 1500 mm of rainfall;
- Danané, in the west of the country, is in the humid forest zone; it has annual rainfall of 2000 mm;
- Gagnoa, in the center-west of the country, is in the forest zone; it has a bimodal rainfall regime, with a total of 1400 mm per year.

In effect, the small grant funded one field 'observer' and general agronomy and breeding activities. Part of it was also used to purchase a few small-scale threshing machines and two motorbikes.

The thresher–cleaner in West Africa

History of its introduction and spread

Several times over the last four years we have alluded to the success of the thresher–cleaner that WARDA has helped introduce to the Sahel. However, the pages of the *WARDA Annual Reports* have not carried any of the story since the 1996 Report. That report—part of the story 'A Tradition in the Making,' specifically pages 35–37—gave the background to the story, but by the end of 1996 the machine still required modification for the Sahelian environment (it had been introduced from The Philippines).

Modified prototypes were built by local artisans in Senegal in 1997, and then tested on farmers' fields. On 5 November 1997, over 500 participants (including senior government officials) attended the commercial launch of the thresher–cleaner at Saint Louis, '*Journee du lancement de la batteuse/vanneuse ASI*.' It was at this meeting that the thresher–cleaner was named 'ASI,' from WARDA (**A**DRAO in French), the Senegalese extension authority for the Senegal River (*Société d'aménagement et d'exploitation des terres du Delta du Fleuve Sénégal et des vallées du Fleuve Sénégal et de la Falémé*, **S**AED) and the Senegalese national agricultural research institute (*Institut sénégalais de recherches agricoles*, **I**SRA)—the principal partners in its development. The ASI has subsequently been a commercial success in Senegal, and by the end of 2000 there were over 100 working machines, mostly in the Senegal River valley.

As it was principally designed for the conditions of the Senegal River valley, it was a simple move to extend the Senegalese prototype to southern Mauritania. With World Bank support, two Mauritanian machinists were trained in ASI construction at the WARDA Sahel Station in 1998/99. These men then returned and constructed the first prototype thresher–cleaner for Mauritania. The accepted and commercially released thresher–cleaner in Mauritania was dubbed 'SAC,' for the Mauritanian rural extension service (*Societé nationale pour le développement rural*, **S**ONADER), **A**DRAO and the Mauritanian national agricultural research center (*Centre national de recherche agronomique et de développement agricole*, **C**NRADA). As in Senegal and each subsequent country to which the thresher–cleaner has been extended, the work has been a partnership between WARDA, national research and extension, and local artisans. By the end of 2000, there were about 15 SAC thresher–cleaners operating in the Senegal River valley of Mauritania.

Next, the thresher–cleaner was introduced to Burkina Faso and Mali with funding from the International Development Research Centre (IDRC) in 1998 and 1999 (*see* main story). By the end of 2000, there was still only the one prototype INADI—*Institut de l'environnement et des recherches agricoles* (**IN**ERA), **AD**RAO, *Institut de recherche en sciences appliquées et technologies* (**I**RSAT)—thresher–cleaner in Burkina Faso, but at least 30 ACIER—***A**DRAO en **C**ollaboration avec l'Institut d'economie rural* (**IER**)—thresher–cleaners in Mali.

In February 2000, a prototype thresher–cleaner was made at the WARDA headquarters workshop and tested in the M'bé valley, Côte d'Ivoire. In 2001, the thresher–cleaner is being 'taken' to The Gambia.

Performance of the ASI thresher–cleaner

The ASI project was started by WARDA in response to farmers' complaints about the performance of the then 'best available' thresher, the Votex, during a survey in 1994. The Votex had been introduced to the region in the early 1990s, to provide a better option than 'waiting in line' for the aging combine-harvesters that had been around for some time (and were not being replaced), or manual threshing. However, the farmers criticized the Votex for its inefficiency (especially in terms of separating grain from straw) and its high labor requirements. Thus, WARDA sought help from the International Rice Research Institute (IRRI) and imported a prototype thresher–cleaner that had been developed in The Philippines (TC800). In addition, IRRI lent the Sahel Station an agricultural engineer to advise on the first Senegalese-built prototype.

Substantial modifications were made to the TC800 design in the development of the prototype ASIs for conditions of the Senegal River valley in the Sahel. Many of these were to do with the need for the ASI to handle manually harvested paddy (as opposed to machine-harvested paddy) and generally to make the machine more robust. It took about 2½ years to develop the ASI into the model that is 'mass-produced' in Senegal today. We could simply say that the success of the ASI—especially in northern Senegal—speaks for itself, but it really does measure-up well against the Votex (*see* Table 3).

Particular attractions of the ASI over the Votex are:

- the processing capacity (6 tonnes per day v 4.3 t/day)
- the grain separation rate (97–99% v 85%), which means that the farmer does not have to provide additional labor for sifting grain from straw, or winnowing
- the net revenue (US$8.02 per tonne v $4.47/tonne), which is mainly a result of the higher capacity of the ASI.

Table 3. Comparison of the first prototype ASI with Votex (Senegal River valley, Senegal, 1996).

Parameter (units)	ASI	Votex
Machine type	Axial flow	Tangential flow
Grain separation rate (%)	97–99	85
Processing capacity (kg per 6-hour day)	6000†	4300
Purchase price (US$)	4138	3276
Fuel consumption (liters per hour)	2	0.8
Total cost per tonne (US$)‡	9.23	9.32
Total cost per hectare (US$)‡	41.51	41.94
Total cost per year (US$)‡§	3044	2204
Net revenue per tonne (US$)‡	8.02	4.47
Net revenue per year (US$)‡§	2645	1058
Internal financial rate of return (%)	65.7	34.1
Benefit/cost ratio	1.7	1.4

† Conservative estimate; Malick Ndiaye cites 1.5 t/hour for the 12.5-hp prototype, and 2 t/h for AGRITECH's 19-hp version.
‡ Including operator labor costs (2 operators for ASI, 1 for Votex), but excluding farm labor (usually 4 farmer-laborers with both machines).
§ On the basis of 55 working days per year.

More of the same... only different

"The whole idea of producing small-scale machinery locally is that modifications can be made for each market niche," says Irrigated Rice Program Leader Kouamé Miézan. "As a first level, each country to which we have taken the prototype design has made its own modifications for local conditions." Thus, there are at least five versions of the thresher–cleaner in the region—two of these are in Senegal.

Senegalese machinist and director of the manufacturing company AGRITECH, Malick Ndiaye 'beefed up' the original ASI prototype. "The original machine was only suitable for towing behind a conventional car," he explains, "but we could see a market for something that could equally well be pulled by animals. Also, the lightweight first model was not suited to the rough conditions prevalent in much of the valley. So, we made a four-wheel version," (the original had only two wheels) "and also made it more robust." AGRITECH also saw a need for greater processing power, so upgraded from a 12.5 horse-power motor to a 19-hp one. "At the same time," continues Ndiaye, "we made some minor modifications to regulate air-flow to compensate for differences in grain moisture content" —wetter grains require stronger air-flow— "and to prevent straw aspiration."

The Mauritanian SAC is almost identical to AGRITECH's ASI. "Almost no modifications were required for Mauritania," explains former Sahel Station Agronomist Marco Wopereis, "because we were still in the same environment—the Senegal River valley."

The Malian ACIER retains the more simple air-flow regulation of the first ASI, and has a 14-hp motor. It has four wheels, but is towed (dragged) along its longest axis, which makes it narrower (for transportation along narrow tracks), but less stable; it can also be pulled by animals.

The Burkina INADI also retains the simpler air-flow regulation, and the smaller motor of the first ASI. Like the ACIER, it has four wheels, but is only suitable for vehicle-towing.

The first Ivorian prototype retains the early air-flow regulator and two wheels for vehicle-only towing, but is heavy framed and has a 19-hp motor.

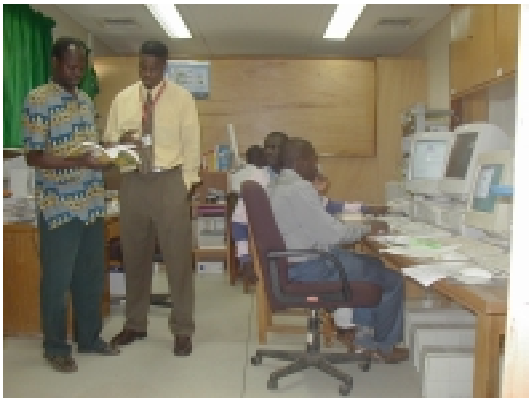
Information and communications technology

In July 1999, Adrian Q. Labor joined WARDA as Information and Communications Technology (ICT) Manager, on a two-year contract paid for by IDRC. "Up to that point in time," explains Director General Kanayo F. Nwanze, "we had been handling ICT matters on an ad-hoc basis, with a lot of the burden falling upon the Biometrics Unit. With the arrival of Labor, we were able to establish an ICT Unit within the Office of the Director General, and really started to make some headway with our ICT capacity building." In fact, the only 'core' ICT staff in post—Technical Assistant Yoni Lébéné—was immediately transferred from Biometrics to ICT.

When Program Division staff were relocated to the new research building and Information and Documentation Center in 2000, ICT Unit was allocated three adjacent offices in the main research complex. "In one of the three rooms," explains Labor, "we have centralized WARDA's servers. One room serves as an ICT reference library thanks to funds provided by IDRC, and the other as a modest computer-training laboratory."

On the hardware side, the 'backbone' fiberoptic cabling has been increased, giving a robust local-area network (LAN) to all buildings at WARDA's M'bé headquarters. And connection to the Genetic Resources Unit buildings some 3 km away is well underway. "This increased capacity has been matched by a 30% increase in computers attached to the LAN," says Labor, "which have been drawn from a combination of new purchases and refurbishment of older machines that were already here."

WARDA's principal servers are all on a Microsoft platform, running either Windows 2000 or NT4.0. They comprise the primary domain server, the Intranet, the SQL, the Exchange (e-mail), the Finance SunSystem, and the experimental servers. "The Intranet, SQL and Exchange servers have all been linked," explains Labor, "so they all now 'talk' to each other. This enables us to establish Center-wide database access to all available information, and we have software accessing all three servers simultaneously." To date, the combined LAN and server system has been used for budgeting, with senior staff being able to plan and monitor their budgeting from their desktops. In addition, an integrated database has been established for both research and administration, enabling related data to be accessed from diverse sources across the Center.



WARDA's computer servers are 'centralized' in one room for easier management by ICT Unit staff

"On the software front," explains Labor, "one of my first tasks was to purge the Center of unwanted computer viruses." This has been done with up-to-date anti-virus software being installed and regularly updated on all machines. "When we got hit by the 'Jokes' virus," (a.k.a. 'Funny,' 'Life cycle stages') continues Labor, "we were immediately able to install the latest anti-virus update, and a monitoring system to watch it spread across the LAN—it was a harmless beastie, but it was interesting to watch how a virus replicates itself across a system so quickly."

With the establishment of its own Intranet, WARDA has been able to move to Web-based applications. Sharing of information has become mush less demanding on the upgraded LAN system—where e-mails were previously sent to all users, such information is now stored in Shared folders on the Exchange server, or on the Intranet itself. "Network printing has now become an acceptable practice at WARDA," says Labor, "after we successfully recalled most of the personal dot-matrix printers and established network laser printers within each department. We can now manage with fewer printers, which require less maintenance and consume less supplies."

Despite these major advances, the one event that will probably stick in the minds of staff members the longest was the installation of a satellite link to the principal Internet service provider in the USA. Almost overnight, WARDA went from being thoroughly isolated from the majority of the world to high-speed Internet access. "The Internet is revolutionizing our information services," says Assistant Documentalist Florent Diouf, "we have now moved to combined print and on-line subscriptions for several journals, and the future of the WARDA Library certainly lies in that direction."

"With the connection of the Exchange server to the satellite link," explains Labor, "we were able to transfer staff mailboxes from their desktops to something that is available across the Internet." WARDA staff can now access their mailboxes from anywhere they can connect to the Internet. WARDA sites beyond headquarters have benefitted from the ICT Unit, too. An Internet lounge has been established at the Bouaké Liaison Office, giving access to the Internet after office hours, not to mention a convenient on-site connection for visitors staying at the WARDA Guest House (in the same building as the Liaison Office). Out-posted staff at the International Institute of Tropical Agriculture (IITA), Ibadan, Nigeria, and in Abidjan are better integrated with headquarters via CGNet (WARDA's service-provider), with dial-up electronic-mail, Internet services and public folders.

Mutual satisfaction

As a consistent donor of unrestricted funds, Canada can justly claim some input into the rest of our research program. When Donald McMaster, Canadian Ambassador to Côte d'Ivoire, visited WARDA's headquarters in 1999, he wrote "The work you have done in developing new varieties adapted to the special conditions of WARDA member countries is most impressive. We can report full satisfaction with the use of Canada's contribution to your Centre."

"We are very happy with Canada's interest in and continued support to our research," says Director General Kanayo F. Nwanze. "With the departure of Labor in mid-2001, the latest round of IDRC–WARDA collaboration will come to an end." However, IDRC has recently been involved in helping the CGIAR to develop a proposal for a 'System-Wide Initiative on the Impact of HIV/AIDS on Agriculture, Agricultural Research and Development,' and WARDA is taking a leading role in that Initiative. "We look forward to doing new things with both IDRC and CIDA," concludes Nwanze. "We are not yet sure what the next area of mutual interest will be, but we are confident that it will be as successful as our earlier collaborative links."

The Year in Review: 2000

THE YEAR 2000 was another busy one for WARDA and its many partners. Many of the activities were a direct extension of those started, or at least planned, in 1999. The momentum started by the recruitment of many new senior staff in the preceding three years (1997–1999), meant that 'Y2K' was a year for implementation of several new ventures.

The first 'event' of the year was a **Training Workshop on the Community-based Seed System** (CBSS), held in Korhogo, northern Côte d'Ivoire from 17 to 19 January. The CBSS has become a powerful mechanism in integrating traditional knowledge systems into modern technologies, partnering with farmers and national extension services to respond to a major gap in the seed sector.

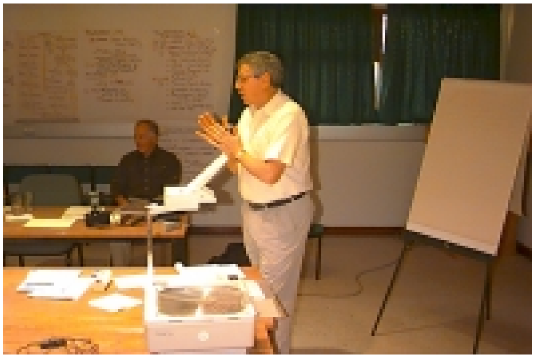
The Main Phase of WARDA's **Fourth External Program and Management Review** took place from 19 January to 12 February. This built upon the Initial Phase that had taken place between 21 November and 3 December 1999. The Panel (chaired by Dr Mandi Rukundi of Zimbabwe) took on board a wide range of opinions, especially from our Member States, with visits to three sites in Côte d'Ivoire, plus Ghana, Guinea, Nigeria and Senegal. Contacts included national-program personnel, directors and farmers; in addition, the Panel interacted with 'advanced' partners such as CIRAD, IRD and PSI-CORAF. In Côte d'Ivoire, they also interacted with the Ivorian Minister of Higher Education, Scientific Research and Technological Innovation. The report of the EPMR was presented to the CGIAR Mid-Term Meeting in Dresden in May 2000 and well received. The overall assessment of the Review Panel was presented by the Director General and Chairman of the Board of Trustees in last year's Report.

In February, WARDA staff **demonstrated** the first Ivorian prototype **thresher–cleaner**—based on the Senegalese ASI model (*see* Box 'The thresher–cleaner in West Africa,' page 50)—in the M'bé valley just outside WARDA's main gate. After some minor field adjustments, the prototype performed up to the standard we have come to expect from these machines, and the demonstration was watched with interest by over 20 farmers on each occasion that it was demonstrated. Irrigated Rice Program Leader Kouamé Miézan was on hand to explain the machine's advantages and to answer questions.

Thresher–cleaner demonstration, M'bé valley, Côte d'Ivoire, February 2000

The last two days of February saw the first project planning meeting of the new **Participatory Technology Development (PTD) Project** with Hohenheim University, at WARDA Headquarters. The project is being funded by Germany (BMZ through GTZ), and activities started in April 2000, after the recruitment of a project scientist. The project is operating in Benin and Nigeria with seven national partner institutions, plus farmers groups, at three key sites (1 in Benin, 2 in Nigeria). It aims to develop and adapt methodologies for ensuring participatory adaptation and dissemination of appropriate technologies for rainfed systems in the target countries. The project is also building national partner capacity in participatory research through on-the-job training and postgraduate fellowships. The third objective is to improve feedback of farm-level constraints, potential acceptability and adoption of technologies among farmers, extension agents and researchers.

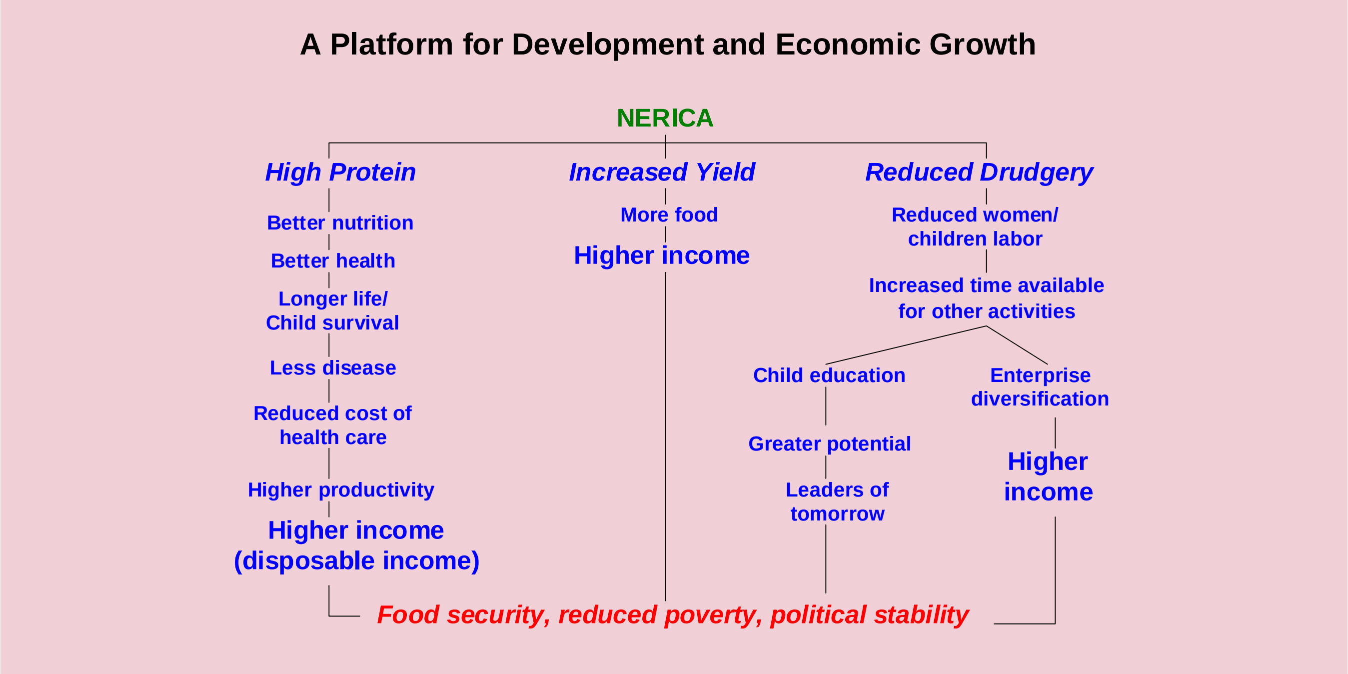
On 2 and 3 March, WARDA managers and other key personnel took part in a **Strategic Marketing Consultation Workshop** at Headquarters. John Riggan of The Conservation Company and Richard Steckel of AddVenture Network, Inc. facilitated the meeting, which aimed at linking public-awareness and resource mobilization to increase the funding base of the Association. Historically, WARDA has been funded by the public sector of donor countries and member states. However, with public money becoming increasingly scarce, there is an urgent need to diversify income sources. The workshop looked at both philanthropic and social-enterprise options. The principal outcomes were 'a platform for development and economic growth' based on NERICA, and a decision to pursue the establishment of a business plan for the Association.



John Riggan (foreground), facilitating the concluding session of the Strategic Marketing Workshop (Richard Steckel is shown in the background)

Being an even-numbered year, the **National Experts Committee** met at WARDA Headquarters on 20 and 21 March. The National Experts Committee (NEC) comprises the Directors of the NARS of WARDA's member states. This Second WARDA/NEC Meeting was attended by representatives from 15 member countries: Benin, Burkina Faso, Chad, Côte d'Ivoire, The Gambia, Ghana, Guinea, Guinea Bissau, Liberia, Mali, Mauritania, Niger, Nigeria, Senegal and Sierra Leone. Cameroon and Togo were absent. WARDA's Board of Trustees was represented by Dr Diomandé Mamadou, Chairman of the Board Program Committee. The purpose of this statutory meeting is to provide a regular forum for interaction between WARDA and its partners in the national agricultural research systems (NARS). This is particularly important as the starting point (that is, at the country level) in a multilevel stakeholder consultation process. The meeting reviewed a draft of WARDA's 2001–2010 Strategic Plan and progress at WARDA since the first NEC meeting in 1998, and made seven conclusions and recommendations. Further details of the meeting are available on our Web-site at www.warda.cgiar.org/news/nec2.htm.

The first meetings under Phase 2 of the **Inland Valley Consortium** (IVC) took place at WARDA Headquarters from 2 to 8 April. In fact, the agenda comprised three separate meetings: the Annual Workshop, at which results from the 1999 season were presented, along with plans for 2000 and beyond; the first Consortium Management Committee (CMC) Meeting; and the Common Fund for Commodities (CFC) Project Coordination Meeting.



After the creation of the West and Central Africa Rice Research and Development Network (known by its French acronym of ROCARIZ) from the merger of the WARDA/NARS Task Forces and WECARD-CORAF Rice Network in 1999, April saw the First **Regional Rice Research Review** (4Rs meeting) for West and Central Africa being held at WARDA Headquarters from 10 to 13 of the month. The 4Rs seeks broad participation from rice stakeholders throughout the region, and beyond, so as to enhance the relevance and applicability of research and development activities coordinated by ROCARIZ. The first 4Rs meeting drew over 100 participants from West and Central Africa, other parts of Sub-Saharan Africa, and beyond. Further details of the meeting are available on our Web-site at www.warda.cgiar.org/news/4Rs.htm.

The first 4Rs was immediately followed, on 14 and 15 April, by the first workshop of the **International Network for Genetic Evaluation of Rice in Africa** (INGER-Africa) since its relocation to WARDA from IITA in 1997. The meeting reviewed the achievements in germplasm exchange from 1992 to 2000; reviewed the mechanisms for nursery composition and planned activities for the coming three years; and provided a platform for the formal launch of the INGER-Africa Phase II project funded by DFID. Some 40 INGER-Africa collaborators and members of the Varietal Improvement and Mangrove Swamp Rice Task Forces (ROCARIZ) from all 17 WARDA member states, the Democratic Republic of Congo, Kenya, Mozambique and Tanzania participated. The value of the Network in promoting germplasm exchange and testing is well appreciated by all collaborators, but the need for timely feedback of nursery results to the coordination unit at WARDA was stressed.

The business of April did not let up even then, as the members of the Regional Network for Participatory Varietal Selection (PVS) met at WARDA Headquarters from 17 to 21 April for the third **Participatory Rice Improvement and Gender/User Analysis Workshop**.

The workshop brought together PVS practitioners from all 17 WARDA member states to discuss the progress in their work, and to formally establish the Network. In addition, representatives were sent by donors to the PVS research, namely the Rockefeller Foundation, the CGIAR Program on Participatory Research and Gender Analysis for Technology Development and Institutional Innovation, the UK Department for International Development (DFID), and the UNDP Technical Cooperation among Developing Countries (TCDC). The summary proceedings of the workshop were published in October as *Participatory Varietal Selection: The Flame Spreads into 2000*.

From 23 to 25 May, WARDA hosted key stakeholders, plus representatives from the donor (IFAD), for the first regional planning workshop of the **Participatory Adaptation and Diffusion of Technologies for Rice-based Systems (PADS)** project. The project aims to work with and strengthen the capacities of national and local partners to evaluate, adapt and disseminate improved rice technologies through appropriate participatory methods. Four countries are involved—Côte d'Ivoire, The Gambia, Ghana and Guinea—within each of which, WARDA is bringing together key rice stakeholders, namely national research and extension, NGOs, private sector and farmers. In addition to the regional planning workshop, national planning workshops were held in participating countries to establish networks of key partners and identify the best available technologies from all sources (WARDA, national research and extension, farmers themselves) for inclusion in the project process. During the year, key constraints to rice production and marketing were identified through rapid rural appraisals, and a first round of research and training activities was conducted.

On 30 May, we hosted a meeting with representatives of the FAO's **World Food Programme** (WFP) to review and plan collaborative activities in our host country, Côte d'Ivoire. In particular, WARDA and WFP are collaborating in developing low-cost technology options for small-holder farmers, and participatory varietal selection (PVS). New PVS trials were started at two WFP sites in 2000—Bouna (in Zanzan) and Dabakala (in the Bandama Valley). In addition, WARDA provided training in community-based seed systems (CBSS) and general rice production to the project; full agro-ecological characterization of the Bandama Valley, and socio-economic characterization of all WFP sites in the country.

From 26 to 30 June, the full WARDA **Board of Trustees** met at M'bé for the first of their biannual meetings. High on the agenda was a thorough review of the EPMR report. The Board endorsed many of the recommendations of the report, including the need to reduce the number of Board meetings. Until then, the full Board had met twice a year, usually in June and November, but at this meeting the Board members agreed that the full Board should meet only once a year, and then the Executive and Finance Committee (of the Board) should return later in the year for their second meeting.

June and July saw a final in-depth evaluation of the **Interspecific Hybridization Project** by UNDP. The two-man team started by meeting our partners in Cornell University, USA, and IRD, France—two advanced research institutions that have proved vital links in the Project's activities. The team then visited Headquarters for in-depth discussions with WARDA scientists involved in the project, before visiting partner national programs in Guinea and Nigeria. The final report was submitted to UNDP in July. The report commended the work done in Phase 1. Subsequently, UNDP funding was received for the first year of Phase 2 in 2000. Given the uptake of NERICAs in Guinea, the report projects that some 400,000 tonnes of NERICA could be produced in the region (annually) by 2005, potentially saving US$ 100 million that would otherwise be spent on rice imports.

On 13 July, WARDA's '**Employees of the Year 2000**,' Mahaman Moussa (GIS Research Assistant) and Ogo Frédérick (Internal Audit Assistant), attended the Annual Gala of the *Jeune Chambre Economique* (JCE) of Bouaké at the Bouaké Ran Hotel, where they were presented with certificates and commemorative plaques.

During the year, news of WARDA reached the **Harvard Business School** (HBS), prompting an extremely positive reaction. Between 7 and 11 August, HBS sent Senior Researcher Cate Reavis to WARDA headquarters for discussions with key personnel, with a view to developing a case study on WARDA for use in their own program. The final case-study document was discussed in two 80-minute sessions at an HBS Agribusiness Seminar, where it was well received by over 200 senior officials (including many chief executive officers) drawn from multinational and private companies world-wide, and the US State Department. The document will provide a useful tool to help prepare a business plan in 2001.

From 23 August to 1 September, a **PRIGA/PVS Monitoring Tour** visited Mali, Niger and Burkina Faso. The team visited seven upland, lowland and irrigated sites, meeting 23 NARES partners (including a UN Volunteer in Burkina Faso) and about 80 farmers.

In August and September, we ran a series of **Basic Rice Production Courses** for farmers in Côte d'Ivoire as part of the collaborative work with the World Food Programme. The courses covered the rice life-cycle and recommended cultural practices. The first of these was at Bodokro on 10 August, followed by Dabakala on 8 September, Bondoukou on 14 September, and Bouna on 18 September. Some 202 farmers took part, including 66 women.

Standing: first and second from left, Mahaman Moussa and Ogo Frédérick, WARDA's '**Employees of the Year 2000**' at the Annual Gala of the *Jeune Chambre Economique* of Bouaké

From 11 to 14 September, a team from WARDA traveled to Bamako (Mali) for the first CGIAR **inter-center collaboration** meeting with counterparts from IITA and ICRISAT as the three centers with major investments in West and Central Africa. This was part of an ongoing process, started in 1999, when IITA and WARDA expanded discussions related to the signing of

The PRIGA Monitoring Tour team at Sébéry, Niger

a new 'Memorandum of Understanding.' Since then, the ongoing discussions on the role and structure of the CG System as a whole has added impetus to our desire to make the most of available resources. Our counterparts at IITA share our views and we are working towards certain common services, shared resources and activities, and overall closer collaboration in our efforts to alleviate poverty in our mandate region. The meeting identified priority areas for joint action: integrated natural resource management (INRM); socio-economic and policy research; integrated pest management (IPM); crop improvement, including the use of transgenics; bionomics and biosafety; and, genomics. In addition, it was agreed that an inventory of centers' activities with national and international research organizations should be established.

Despite the postponement of a few scheduled regional and international meetings around the time of the presidential elections in our host country (September and October), the impetus was maintained with a **Monitoring Tour** from 4 October to 3 November. **PRIGA/PVS** activities in Ghana, Togo, Benin, Nigeria, Senegal, Mauritania and The Gambia were monitored and evaluated by the six-person monitoring team consisting of WARDA and UN/WARDA staff, and a PhD student from Cornell University (working on the Interspecific Hybridization Project). They visited 28 PRIGA/PVS sites, interacting with at least 281 farmers; they worked with, or met, at least 27 NARS representatives and 2 JOCVs.

The PRIGA Monitoring Tour team assessing NERICA field of farmer Bidifayi Essohanan, at Amou-Oblo, Togo

Farmers assessing PVS trials, forest zone, The Gambia

As WARDA reaches towards its goal of becoming the hub of a rice research, development and information system for the region, so we connect with new partners. On 12–13 October, WARDA took the first steps in broadening its network of partners, at a preliminary **Workshop on Partnerships between WARDA and Ivorian Non-Governmental Organizations** (NGOs) at its Headquarters. The meeting's objectives were for WARDA and the NGOs to "get to know" each other, to raise the awareness of WARDA's perceived need to broaden its partnerships to include NGOs, and to discuss possible areas of, and modes for, future collaboration. Some 35 NGOs were represented, covering a range of interests, including rural and social development, farmers' organizations, and women's and child concern. WARDA presented an overview of its existing partnerships, and its participatory research and development activities. We are looking forward to future fruitful work with some of the organizations we met that day.

During the CGIAR's International Centers Week in Washington, DC, Thursday 26 October was a 'Red Letter Day' for WARDA. On that day, we received the prestigious **CGIAR King Baudouin Award** for our development of the 'New Rice for Africa' (NERICA). The Award was established in 1980, when the CG System received the King Baudouin International Development Prize from Belgium "for its contribution to the qualitative and quantitative improvement of food production in the world." The CG Award has been made biennially ever since. In his presentation speech, CGIAR Chairman Ian Johnson said that TAC (the Technical Advisory Committee of the FAO and CGIAR) had "selected NERICA as a major scientific breakthrough from three perspectives: high-quality science; impact; and, partnership. TAC noted, in particular: the use of cellular biology techniques in interspecific hybridization to overcome hybrid sterility barriers; rapid adoption of the new varieties by over 20,000 farmers in Guinea alone...; close and effective partnerships by WARDA with farmers, NARIs, other centers, and advanced research institutions." We con-


The King Baudouin Award of the Consultative Group on International Agricultural Research

West Africa Rice Development Association (WARDA)

For the development of high-yielding upland rice varieties (called the New Rice for Africa) which contribute to agriculture and human welfare in West and Central Africa

The King Baudouin Award Certificate

sider it a particular honor to receive the Award at the turn of the millennium, and on the 20th anniversary of the establishment of the Award.

Further **Monitoring Tours** were conducted in November. From 8 to 24, a **WARDA/IVC** team visited Ghana, Togo, Benin, Nigeria and Cameroon. This completed a ‘tour’ of 8 of the 10 IVC member countries, as earlier trips had been made within Côte d’Ivoire, and to Burkina Faso and Mali. The team met with the National Coordination Unit (of IVC) in each country, which include extension services, universities and farmers’ organizations, in addition to NARS. Discussions were held on progress made in disseminating IVC phase I results, and the need to initiate the new (Phase II) research themes at the earliest opportunity. These visits preluded upcoming planning meetings on these same subjects in early 2001.


Adeta inland valley at the foot of the Atacora mountain range, Togo


The IVC Monitoring Tour in the Bendeh valley, southeast Nigeria


IVC Regional Coordinator, Marie-Jo Dugué discusses with SPIRIVWA Project Coordinator, Doffangui Koné, Guessihio inland valley, Côte d'Ivoire

From 13 to 20 November, a **ROCARIZ Monitoring Tour** visited Mali, Burkina Faso and Côte d'Ivoire to evaluate the implementation of ROCARIZ irrigated-rice activities in Burkina Faso and Mali and on-going national research activities; to evaluate farmers' technology needs and problems, and their perceptions of available technologies through discussion; to assess irrigated-rice production status and constraints as background to updating research priorities; to bring together national and WARDA scientists, extension agents and farmers to identify research needs and share relevant experience; to evaluate the performance of technologies in ROCARIZ trials and identify new areas of collaboration. Five WARDA scientists were involved, along with a consultant from the donor, USAID, and 11 NARS partners from Burkina Faso, Côte d'Ivoire, Mali, Senegal and Togo.

From 20 to 23 November, WARDA and the World Food Programme (WFP) organized a **Training Course on Rice Production** for 3 WFP Project staff and 32 ANADER (the Ivorian extension service) supervisors (representing 10 of the WFP project locations in Côte d'Ivoire). The course covered an introduction to WARDA, rice biology, cultural and post-harvest practices recommended to farmers by WARDA, and constraints to rice production in the region. Additional discussion points included the INGER-Africa and CBSS mechanisms of seed distribution and production, and the use of PVS in technology transfer. Directly related to the on-going collaboration with WFP and ANADER, another, shorter program was held the following week, on 28 and 29 November, to train ANADER extension agents in rice production. The 33 participants from Beoumi, Bouaké, Bondoukou, Dabakala, Katiola and Sakassou discussed rice life-cycle, cultural practices and major constraints to rice production, including a full day of practical exercises in the field. Both courses were well received by their respective participants.

From 21 to 24 November, the WARDA-based Human Health Consortium co-organized the **International Conference 'Water & Health—Ouaga 2000,'** subtitled *Health and Nutritional Impacts of Water Development Projects in Africa*, in Ouagadougou, Burkina Faso. The other co-organizers were the *Centre national pour la recherche scientifique et technologique* (CNRST, Burkina Faso), the *Institut de recherche pour le développement* (IRD, Burkina Faso and France), and the *Ecole inter-états d'ingénieurs de l'équipement rural* (EIER, Burkina Faso). The meeting brought together 156 participants from 18 African countries, 3 European countries, Canada and Sri Lanka. As noted last year ('Perception is Reality,' *WARDA Annual Report 1999*, pages 38–45), this conference effectively marked the end of phase I of the Health Consortium; however, 10 papers reporting results from the Consortium's research are scheduled to be published in a supplement to the *Journal of Tropical Medicine and International Health*, in 2001.

Scenes from the ROCARIZ Monitoring Tour, November 2000: meeting with farmers in Côte d'Ivoire (top); in the field in Burkina Faso (bottom)

From 22 to 24 November, the **Executive and Finance Committee of WARDA's Board of Trustees** came to Headquarters for their second meeting of the year. As mentioned above, this was the first year that the full Board did not meet twice. The Board was thereby implementing a cost-cutting measure on itself, in addition to following a recommendation from the EPMR.

The **Ivorian National [Varietal] Release Committee** met at the offices of *Project national riz* (PNR) in Bouaké on the morning of 20 December, under the chairmanship of Dr Sery Georges of PNR-Abidjan. WARDA was represented by consultant Technology Transfer Agronomist Amadou Moustapha Bèye. The meeting considered and then formally released two WARDA-developed varieties:

- NERICA 1 (WAB 450-I-B-P-38-HB), named *Bofani* meaning "good perfume" in the Agni language—the name relates to the aroma of the variety
- NERICA 2 (WAB 450-11-1-P31-1-HB), named *Keah* meaning "old man" in the We language—the name refers to the awns of the variety that look like an old-man's beard.

These are the first two interspecific rice varieties to be released by registration within the region. Particular advantages of NERICAs 1 and 2 are: high productivity; short growing cycle (95–110 days); good acceptability with farmers, and grain quality. NERICA 2 scored very well in consumer tests because of its aroma. At the request of PNR, WARDA agreed to produce *Fiches techniques* (single-sheet leaflets with agronomic details) of the varieties through the PADS project.

"The events of year 2000 attest to WARDA's three-pronged vision," concludes Director General Kanayo F. Nwanze, "as a center of excellence, a model regional institution, and as the hub of an efficient technology and knowledge delivery system. It is gratifying that our achievements and outputs confirm that Vision."

Financial Statement

1. Position for the year ended 31 December 2000 (in US$)

ASSETS	2000	1999
Current Assets		
Cash and Cash Equivalent	2 326 415	2 637 527
Accounts Receivable:		
Donor	950 025	1 044 533
Employees	382 296	177 948
Others	777 405	902 768
Inventories	615 187	683 361
Prepaid Expenses	19 737	30 670
Total Current Assets	**5 071 065**	**5 476 807**
Property and Equipment		
Property and Equipment	8 855 580	8 439 522
Less: Accumulated Depreciation	(6 330 906)	(5 631 807)
Total Property and Equipment-Net	**2 524 674**	**2 807 715**
TOTAL ASSETS	**7 595 738**	**8 284 521**

LIABILITIES AND NET ASSETS	2000	1999
Current Liabilities		
Bank Balances (Overdraft)	137 160	71 067
Accounts Payable:		
Donors	2 976 460	3 875 936
Employees	231 786	129 818
Others	1 914 644	1 288 254
Provisions and Accruals	1 096 192	1 024 696
Total Current Liabilities	**6 356 242**	**6 389 770**
Total Liabilities	**6 356 242**	**6 389 770**
Net Assets		
Unrestricted Net Assets	1 239 496	1 894 751
Total Net Assets	**1 239 496**	**1 894 751**
TOTAL LIABILITIES AND NET ASSETS	**7 595 738**	**8 284 521**

2. Statement of activities by funding for the years ended 31 December 1999 and 2000 (in US$)

	Unrestricted	Restricted	Total 2000	Total 1999
REVENUE				
Grants	4 679 325	3 407 242	8 086 567	9 069 642
Member States—Operating Income	185 077		185 077	83 924
Member States—Capital Dev. Income	112 821		112 851	
Transfer of Restricted Assets—Income	112 857		112 857	
Other Income	293 024		293 024	399 778
TOTAL REVENUE	**5 383 104**	**3 407 242**	**8 790 376**	**9 553 344**
OPERATING EXPENSES				
Research Programs				
Program Related Expenses	2 975 479	3 407 242	6 382 721	5 530 836
Management and General Expenses	4 004 156		4 004 156	4 034 582
Total Expenses and Losses	**6 979 635**	**3 407 242**	**10 386 877**	**9 565 418**
Indirect Cost Recovery	(1 188 731)		(1 187 868)	**(258 498)**
Total expenses and losses	**5 790 904**	**3 407 242**	**9 199 009**	**9 306 920**
EXCESS/(DEFICIT) OF REVENUE OVER EXPENSES				
Change in Net Assets	**(407 800)**		**(407 800)**	**246 424**
Allocated to Capital Fund in Prior Year				**(75 051)**
Change in Net Assets before Cumulative Effect of Change in Accounting Policy	(407 800)		(407 800)	**171 373**
Bad Debt Written Off—CIMMYT	(152 691)		(152 691)	
Cumulative Effect of Change in Accounting Policy	1 799 987		1 799 987	1 723 378
Change in Net Assets	**1 239 496**		**1 239 496**	**1 894 751**
Net Assets at End of Year	**1 239 496**		**1 239 496**	**1 894 751**
MEMO ITEM				
Management and General Expenses by Natural Classification				
Personnel Costs	*1 682 802*		*1 682 802*	*1 449 371*
Supplies and Services	*1 405 855*		*1 405 855*	*1 613 986*
Operational Travel	*109 562*		*109 562*	*235 565*
Depreciation	*805 937*		*805 937*	*735 660*
Gross Operating Expenses	***4 004 156***		***4 004 156***	***4 034 582***

3. Grants for the year ended 31 December 2000 (in US$)

UNRESTRICTED	2000	1999
Belgium	162 069	115 796
Canada	470 212	468 133
Denmark	126 199	294 737
France*	141 000	89 455
Germany		328 940
Japan	654 340	1 584 382
Netherlands*	704 920	247 083
Norway	255 807	279 641
Sweden	336 344	442 938
United Kingdom*	268 434	260 720
USAID	250 000	250 000
World Bank	1 310 000	2 150 000
Total unrestricted grants	**4 679 325**	**6 511 825**

TEMPORARILY RESTRICTED		
African Development Bank (Institutional Support)	290 274	155 787
Canada (Laval University)	7 164	45 134
Canada (FDCIC Project)	10 333	11 342
CFC/IVC SPIRIVWA	27 545	149 391
Denmark (Phytosanitary & Seed Health)	144 391	24 107
European Union (Crop & Resources Management)	94 760	
France (Inland Valley Consortium)		87 337
France (Collaboration IRD)	3 800	
Gatsby Foundation (Containment Facility)	31 520	30 708
Gatsby Foundation (Dissemination)	138 847	
GTZ (Soil-Nitrogen Project)		48 691
GTZ (Projet riz nord)	76 467	78 032
GTZ (Improved Nutrient Management)	33 173	91 011
GTZ (Hohenheim Project)	316 026	
IFAD (RADORT Project)		132 984
IFAD (PADS Project)	92 393	
Japan (Post-doctoral Studies)	26 212	41 120
Japan (Grain Quality)	68 034	40 381
Japan (Interspecific Hybridization Project)	307 572	427 000
Japan/MAFF/WARDA Project	108 619	115 951
Japan (RYMV Project)	151 491	

*The use of these Grants has been restricted towards selected projects in CGIAR Approved Agenda for WARDA

TEMPORARILY RESTRICTED (continued)

	2000	1999
Japan (Blast Project)	40 468	
Japan (Project 1.3 Watershed Management)	200 000	
Japan (Project 3.4 Part. Technology)	200 000	
Netherlands (Inland Valley Consortium)		323 258
Norway (Health—Vector Borne Diseases Project)		132 997
Norway (Training Project)	12 867	46 745
Rockfeller (Anther culture Project)	130 323	178 250
Rockfeller (Post-doctoral Studies)	45 125	5 978
UNDP—Germplasm Impact Assessment & Evaluation	26 001	13 999
UNDP/TCDC—IHP Phase 2	117 350	
United Kingdom (Weeds Project)	25 480	15 851
United Kingdom (RYMV CRF Project)	67 425	22 439
United Kingdom (Soil Degradation CRF Project)	33 342	27 128
United Kingdom (Seed Priming Project)	7 135	14 343
United Kingdom (INGER-Africa Phase 2)	141 683	7 895
United Kingdom (Wild Rice Project)	10 164	11 716
United Kingdom (University of Wales)	20 434	19 400
United Kingdom (Root Penetration—University of Aberdeen)	12 002	7 026
United Kingdom (DFID/HRI Blast Project)	2 501	
USAID (Arkansas Linkage Grant)		11 199
USAID (Network Project)	280 130	194 409
USAID (Sub-Sahara Africa Technology Dissemination Project)		2 732
USAID (Impact Assessment Project)	100 000	
USAID (Sub-Saharan E-mail Project)	6 192	43 477
Total restricted grants	**3 407 242**	**2 557 817**
TOTAL GRANTS	**8 086 567**	**9 069 642**

Board of Trustees

* Joined in 2000
** Left in 2000

Senior Staff and Associates

Office of the Director General

Kanayo F. Nwanze	Director General
P.-Justin Kouka	Executive Assistant to the Director General
Adrian Q. Labor	Information and Communications Technology Manager (IDRC)
Nko Umoren**	Internal Auditor
Guézi Norberte Zézé	Public Awareness Assistant

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Timothy L. Bertotti*	Interim Director of Administration and Finance
Jean-Baptiste Adjovi*	Senior Accountant (Budgetary Control & Projects)
Bola Andrews**	Administrative Officer for General Services and Security
Antoinette Baroan**	Personnel Officer
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Gabriel Dao	Interim Head of Human Resources and Administrative Services
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Gilbert Kato	Transport Officer
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Olusegun Olubowale	Senior Accountant
Gaston Sangaré	Farm Manager

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Monty P. Jones	Deputy Director of Research and Rainfed Rice Program Leader
Willem A. Stoop*	Interim Associate Director of Research
Frank Abamu	Agronomist/Crop Modeler (Laval University/CIDA)
Mark Abekoe**	Soil Agronomist (Visiting Scientist)
Abdoulaye Adam	Biometrician
Godwin Akpokodje*	Policy Economist (Visiting Scientist, Nigeria)
Aliou Diagne*	Impact Assessment Economist
Alassane Diallo	Documentalist
Sitapha Diatta	Soil Physicist
Olaf Erenstein*	Production Economist

Koichi Futakuchi	Crop Ecophysiologist
Robert Guei	INGER-Africa Coordinator
Assétou Kanouté*	Technology Transfer Scientist (Visiting Scientist)
Mohamed Kebbeh*	Production Economist (Sahel)
Frédéric Lançon	Policy Economist Acting Rice Policy and Development Program Leader
Aboubacar Madougou*	Translator
Guy Manners	Information Officer
Kouamé Miézan	Irrigated Rice Program Leader (Sahel)
Augustin Munyemana*	Participatory Technology Development Scientist (Nigeria)
Marie-Noëlle Ndjiondjop	Molecular Biologist
Francis Nwilene	Entomologist
Olumuyiwa Osiname	WARDA Interim Coordinator in Nigeria (Nigeria)
Kanwar L. Sahrawat	Soil Chemist
Fassouma Sanogo	Translator
Yacouba Séré	Pathologist
Mémouna Sidi-Touré**	Translator
Brent Simpson**	Systems Development and Technology Transfer Program Leader
Aïssata Sylla	Desktop-publishing Assistant
Thomas Teuscher**	Human Health Project Coordinator
Marco Wopereis	Irrigation Agronomist (Sahel)** Natural Resource Management Scientist (Headquarters, DGIS)*
N'guessan Yoboué*	Germplasm Scientist (Visiting Scientist)

Collaborating Scientists

Alain Audebert	Physiologist (CIRAD)
Olivier Briët	Associate Medical Entomologist (DGIS)
Marie-Josèphe Dugué*	Inland Valley Consortium Regional Coordinator (*Coopération française*)
Pierrick Fraval*	Water Management Economist (Sahel, IWMI/*Cemagref*)
Stephan Häfele	Associate Agronomist (Sahel, GTZ)
Wilfried Hundertmark**	Water Management Specialist (IWMI)
Jean-Yves Jamin**	Inland Valley Consortium Regional Coordinator (*Coopération française*)
David E. Johnson**	Weed Scientist (NRI)
Rebecca Kent	Weed Scientist (DFID/NRI)
Hla Myint*	Information and Data Analyst (UNV)
Takeshi Sakurai	Agricultural Economist (JIRCAS)
Satoshi Tobita	Physiologist/Molecular Biologist (JIRCAS)
Petrus van Asten	Associate Soil Scientist (Sahel, DGIS)
Hideo Watanabe**	Grain Quality Specialist (JICA)
Myra Wopereis-Pura*	Technology Transfer Officer (UNV)

* Joined in 2000
** Left in 2000

Visiting Scientists

THE VISITING Scientist Scheme was introduced in 1998 as a mechanism for NARS scientists to be posted at one of WARDA's stations, working as part of the WARDA team. The positions are open to full-time national scientists nominated by their respective institutions. During the secondment, of up to one year, Visiting Scientists are full members of WARDA's inter-disciplinary teams and are involved in the day-to-day activities of the Association.

Visiting Scientists bring fresh blood and insight into the WARDA program and, we hope, take back something valuable to their national programs on completion of their tour of duty with us. In 2000, two Visiting Scientists finished their term of secondment to WARDA, and three more started theirs.

Mark Abekoe is a Lecturer at the University of Ghana, Legon, Accra, in the Department of Soil Science. He stayed at WARDA from July 1999 to June 2000 as Soil Agronomist, working on phosphorus adsorption–desorption and P fractions in West African soils. Seven soils from the humid-forest zone of three West African countries were studied. The results showed that soils have widely differing P requirements, because of their different adsorption and desorption characteristics. Thus, different soils require different management regimes in terms of fertilizer application (many of few applications, large or small doses). His research also covered integrated nutrient management (mixing different crop residues with rock-phosphate) to improve rice production. Phosphorus uptake by the rice crop was greater with a mixture of crop residue and rock-P application than with rock-P alone. Meanwhile, WARDA continues to develop varieties adapted to low levels of available P, as a major component in improving crop production in the humid-forest zone.

Godwin Akpokodje is a Research Fellow at the Nigerian Institute of Social and Economic Research (NISER), Ibadan, Nigeria, where he has contributed to several studies on Nigerian agricultural policy in relation with regional and international institutions. He was seconded to our Nigeria Station (based at IITA Head-quarters, Ibadan) as Policy Economist from November 2000. He is carrying out a study on historical and recent changes in Nigerian rice policy and their impact on rice production in Nigeria.

Assétou Kanouté is a Lecturer–Researcher at *Institut polytechnique rural de Katibougou*, Mali. She is a range-management ecologist, with experience in working with NGOs and grass-roots organizations, especially rural women's organizations. She came to WARDA in February 2000 to join the technology transfer team, with special interest and emphasis on partnerships. She has assisted with an assessment of traditional seed-exchange mechanisms at three key sites in Côte d'Ivoire, and with participatory legume assessments at the same sites. With the PTD Coordinator, she organized the first rice planning workshops with farmers in two states in Nigeria (Ogun and Kogi) and in Benin. In addition, Assétou organized the Ivorian NGO workshop at WARDA (*see* 'The Year in Review,' page 60), and initiated a socio-economic survey on financial systems in Ogun State. She also has initiated a directory of Ivorian NGOs. Along with the Production Economist, Assétou represented WARDA at a gender and diversity workshop in Kenya. She has also started a socio-economic study on constraints and opportunities on rice farming systems in four regions of Côte d'Ivoire.

Mohamed Kebbeh was Principal Researcher in Agricultural Economics at the National Agricultural Research Institute (NARI), The Gambia. He joined the WARDA Sahel team in June 1999 as a production economist, with three principal research topics: assessing the perceptions of farmers (and other actors in the irrigated rice sector) of the performance of the thresher–cleaner in Burkina Faso and Mali; evaluating the socio-economic factors that affect yield and productivity of irrigated rice in the Senegal River valley at the farm level; and, conducting farm- and micro-level characterization studies in the Senegal River valley. Several results from the last two areas are presented in this Report (*see* 'Integrated Crop Management: Getting it Right on the Farm on a Wide Scale,' page 9).

N'guessan Yoboué is a Lecturer–Researcher in the Department of Agriculture and Animal Resources at the *Institut national polytechnique Houphouet-Boigny* (INP-HB), Yamoussoukro, Côte d'Ivoire. He is a biologist and agronomist, specializing in plant genetics and improvement, focusing on genetic resources. He joined WARDA's Genetic Resources Unit in June 2000 to assess the impact of new rice varieties on farmers (economic, general well-being, poverty reduction), the effect of the introduced varieties on farm-level rice diversity, and to characterize the current level of on-farm rice biodiversity. The first aspect of the work is the collection of genetic resources from farms, and comparing their utilization with that of improved varieties; later, the collected material will be characterized at WARDA.

Training

Courses Given in 2000

Title and dates	Location	Language	Participants		
			Male	Female	Total
Community-based Seed Systems Training Workshop 17–19 January	Korhogo, Côte d'Ivoire	French, Dioula, Senoufo	25	15	40
Basic Rice Production for Farmers 10 August	Bodokro, Côte d'Ivoire	French, Baoulé	45	7	52
Basic Rice Production for Farmers 8 September	Dabakala, Côte d'Ivoire	French, Senoufo	17	12	29
Basic Rice Production for Farmers 14 September	Bondoukou, Côte d'Ivoire	French, Dioula	27	22	49
Basic Rice Production for Farmers 18 September	Bouna, Côte d'Ivoire	French, Dioula, Lobi	27	25	52
Assessment of Rice Competitiveness 24 October to 5 November	Conakry, Guinea	French	25	0	25
Rice Production Training for World Food Programme Project Staff and ANADER Supervisors 20–23 November	M'bé, Bouaké, Côte d'Ivoire (WARDA)	French, English	32	3	35
Formation à la riziculture pour ANADER conseil agricole 28–29 November	M'bé, Bouaké, Côte d'Ivoire (WARDA)	French, English	32	1	33
Total			**230**	**85**	**315**

Postgraduate Trainees in 2000

Name and thesis topic	Institution	Sponsor	Degree
Adesanyo, O.O. Soil chemistry	University of Agriculture, Abeokuta, Nigeria	WARDA/ University Hohenheim	PhD
Afolabi, Aboladi Production of transgenic resistance to rice yellow mottle virus in rice	University of East Anglia, UK	WARDA/ John Innes Centre	PhD
Akanvou, René Optimizing rice–legumes intercropping in inland valleys in West Africa: A systems approach to interspecific competition	Wageningen Agricultural University	Netherlands/ WARDA	PhD
Aloko, Kiodé Gabriel Genetic studies of soil acidity tolerance in rice	Louisiana State University	Rockefeller Foundation	PhD
Amoussou, Pierre-Louis Genomics of rice yellow mottle virus	University of East Anglia, UK	WARDA/John Innes Centre	PhD
Assingbé, Paulin Rice agronomy, Benin	University of Abidjan	WARDA/ Hohenheim University	PhD
Bognonkpe, Jean Pierre Irenee Native soil nitrogen dynamics and use efficiency by lowland rice as a function of slope management	University of Abidjan	WARDA/GTZ	PhD
Bousquet, Violaine Variation de l'enracinement du riz pluvial en fonction du cultivar et du type de sol	Institut National Polytechnique de Nancy	CIRAD	DEA
Cairns, Jill Root penetration and QTL mapping in upland rice	University of Aberdeen	DFID	PhD
Chovwen, Anthony Sociology	University of Ibadan, Nigeria	WARDA/ Hohenheim University	PhD

Clark, Cary Rural finance systems and related constraints for lowland rice intensification	University of Reading	Private/WARDA	PhD
Dudnik, Nina Molecular biology	—	Fulbright	—
Guèye, Talla Nitrogen use efficiency in irrigated rice	University of Göttingen	DAAD	PhD
Häfele, Stephan Soil fertility management in irrigated rice	University of Hamburg	GTZ	PhD
Jalloh, Alpha Bella Genetics of iron toxicity tolerance in *indica* rice	University of Sierra Leone	AfDB	MPhil
*Keijzer, Pieter*** Incremental yield and profitability gains from improved soil fertility and weed management in rainfed and irrigated lowland rice	Wageningen University	Wageningen University/ WARDA (IVC)	Msc
Maji, Alhassan Tswako Genetics of resistance to African rice gall midge in *Oryza glaberrima*	University of Ibadan	Rockefeller Foundation	PhD
Mandé, Sémon Assessment of biodiversity in *Oryza glaberrima* using microsatellite markers	Cornell University	Rockefeller Foundation	PhD
Ojehomon, Ohifeme Effects of parboling, storage, and cultivar management on rice grain quality	University of Ibadan	WARDA	PhD
Somado, Eklou Attiogbévi Enhancing nutrient cycling in rice–legume rotations through phosphate rock in acid soil	University of Göttingen	DAAD	PhD
van Asten, Petrus Salt-related soil degradation in irrigated rice-based cropping systems in the Sahel	Wageningen UR	DGIS	PhD

* Completed in 2000
** Started in 2000

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Abbreviations and Acronyms

AAIS	African Association of Insect Scientists
ACIER	**A**DRAO en **C**ollaboration avec l'**IER** thresher–cleaner (Mali)
ADRAO	Association pour le développement de la riziculture en Afrique de l'Ouest (French name of WARDA)
AfDB	African Development Bank
AfRGM	African rice gall midge
AGROPOLIS	Pôle international de recherche et d'enseignement supérieur agronomiques (International Complex for Research and Higher Education in Agriculture, France)
AIDS	Acquired Immune Deficiency Syndrome
a.k.a.	also known as
ANADER	Agence nationale d'appui au développement rural (Côte d'Ivoire)
ARI	advanced research institution
ASI	ADRAO/SAED/ISRA thresher–cleaner (ADRAO, Senegal)
BAD	Banque africain de développement (French name of African Development Bank)
BMZ	Bundesministerium für Wirtschaftliche Zusammenarbeit (Germany)
C&NRM	crop and natural resource management
CABI	Centre for Agriculture and Biosciences International (United Kingdom)
CBSS	community-based seed (production) system(s)
CCLF	CGIAR–Canada Linkage Fund
CD	compact disk
CDC	Center Directors Committee (CGIAR)
CFC	Common Fund for Commodities [donor]
CG	Consultative Group on International Agricultural Research
CGIAR	Consultative Group on International Agricultural Research
CIAT	Centro Internacional de Agricultura Tropical
CIDA	Canadian International Development Agency
CIFOR	Center for International Forestry Research
CIMMYT	Centro Internacional de Mejoramiento de Maiz y Trigo
CIP	Centro Internacional de la Papa
CIRAD	Centre de coopération internationale en recherche agronomique pour le développement (France)
CIRIZ	a farmers' cooperative (Senegal)
cm	centimeter(s)
CMC	Consortium Management Committee (IVC)
CNRADA	Centre national de recherche agronomique et de développement agricole (Mauritania)
CNRST	Centre national pour la recherche scientifique et technologique (Burkina Faso)
CO_2	carbon dioxide
CORAF	Conseil Ouest et Centre Africain pour la recherche et le développement agricole (*formerly*, Conférence des responsables de la recherche agronomique africaine)
CRF	Competitive Research Funds (DFID)
DAAD	Deutscher Akademischer Austauschdienst
DAS	days after sowing; days after seeding

DEA	Diplôme d'études approfondies (degree)
DFID	Department for International Development (UK)
DGIS	Directorate General for International Cooperation (The Netherlands)
DVS	development stage (of crop plant)
ECA	Economic Commission for Africa (UN)
ed.	editor(s)
EIER	Ecole inter-états d'ingénieurs de l'équipement rural (Burkina Faso)
ENCR	Ecole nationale des cadres ruraux de Bambey (Senegal)
EPMR	External Program and Management Review
FAO	Food and Agriculture Organization of the United Nations
FDCIC	Fonds de Contrepartie Ivoiro-Canadien
FERRIZ	Fertilisation du riz irrigué, operational framework for soil fertility management
Fig.	Figure
FRABS	Fraction of incoming radiation
g	gram(s)
GIS	geographical information system
GMO	genetically modified organism
GTZ	Gesellschaft für Technische Zusammenarbeit (Germany)
ha	hectare(s)
HBS	Harvard Business School (USA)
HIV	Human Immunodeficiency Virus
hp	horse-power
HRI	Horticultural Research International (UK)
IAEA	International Atomic Energy Agency
ICARDA	International Center for Agricultural Research in the Dry Areas
ICLARM	International Center for Living Aquatic Resources
ICM	integrated crop management
ICRAF	International Centre for Research in Agroforestry
ICRISAT	International Crops Research Institute for the Semi-Arid Tropics
ICT	information and communications technology
IDRC	International Development Research Centre (Canada)
IER	Institut d'économie rural (Mali)
IFAD	International Fund for Agricultural Development
IFPRI	International Food Policy Research Institute (Washington, DC, USA)
IHP	Interspecific Hybridization Project (WARDA)
IITA	International Institute of Tropical Agriculture (Ibadan, Nigeria)
IKP	I Kong Pao (rice cultivar, Senegal)
ILRI	International Livestock Research Institute (Nairobi, Kenya and Addis Ababa, Ethiopia)
ILTAB	International Laboratory for Tropical Agricultural Biotechnology (USA)
INADI	**IN**ERA, **AD**RAO, **I**RSAT thresher–cleaner (Burkina Faso)
INERA	Institut de l'environnement et des recherches agricoles (Burkina Faso)
INGER	International Network for the Genetic Evaluation of Rice
INP-HB	Institut national polytechnique Houphouet-Boigny (Yamoussoukro, Côte d'Ivoire)
INRM	integrated natural-resources management
INTERCOM	crop–weed competition model
IPGRI	International Plant Genetic Resources Institute (Rome, Italy)
IPM	integrated pest management
IRD	Institut de recherche pour le développement (France)
IRR	internal rate of return (economics)

IRRI	International Rice Research Institute (Los Baños, The Philippines)
IRSAT	Institut de recherche en sciences appliquées et technologies (Burkina Faso)
ISBN	International Standard Book Number
ISNAR	International Service for National Agricultural Research (The Hague, The Netherlands)
ISRA	Institut sénégalais de recherches agricoles (Senegal)
IVC	Inland Valley Consortium (WARDA)
IWMI	International Water Management Institute
JCE	Jeune Chambre Economique (Côte d'Ivoire)
JICA	Japan International Cooperation Agency
JIRCAS	Japan International Research Center for Agricultural Sciences
JOCV	Japanese Overseas Cooperation Volunteer
K	potassium
kg	kilogram(s)
L	liter(s)
LAI	leaf area index
LAN	local area network
LTFE	long-term fertility experiments
m	meter(s)
MAFF	Ministry of Agriculture, Forestry and Fisheries (Japan)
mm	millimeter(s)
MPhil	Master of Philosophy (degree)
MSc	Master of Science (degree)
N	nitrogen
Na	sodium
NARES	national agricultural research and extension system(s)
NARI (1)	national agricultural research institute
NARI (2)	National Agricultural Research Institute (The Gambia)
NARS	national agricultural research system(s)
NCRI	National Cereals Research Institute (Nigeria)
NEC	National Experts Committee (WARDA)
NERICA	New Rice for Africa
NGO	non-governmental organization
NISR	Nigerian Institute of Social and Economic Research
NRI	Natural Resources Institute (UK)
OECD	Organisation for Economic Co-operation and Development
OryzaS	crop model
P	phosphorus
p./pp.	page(s)/pages
PADS	Participatory Adaptation and Diffusion of technologies for rice-based Systems (WARDA project)
PhD	Doctor of Philosophy (doctorate)
PNR	Projet national riz (Côte d'Ivoire)
PRIGA	Participatory Rice Improvement and Gender Analysis (WARDA)
PSI	Pôle Systèmes Irrigués (CORAF)
PTD	participatory technology development
PVS	participatory varietal selection
QTL(s)	quantitative trait locus (loci)
RGRL	relative growth rate of leaves
RIDEV	rice development (crop model)
RNA	ribose nucleic acid (genetic material)

ROCARIZ	Réseau Ouest et Centre Africain du Riz (WARDA/CORAF Rice Research and Development Network for West and Central Africa)
RYMV	rice yellow mottle virus
SAC	**S**ONADER, **A**DRAO, **C**NRADA thresher–cleaner (Mauritania)
SAED	Société d'aménagement et d'exploitation des terres du Delta du Fleuve Sénégal et des vallées du Fleuve Sénégal et de la Falémé (Senegal)
SDI	selective dissemination of information
SLA	specific leaf area
SONADER	Société nationale pour le développement rural (Mauritania)
SPIRIVWA	Sustainable Productivity Improvement for Rice in Inland Valleys of West Africa (IVC project funded by CFC)
SQL	Structured Query Language (computer database language)
suppl.	supplement
t	tonne(s)
TAC	Technical Advisory Committee (CGIAR)
TCDC	Technical Cooperation among Developing Countries (UNDP)
TF	farmer's practice (field trial)
UK	United Kingdom
UN	United Nations
UNDP	United Nations Development Programme
UNV	United Nations Volunteer
US	United States
USA	United States of America
USAID	United States Agency for International Development
v	versus
WARDA	West Africa Rice Development Association
WARIS	West Africa Rice Information System (WARDA)
WECARD	West and Central African Council for Research and Development (English of CORAF)
WFP	World Food Programme (FAO)
Y2K	year 2000

About the Consultative Group on International Agricultural Research (CGIAR)

The Consultative Group on International Agricultural Research (CGIAR) was founded in 1971 as a global endeavor of cooperation and goodwill. The CGlAR's mission is to contribute to food security and poverty eradication in developing countries through research, partnership, capacity building and policy support, promoting sustainable agricultural development based on the environmentally sound management of natural resources. The CGIAR works to help ensure food security for the twenty-first century through its network of 16 international and autonomous research centers, including WARDA. Together, the centers conduct research on crops, livestock, fisheries and forests, develop policy initiatives, strengthen national agricultural organizations, and promote sustainable resource management practices that help provide people world-wide with better livelihoods.

The CGIAR works in partnership with national governmental and non-governmental organizations, universities and private industry. The United Nations Development Programme, the United Nations Environment Programme, the World Bank, and the Food and Agriculture Organization of the United Nations sponsor the CGIAR. The CGlAR's 57 members include developing and developed countries, private foundations, and international and regional organizations. Developing world participation has doubled in recent years. All members of the OECD (Organisation for Economic Co-operation and Development) Development Assistance Committee belong to the CGIAR.

The CGIAR is actively planning for the world's food needs well into the twenty-first century. It will continue to do so with its mission always in mind and with its constant allegiance to scientific excellence.

CGIAR Centers

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

West Africa Rice Development Association

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