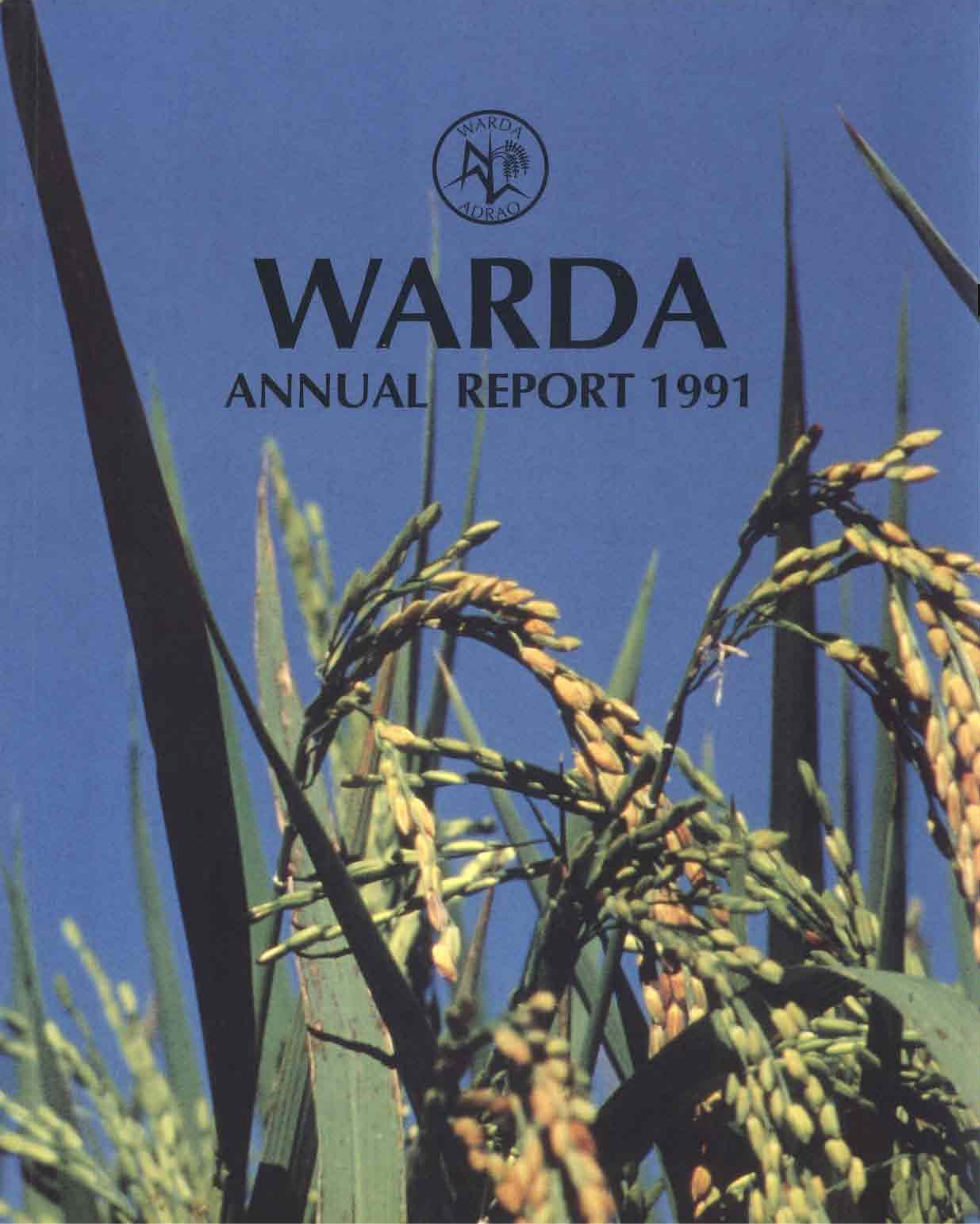
WARDA

ANNUAL REPORT 1991



WARDA

ANNUAL REPORT 1991

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West Africa Rice Development Association (WARDA)

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Contents

Foreword

In approving WARDA's Medium-Term Implementation Plan (1990-94), the Technical Advisory Committee (TAC) of the Consultative Group on International Agricultural Research (CGIAR) endorsed the construction of a new Main Research Center and Headquarters in Côte d'Ivoire as essential to the implementation of WARDA's research, training and communications programs. A major focus of WARDA's activities in 1991, therefore, was the establishment of these facilities. Construction work on the first phase began in late 1990 and was scheduled for completion by February 1992 and occupancy in May 1992; rapid progress was made and by December 1991 it was clear that the deadline for completion would be met.

The year 1991 also saw considerable progress in the development of new program structures and research teams following the major staff changes and program reorientation in 1990. In line with its commitment to forging stronger links with the national agricultural research systems of member states, WARDA consolidated its program of partnership through the establishment of research Working Groups and Task Forces. The major assumption underlying this strategy is that in order to arrive at the most cost-effective means of generating and transferring rice technologies within West Africa, the entire rice science infrastructure in the region should be viewed as an integrated and interdependent system. It was against this background that WARDA's programs for 1991 were implemented.

This report includes feature articles and summaries of WARDA's research, training and communications actitivies during 1991, as well as a special article on the design and construction of the Main Research Center and Headquarters at M'bé. One of the feature articles focuses on the development of WARDA's information retrieval and dissemination services for rice scientists in West Africa.

Among the research topics covered in the feature articles are low-input rice crop management in rainfed uplands, the environmental and genetic factors governing crop duration in the Sahel and WARDA's role in the inter-center effort to characterize *Pyricularia oryzae* populations. There is also a report on progress in regional collaboration in rice improvement for the mangrove swamp environment, following the conversion in 1990 of WARDA's mangrove research activities into a network-based structure. As part of the Association's effort to assess the impact of research activities at farm level, a study was conducted on the diffusion, adoption and economic impact of improved mangrove swamp varieties in West Africa; the results of the study are presented in this report.

On behalf of the Board of Trustees and management and staff, I have great pleasure in presenting the *WARDA Annual Report 1991*. We hope that the activities described in this report will contribute significantly to the CGIAR effort on sustainable food production in sub-Saharan Africa.

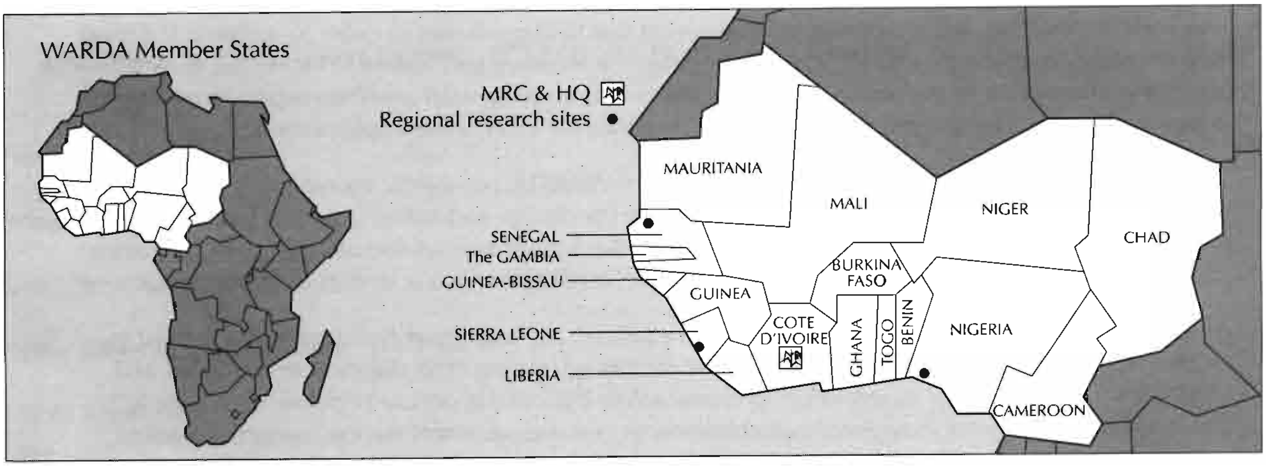
Eugene R. Terry, PhD (Illinois)
Director General

About WARDA

The West Africa Rice Development Association (WARDA) is an intergovernmental research association with a mandate to conduct rice research, training and communication activities for the benefit of the West African region. Formed in 1971 by 11 countries with the assistance of the United Nations Development Programme (UNDP), the Food and Agriculture Organization of the United Nations (FAO) and the Economic Commission for Africa (ECA), it now consists of 17 member countries including Cameroon which joined in 1991 (*see* map). WARDA is a member of the network of 17 international agricultural research centers supported by funds from donors of the Consultative Group on International Agricultural Research (CGIAR).

WARDA's goal is to strengthen West Africa's capability in the science, technology and socio-economics of rice production. Through these efforts, it is envisaged that the livelihood of the small farm family can be sustained and improved, opportunities for rural employment increased and prospects for food security enhanced.

The Headquarters of the Association are located in M'bé, Côte d'Ivoire. WARDA maintains regional research sites near St Louis in Senegal, at Rokupr in Sierra Leone and at Ibadan in Nigeria.



DONORS

- Member States in West Africa
- African Development Bank (AfDB)
- Belgium
- Canada
- Deutsche Gesellschaft für Technische Zusammenarbeit (GTZ)
- European Economic Community (EEC)
- France
- Germany
- International Development Research Centre (IDRC)
- Italy
- Japan
- Rockefeller Foundation
- Sweden
- The Netherlands
- United Kingdom
- United Nations Development Programme (UNDP)
- United States of America
- World Bank

COUNCIL OF MINISTERS

BOARD OF TRUSTEES

Calendar of Events in 1991

January	22-23	18th Ordinary Session of the Council of Ministers in Abuja, Nigeria
	31	Farm Development Committee meeting, M'bé, Côte d'Ivoire
February	6	Farm Development Committee meeting, M'bé, Côte d'Ivoire
	8	Director General visits Chairman of the Council of Ministers and the AfDB
	13-14	B. M'poko and B. Lhoest, UNDP office, Abidjan, Côte d'Ivoire visit WARDA
	21	Tenders Committee meeting (No. 18)
	22	Director General visits new Japanese Ambassador to Côte d'Ivoire
March	1	Swedish Minister of Cooperation, Swedish Ambassador and Dutch diplomats visit WARDA
	9-17	TAC meeting (No. 54) at ISNAR, The Hague, The Netherlands
	11-13	Mangrove Swamp Rice Network workshop, Rokupr, Sierra Leone
	13	L. Brader, Director General of IITA, visits WARDA
	17-7 April	Team from WHO and IDRC visit WARDA regarding the Human Health Hazards Project
	27-29	Prefect, Sous-Prefect, Mayor and French Consul, Bouaké, Côte d'Ivoire visit WARDA
April	2	Program Management Committee meeting
	5-7	In-House Review
	8-9	Board of Trustees Program and Executive Committees meetings
	11-12	Full Board of Trustees meeting
	15-20	Japanese Study Mission visits WARDA
May	1-10	Director General visits WARDA member states as part of a fund drive for MRC & HQ
	8	General staff meeting
	13-14	Working Group on Crop and Resource Management meeting, Bobo-Dioulasso, Burkina Faso
	13-27	Training course: On-farm trial methodology in the mangrove swamp ecosystem, Rokupr, Sierra Leone
	17	Tenders Committee meeting (No. 19)
	20-24	Director General attends CGIAR mid-year meeting in Paris, France
June	22-26	Director General attends CGIAR Center Directors' meeting, Rome, Italy
July	2	Program Management Committee meeting
	4-5	Donors Conference at WARDA
	11	Dutch parliamentarians visit WARDA
	15	EEC delegate, Abidjan, Côte d'Ivoire visits WARDA
August	19-2 Sept	Training course: Mangrove swamp rice production, Rokupr, Sierra Leone
	21-6 Sept	Filming for WARDA documentary/slide presentation
	27	SPAAR delegation visits WARDA
September	11-12	Working Group on Varietal Improvement meeting, Kindia, Guinea
	16	Japanese economist group visits WARDA
	19	Tenders Committee meeting (No. 20)
	20-21	Executive Management Retreat, Yamoussoukro, Côte d'Ivoire
	27	Program Management Committee meeting
	30-11 Oct	In-country Training of Agricultural Trainers course, Moor Plantation, Ibadan, Nigeria
October	1-3	INGER meeting of WARDA, Bouaké
	3	Director General visits Nigerian Ambassador to Côte d'Ivoire
	11	General staff meeting
	23	Board of Trustees Executive Committee meeting, Washington DC, USA
	21-28	CGIAR Center Directors meeting, Washington DC, USA
	21-31	Training course: Seed production and multiplication in the mangrove swamp ecosystem, Rokupr, Sierra Leone
	28-1 Nov	International Centers Week, Washington DC, USA
November	17-30	Training course: Scientific writing for agricultural research scientists, Lomé, Togo
December	2-5	J-P. Jacqmotte, Senior Finance Officer, CGIAR Secretariat, visits WARDA
	12	Program Management Committee meeting

SPECIAL REPORT

THE DEVELOPMENT OF WARDA'S MAIN RESEARCH CENTER AND HEADQUARTERS 1988-92

Peter B. Mather

The Initial Steps

In 1987 the Technical Advisory Committee (TAC) of the Consultative Group on International Agricultural Research (CGIAR) endorsed the decision of WARDA's Board of Trustees to establish a new Main Research Center and Headquarters within WARDA's priority rice growing environment — the upland/inland swamp continuum. The project was initiated later that year, soon after the current Director General, Dr Eugene R. Terry, assumed office at the then WARDA headquarters in Liberia. A development grant proposal was prepared and submitted to donors. A site selection report recommended the location of the site at M'bé, near Bouaké in Côte d'Ivoire. This choice was confirmed towards the end of the year.

By February 1988, a Development Officer, Peter B. Mather, was on staff. His brief was twofold: to implement the development proposal and to organize the move from Liberia to temporary premises in Côte d'Ivoire.

The next step was to identify WARDA's physical space requirements. This task proceeded quickly, under the direction of a newly established Technical Monitoring Committee. At the same time, the Director General proposed guidelines for the overall character of the new center, including the respect to be paid to traditional building forms whilst exploiting modern materials and techniques. Consultant architects and engineers, Norman & Dawbarn of the UK and Nigeria, were appointed to prepare a concept design scheme meeting these requirements.

Moving to Côte d'Ivoire

The plans for moving to Bouaké were completed in March 1988. Premises were obtained in the city's Kennedy district and work began on their rehabilitation. Protocols for the move were arranged at governmental level. The Executive Committee of the Board of Trustees, at its meeting in Bouaké in April 1988, endorsed plans to create temporary, prefabricated laboratories and offices on the site at M'bé. The Training Center at Fendall and the station at Suakoko were to remain in Liberia, together with a small liaison office in Monrovia.

The move was under way by early May and WARDA began work at its new temporary headquarters. A second building in the Kennedy district, the Annexe, was acquired, rehabilitated and occupied by the

Finance and Documentation Units in June. By this time 15 members of staff had been transferred. A third building was acquired later in the year when it became vacant next door to Kennedy 1.

The Concept Design

At an early stage, a suitable site for the new building was identified at M'bé — central to the potential area for the research farm and with a commanding view of the lowland rice areas.

A concept design, including costs, was prepared. After approval by WARDA, it formed the basis of a submission to donors at the CGIAR meeting in Berlin in mid-May 1988. Donors endorsed the design, recommending that the scheme should be flexible in detail and capable of phased development.

Developing the Construction Program and Detailed Brief

A phased design and construction program was prepared in May 1988 which included the various stages of approval by WARDA, by its Board of Trustees and by donors. June 1992 was projected as the target completion date for the first phase of construction.

A detailed architect's brief was developed rapidly under the guidance of an interim Technical Monitoring Committee. Serving on the committee and working closely with the architect were WARDA's newly arrived Director of Administration and Finance, Gordon B. MacNeil, and the Director of Research, Peter J. Matlon.

Internal procedures were developed for managing the project, involving WARDA management and the Board of Trustees, while external administrative procedures with consultants and contractors were also developed. These procedures, which specified methods of engagement and terms of reference for the various consultants, were ratified by the Executive Committee of the Board of Trustees in October 1988.

The terms of reference for the consultants reflected WARDA's Medium-Term Implementation Plan and took into account the research program and its physical requirements, the potential increase in staff numbers and the needs of the Administration and Services Divisions. Analyses included lists of staff and grades, their space and equipment requirements, the organization of divisions and units and their interactions and the service and maintenance needs in proportion to the growing institution.

The fundamental principles of the design were that it should:

- have in-built flexibility
- be modular in its conception
- be replicable by the region's national agricultural research systems
- have efficient spatial relationships
- achieve a balance between economy, utility and durability
- provide an attractive working environment

Developing the Design

In response to an international advertisement, over 70 applications were received for consultancy design services from 17 different countries. A consultant was eventually appointed from a shortlist of five firms in

February 1989 by the Tenders Committee, a committee of the Board of Trustees, with the assistance of the Deputy Chairman of the Board. The successful consultant, Norman & Dawbarn, was the same firm that had prepared the concept design.

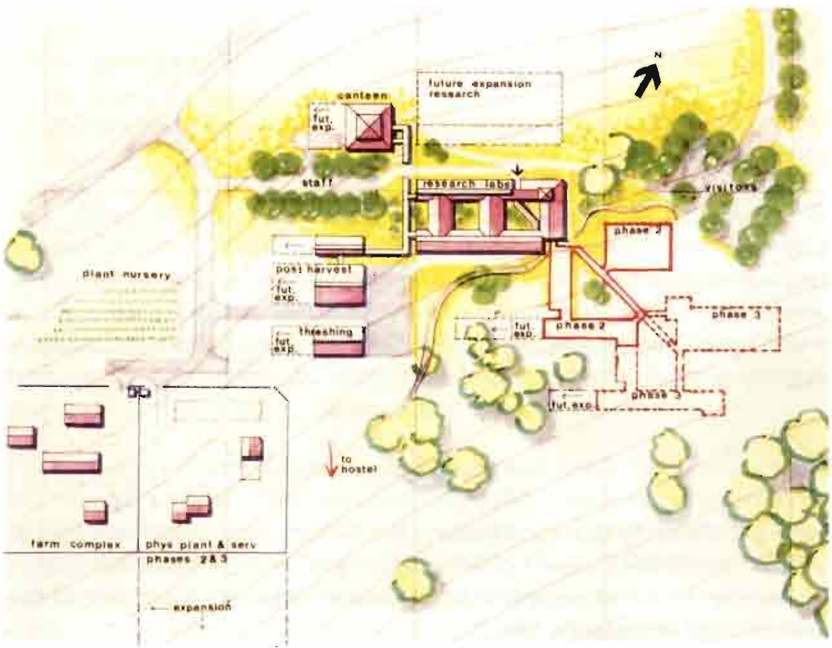
The consultants were instructed to proceed with the design stage in three steps:

- an outline design of Phases 1, 2 and 3 (including topographical and soil surveys of the site)
- a scheme design of Phase 1
- a detailed design of Phase 1

The accommodation initially envisaged for the three construction phases was as follows:

- *Phase 1:* The research building, including laboratories and offices for physiology, agronomy, soil science, weed science, pathology, entomology, plant breeding, germplasm and an inter-center activity unit, together with a gross area of 3563 m^2 consisting of an insectarium, the farm complex, a generator/transformer house, a volatile-chemical store, postharvest facilities, canteens, a welfare building, part of the maintenance unit, a fuel station and control posts. Accompanying infrastructure was to include the access road and railway bridge, water borehole and electricity supplies, sewage treatment, microwave telephone connection to Bouaké, plant nursery and landscape works.
- *Phase 2:* This was to consist of the training, communications and documentation building, an initial group of hostels and research field sheds.
- *Phase 3:* The final phase included the administration building, conference and restaurant facilities, the rest of the maintenance unit and tarmacadam to the access road.

Additional accommodation for which further areas were reserved included essential staff housing, a second group of hostels, senior and junior staff housing and recreation facilities.



Site plan of the Main Research Center and Headquarters, Phases 1-3

WARDA's strategy and policies for this capital development were endorsed at the 1989 CGIAR meeting in Canberra, Australia, with a proviso that further refinement of the phasing proposals should be considered — the possibility of phasing within a phase.

Cost planning

Starting in 1988, accommodation needs had all been costed in US $ per square meter. They were regularly monitored and updated. Since no building cost index exists in Côte d'Ivoire, advice on costs was obtained from many sources and countries. At each stage, target costs and, later, contract prices were developed and were then converted by sine curve projection into cash flow analyses for the purposes of budgeting by the Director of Administration and Finance.

The research building

It was realized that the research building would have to be designed in the absence of the scientists who were to use it, as they had not yet been appointed. The Director of Research and the consultant put together a design which met the overall requirements of the current and potential research program.

The research building is characterized by:

- interchangeable laboratory and office modules, offering maximum flexibility for future program changes
- a close relationship between scientists and their laboratory, facilitating interaction and close supervision
- services supplied from the external wall side only and the resulting peninsular laboratory bench arrangement
- the dispersal into a service zone of the specialized areas such as the preparation, grinding and balance rooms and fume cupboards
- the provision of a standard internal corridor to allow interdisciplinary activities
- a services gallery located above the specialized areas, allowing maintenance and modifications to be made without disturbing the work in the laboratories
- the provision of 'dirty' areas for storage and work on material brought in from the field, including provision for direct external access
- the separation of serviced areas, such as the laboratories, from non-serviced areas, such as offices for statistics, economics and administrative support

Once the designs had been completed, preparation of the working drawings, specifications and tender documents began and advertisements were placed internationally for the pre-qualification of contractors. The tender documents were arranged so that WARDA could proceed with various sizes of contract, according to its budget at the time of acceptance. In October 1989, donor and Board approval was obtained for Phase 1 during International Centers Week in Washington, USA. The documents were issued to the short-listed contractors in March 1990.

Laying the Foundation Stone

On 4 April 1990, the Ivorian Minister of Agriculture, Water and Forestry, the Chairman of WARDA's Board of Trustees and a representative of the Chairman of the Council of Ministers, together with representatives of the local villages and WARDA staff, took part in a ceremony involving ground breaking, the laying of the first brick and the pouring of a traditional libation to bless the site.

Professor Dr Heinrich C. Weltzien (Chairman, WARDA Board of Trustees) laying the foundation stone of the Main Research Center and Headquarters, assisted by Peter B. Mather (Development Officer), while Dr Eugene R. Terry (Director General) looks on *(left)*; the Head of the village community at M'bé pouring a libation to bless the site at the ground-breaking ceremony *(right)*

Cost Problems

Whilst it had been recognized from the start that estimating building costs was difficult and that costs were generally high in Côte d'Ivoire, it had nevertheless been felt that the downturn in the local economy might result in competitive, low bids. The opposite turned out to be true: the lowest bid was about twice the budgeted figure. WARDA was compelled to implement contingency arrangements immediately, as follows:

- a period of up to 6 months between submission of the bids and acceptance had been specified in case negotiations were necessary
- prices were individually checked and the submissions vetted for anomalies
- the consultants investigated alternative specifications for items that were expensive in Côte d'Ivoire
- the contract was divided into two parts, the main building contract and the mechanical and electrical services contract, in order to assist negotiations for reductions
- WARDA re-examined its staffing structure and operational needs; this resulted in areas of the building being identified as not needed immediately; it was decided that these areas should be built as bare shells, with no services or finishes, to be completed later

As a result of these contingency activities, the contractors with the two lowest bids were invited to re-submit their tenders in August 1990. However, the prices received were still beyond WARDA's budget. Further reductions were proposed and further areas for the contractor to examine were identified. Throughout this process, a clearly stated objective was that the quality of the materials used and the ultimate function of the building should not be affected.

The outcome of these lengthy negotiations was a reduced, initial construction contract — Phase 1A, called the 'Research Phase'. This phase included the research building (incomplete due to the bare shell areas), the volatile-chemical store, the insectory, the generator house, the research farm workshops, the fuel station, the gatehouse, substantially reduced siteworks and septic tanks (instead of sewage ponds). WARDA was to undertake the basic infrastructural works — water, electricity, telephones and access road improvement — outside the construction contract. The completion date envisaged for Phase 1A was February 1992.

The omitted works, called Phase 1B, included the remainder of the research building, the cafeteria, post-harvest facilities, farm offices, the physical and plant services unit, the screenhouses and greenhouses, the main access road and railway bridge, internal roads, pathways and landscaping.

Contracts Signed

By the end of September 1990, the Tenders Committee was able to make a recommendation to the Executive Committee of the Board of Trustees, which approved acceptance of the lowest negotiated bids at its October meeting in Washington. The main building contract was awarded to the Société d'Etudes et de Travaux d'Afrique de l'Ouest (SETAO), a subsidiary of Bouygues, a large European firm of contractors. The mechanical and electrical services contract was awarded to Réfrigération Ivoirienne de Conditionnement d'Air (RICA)/CLEMCI of Abidjan.

Although there was some uncertainty about funding for the project and some nervousness at the step WARDA was about to take, it was clear that there would be serious consequences for the Association if building operations were further delayed or halted altogether. Accordingly, on 19 November 1990, the Director General and the Development Officer handed over letters of acceptance to the contractors in Abidjan. Copies of the contract documents were made and formally signed on 11 December.

Work Starts on Site

Although some preparatory work was done in December 1990, work on site began in earnest in mid-January 1991. Site clearance was undertaken by a local regiment of the Ivorian Army, acting as subcontractors to SETAO. Building work progressed rapidly. Progress in each of the building areas was closely monitored each week, together with the costs incurred. When the contractor had prepared his initial program he had proposed completion of the works by December 1991. In the event the original date of February 1992 was maintained in order to reduce cash flow problems.

Parallel with the building contract, WARDA began other essential infrastructural works, including a water borehole, microwave telephone connection to Bouaké and electrical power supply from the national grid. Later in the year work started on the main access road, using WARDA's own labor and plant.

The Funding Crisis

The uncertain funding situation at the outset of the project was not being resolved as had been hoped. Indeed, a funding crisis now loomed. At the request of the Board, contingency plans were made to safeguard against financial shortfalls. It was realized that if the contract had to be terminated, there would be penalties in addition to the costs of the work already carried out. Protective measures would have to be afforded in order to preserve what had been half built. Termination of the contract would be poor value for money.

A 'retreat' was held in Yamoussoukro, at which WARDA's management closely examined the financial state of the Association, considering both capital development and recurrent expenditure. The result was that operating budgets were cut to the bare minimum and preparations were made to terminate the building contract in late May or June if the financial resources forecast for August became seriously inadequate. In addition, a 'last ditch' donors' conference was planned.

The conference was held in Bouaké and at M'bé at the beginning of July 1991. The donor representatives saw the progress of the building, interacted with the staff and looked at WARDA's research, training and communications activities — in short, they witnessed WARDA in operation. The result was highly positive. Given some additional donations and encouragement, WARDA visibly drew breath. Immediately after the conference WARDA took steps to:

- negotiate for a loan or line of credit with a bank in New York, USA
- instruct the contractor to complete the areas of the research building designated as bare shells
- reconsider accommodating all of WARDA (except Training and Communications) on the M'bé site
- prepare for the occupation and operation of the buildings

These plans were quickly put into operation without affecting WARDA's overall program.

Planning the Occupation and Maintenance

A second retreat was held at Yamoussoukro in September to consolidate the recent progress, plan the next stages and repair the loss of confidence and morale brought about by the earlier financial crisis.

In 1989 it had been realized that not all of the research building could be occupied immediately. The Tenders Committee had therefore approved a policy for accommodating the main components of WARDA in the building. Following the Yamoussoukro meeting it was clear that a physical consolidation of WARDA was not only desirable but necessary. In addition, WARDA had to make provision for the replacement of the Training Center facilities that had been lost in the Liberian civil war.

After reappraising the space requirements, reallocation plans were drawn up and approved in October for:

- *Research Building A*: Continuum Research Program, Director General, Directors of Administration and Finance, Research, Training and Communications (each with their own staff), Farm Development, and an embryonic Physical Plant and Services Unit
- *Farm Complex:* plant and equipment workshops and spare parts store
- *Upland Center:* farm operations, Personnel and Finance Units, operations of the International Network for Genetic Evaluation of Rice (INGER)
- *Kennedy 1 and 2:* Training Center and Publications
- *Annexe*: Documentation

Front view of the research building, November 1991

Task forces were established to make arrangements for the occupation of the buildings and for landscape policy and implementation. A maintenance program for the new buildings was formulated and adopted by WARDA's management in August 1991. Although the Physical Plant and Services Unit had been deleted from Phase 1A, it was realized that an embryonic service would be required. Accordingly, the plan made allowance for reinstating the service and for enlarging it later on according to need. Later in the year a Clerk of the Works was appointed to head the service. His initial tasks were to collate the building records and to assess and, if possible, acquire additional supplies of the building materials used.

Completion of Phase 1A

On 26 February 1992 the contractor handed over the buildings to WARDA management. The project had been completed on schedule despite all the difficulties — the complex contract, the constant financial problems, the requirement to complete the bare shell areas imposed part way through the contract period, amendments made to accommodate the newly arrived scientists and the incorporation of modifications to transform Phase 1A, the research phase, so as to accommodate other operations in addition to research.

On 26 February 1992, the contractor handed over the buildings to WARDA management at a ceremony at M'bé *(above);* one of the internal courtyards of the research building *(left)*

Generator house

On completion of the building contract, fitting out and commissioning began. WARDA's Board of Trustees were the first occupants of the building, holding their meeting in the conference room on 11 April 1992. To celebrate the occasion the acting Chairman and other Board members performed a benediction and libation. At this meeting the room was named the 'Heinrich C. Weltzien Conference Room' in honour of the Chairman of the Board, whose resignation, due to ill health, was accepted with regret at the meeting.

Minimum laboratory furniture and equipment were installed and staff began to occupy their new place of work in May 1992. WARDA's own staff are completing the site works which had to be omitted from the building contract, together with the main access road. This work will carry on into 1993.

Conclusion

The planning, design and construction of WARDA's new Main Research Center and Headquarters may be judged a success.

The project planning and implementation stages are summarized overleaf. The schedule established in mid-May 1988 was maintained and the original target date for completion of June 1992 achieved. WARDA's requirements were clearly identified and the basic concept successfully adapted to available resources.

Nevertheless, the original, balanced Phase 1 was reduced to a bare minimum and WARDA had to implement emergency measures to offset the cutbacks in funding. Inauguration of the subsequent phases, in line with the development of WARDA's activities, has become essential.

The project's success owed much to the structured cooperation and intervention of WARDA's management, staff and consultants, all of whom had to respond flexibly to rapidly changing circumstances. The completion of the project demonstrates the determination of WARDA's management and Board of Trustees to fulfill the Association's important mandate.

Project implementation schedule

1987

Initiation
- Arrival of Director General, Eugene R. Terry — September
- Development Grant proposal finalized — October
- Selection of M'bé site confirmed — December

1988

- Arrival of Development Officer, Peter B. Mather — February
- Appointment of concept design Consultants, Norman & Dawbarn — February
- Initial schedules of accommodation prepared — February/March
- Study tours of other centers — February/March
- Relocation plans finalized — March
- Temporary buildings rehabilitated — March/April
- Approval of temporary laboratories and offices on M'bé site by Board of Trustees — April

Concept design
- Technical Monitoring Committee established — February
- Study of M'bé site possibilities — March
- Location of buildings on site agreed — April
- Approval of concept design — April
- Presentation to donors at mid-term CGIAR meeting in Berlin — May
- Concept design strategy finalized — July

Brief development
- Program and targets established — May/June
- Management procedures established — June-August
- Brief requirements developed — May-September
- Advertisement placed for consultant pre-qualification — August
- Tenders Committee established — October
- Approval of procedures and brief by Board of Trustees — October
- Documents issued to pre-qualified consultants — November

1989

- Final brief completed — January
- Consultant appointed — February

Outline design (Phases 1, 2 and 3)
- Soil and topographical surveys initiated — March

1989 (contd.)

- Outline design approved by WARDA Board of Trustees — May
- Donors approve outline design at CGIAR meeting, Canberra, Australia — May

Scheme design (Phase 1)
- Scheme design begun — June
- Site surveys completed — July
- Scheme design approved — July

Detail design (Phase 1)
- Detail design approved — September
- Contractors advertised for internationally — September

Production information/Bid documents
- Donor and Board of Trustees approval for Phase 1 given at CGIAR meeting, Washington DC — October
- Contractors pre-qualified — December

1990

- Development stage completed — February
- Contract out to tender — March
- Foundation stone laid — April
- Tenders submitted and assessed by consultants — May
- Negotiations on tender reduction — June-September
- Recommendation to Board of Trustees — September
- Approval to let contract — October
- Letters of acceptance issued — November
- Contract signed — December

1991

Construction stage
- Work begun on site — January
- Planned Maintenance Program adopted — August
- Physical Plant and Services Unit established — September
- Reallocation of accommodation — October
- Estates Committee established — November
- Landscape task force established — December

1992

- Buildings completed — February
- Board of Trustees meets in new MRC & HQ — April
- Installation of laboratory furniture begun — April/May
- Initial occupation — May/June

RESEARCH

OVERVIEW

Peter Matlon

In 1991 WARDA entered the second year of its Medium-Term Implementation Plan and the first full season of research for the scientists recruited in 1989 and 1990. Budgetary constraints had limited the Association's total complement of international research positions to 11, less than two-thirds of the total approved by TAC for the Medium-Term Implementation Plan. Despite staff limitations, good progress was made in launching new initiatives in WARDA's main research programs. These initiatives were based on the interdisciplinary team projects developed through the team planning exercises conducted in 1990.

In the Upland/Inland Swamp Continuum Program, regional responsibility for lowland rice breeding was transferred from the International Institute of Tropical Agriculture (IITA) to WARDA with the posting of a WARDA scientist to IITA's headquarters in Ibadan, Nigeria. The momentum established in the former IITA program was maintained and new stress screening activities were initiated. At WARDA's new research farm at M'bé, 18 ha of upland fields were cleared for cultivation, bringing the total upland area to 34 ha, and an irrigation system providing potential coverage for 10 ha of upland trials was installed. An area of 3 ha of irrigated lowland was cleared and an additional 5 ha were developed for use in 1992. Among the farm construction projects completed were a machine and office shed, a crop work area and a shed to house work oxen. Substantial improvements were made to the temporary offices and laboratories.

Activities in the Sahel Irrigated Rice Program, based in Senegal, concentrated on three major thrusts. First, good progress was made in developing the N'diaye research site and in rehabilitating facilities at Fanaye. With the collaboration of the Société Nationale d'Aménagement et d'Exploitation des Terres du Delta du Fleuve Sénégal (SAED), offices, laboratories and experimental fields were established at N'diaye. In addition, SAED provided two buildings for conversion to scientific use and gave WARDA access to irrigated land, on which trials were established in early 1991. Second, a crop physiology research program was launched at N'diaye and Fanaye. Research focused on characterizing the Sahelian environment and identifying the response of a broad spectrum of rice germplasm to temperature and salinity stresses. Third, the new Sahel research team visited national programs throughout West Africa to establish contacts with key scientists, collect secondary data for Sahel characterization work and plan collaborative trials.

The Mangrove Swamp Rice Program became a network of collaborating national programs. The goals of the network are to consolidate the achievements in varietal improvement, develop a more coordinated regional program and accelerate the transfer of technologies and skills to national programs. A regional plan for collaboration in mangrove swamp rice research was developed at a network workshop held in Rokupr, Sierra Leone in March. Under this plan, trials were planted in several WARDA member states and the Association organized three group training courses for national program scientists.

1.1 PHYSIOLOGICAL AND ECOLOGICAL BASIS OF VARIETAL RICE CROP DURATION IN THE SAHEL

Michael Dingkuhn

Background

Compared with the more traditional upland, deepwater and inland valley rice ecosystems of West Africa, irrigated rice production in the Sahel is relatively recent, having been introduced during the colonial period. Irrigated rice is found in development schemes varying in size from 50 to 40 000 ha, scattered over the semi-arid belt of West Africa, but invariably dependent on the rivers that traverse the zone. Earlier development strategies emphasized the expansion of the irrigated area, whereas current trends are to rehabilitate and intensify the use of smaller, more manageable areas.

Intensification is associated mainly with the introduction of rice-rice double cropping, a production system that distinguishes the Sahel from climatically similar rice ecologies in Egypt and Pakistan. Double cropping is currently practised by farmers in the Niono and Selingue schemes of Mali, the rice terraces of Niger and the Kou and Sourou valleys of Burkina Faso. Altogether, this intensified system covered about 15% of the area used for irrigated rice in the Sahel in 1991. Further intensification depends mainly on the availability of rice cultivars that suit farmers' cropping calendars and the climatic conditions of the Sahel.

Production Constraints

In many parts of the Sahel, irrigated rice cultivation is limited to the main (wet) season, which occurs between late July and early November. However, rainfall patterns only indirectly affect the cropping calendar through the seasonal flow of rivers. In areas with continuous access to irrigation water, it is mainly seasonal temperatures that determine when a rice crop can be grown and the length of the crop cycle.

Low temperatures early and late in the year create particularly serious problems for rice-rice double cropping. In order not to miss the most appropriate planting period for the second crop in August, the first (dry-season) crop must be planted as early as mid-February. However, minimum air temperatures between 8°C and 16°C during crop establishment in February and March can delay maturity by up to 60 days, increasing the use of precious irrigation water and exposing the crop to further pest and disease attack. Delayed maturity means that the second crop is often planted late and thus suffers from low-temperature stress during the key phases of grain formation.

In the past, WARDA has emphasized the selection of short-duration rice germplasm for double cropping in the Sahel. Success has been limited by the strong year-to-year variation in dry-season conditions and by variability in crop duration that could not be explained by air temperatures and planting date alone.

In a new approach integrating crop physiology and ecology with breeding, WARDA's Sahel Irrigated Rice Program is seeking to develop rice varieties with a more predictable and constant duration under variable thermal conditions. Research was initiated in 1991 to determine the physiological and ecological basis of varietal crop duration in the Sahel. Designed to have an immediate impact on WARDA's germplasm improvement for the Sahel, this study is also part of a comprehensive, agro-ecological characterization project of the region's irrigated rice ecosystems.

Field Experimentation and Simulation

To characterize the effects of genotype x weather interactions on crop duration, an approach combining experimentation and modeling was chosen. On the basis of micro- and macro-meteorological data and observations on crop ontogeny, the duration from sowing to flowering and from flowering to maturity were related to the cumulative heat units received by the crop. This well-established technique was refined on the assumption that the development of the rice plant to the flowering stage depends on:

- temperature in a linear fashion only within a certain range given by the base (minimum) and optimum temperatures for a genotype
- the immediate thermal environment of the apical growing point

The immediate environment of the growing point for most of the season is the floodwater. Since it was impossible to observe the temperature of this continuously for all varieties, sites and planting dates, a model was developed to simulate water temperature as a function of weather parameters and the leaf canopy.

Experimental Procedures and Germplasm

To analyse the effects of weather and planting date on crop duration and yield, an experimental scheme similar to the rice garden concept developed by the International Rice Research Institute (IRRI) was set up in December 1990 at WARDA's N'diaye and Fanaye sites in Senegal. The varieties Jaya, I Kong Pao (IKP), IR 64, IR 3941-86-2-2-1 (IR 3941), ECIA 125-F4-9 (ECIA) and KH 998 were transplanted from a nearby seedbed in a monthly rhythm into a randomized, strip-plot, rice-rice double cropping scheme with two replications. The varieties were chosen on the basis of their performance in previous germplasm evaluation trials at Fanaye. Jaya (medium duration) and IKP (short duration) served as local checks; IR 64 served as a well-characterized international check. IR 3941 (short duration), ECIA (medium duration) and KH 998 (medium to short duration) were the WARDA selections for the hot dry and cold dry seasons, respectively.

A floodwater level of 0.05 m was maintained throughout the season until 2 weeks after flowering. Each plot received a basal fertilizer application of 150 kg N/ha as urea (applied as triple split), 60 kg KCl/ha and 60 kg P/ha as single superphosphate. Insect pests, spider mites and nematodes were controlled chemically using recommended procedures. Weeds were controlled manually. The soil was a heavy clay (known in the region as *hollalde)* at both sites, with moderate sodic salinity at the coastal N'diaye site. Individual plot size was 28 m^2, with a yield area of 6 m^2. Plant height, tiller number and the dry matter of stems, leaves and panicles were recorded monthly. Crop ontogeny was characterized by germination, heading stage, 50% flowering and maturity.

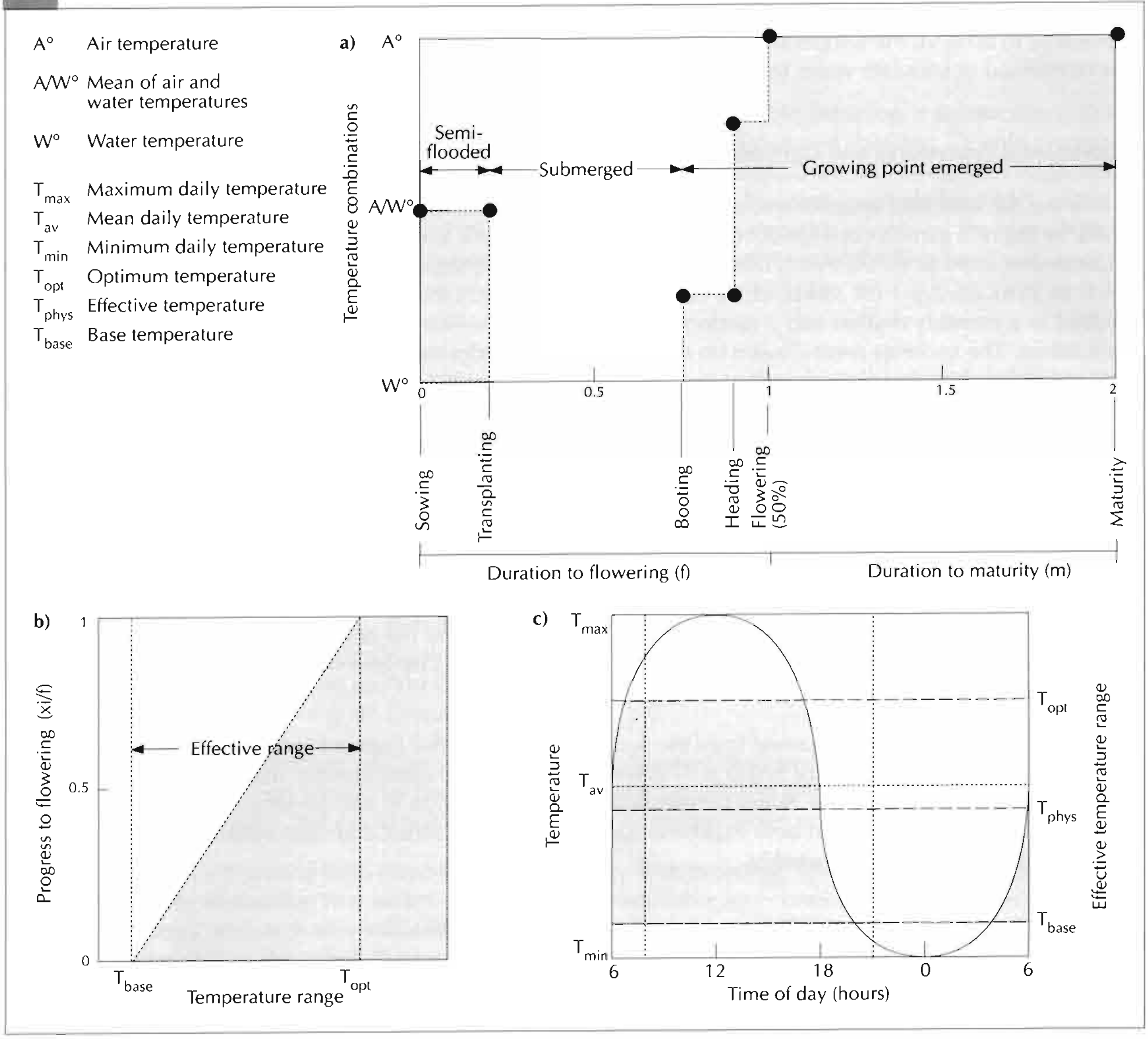
Daily weather records were obtained from the weather stations of the Institut Sénégalais de Recherches Agricoles (ISRA) at Fanaye and of SAED at N'diaye, adjacent to the experimental sites. Solar radiation, soil temperature at a depth of 0.1 m, water temperature at a depth of 0.04 m and air temperature at 2 m above ground were recorded hourly at both experimental sites. Leaf area index and light transmission ratios (LTRs) of the canopy were measured weekly.

Simulation of Crop Duration

Crop duration was simulated following the concept of temperature summation, on the assumption that, for improved cultivars in the Sahel, development to flowering and maturity are controlled thermally.

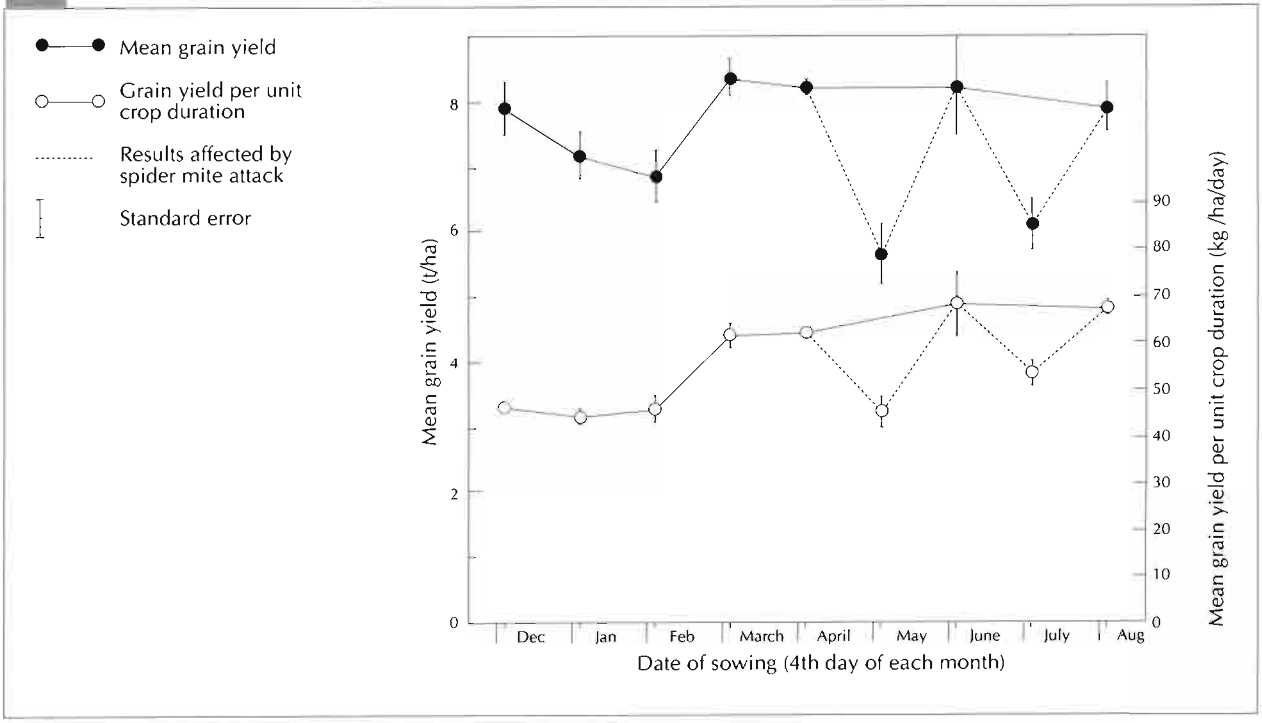
A minimum temperature (T_{base}) below which the development rate is zero, and an optimum temperature (T_{opt}) beyond which the rate remains maximal and constant, were assumed to be characteristic of a given genotype (Figure 1). Daily progress to flowering (xi/f in the figure) and to maturity (xi/m) were related to the thermal environment of the apical growing point. By definition, mean daily progress to an ontogenetic event is the reciprocal of the total duration in days.

FIGURE 1
Input parameters for temperature summation: a) combinations of air and water temperatures as functions of crop development, b) schematic effect of input temperature on progress to flowering and c) relationship between diurnal temperature extrema and input temperature



The thermal time or cumulative heat units at the growing point (T_{sum}) required for flowering was determined for each variety on the basis of nine planting dates at Fanaye and verified on the basis of six planting dates at N'diaye, which has a different (coastal) climate (Figure 2).

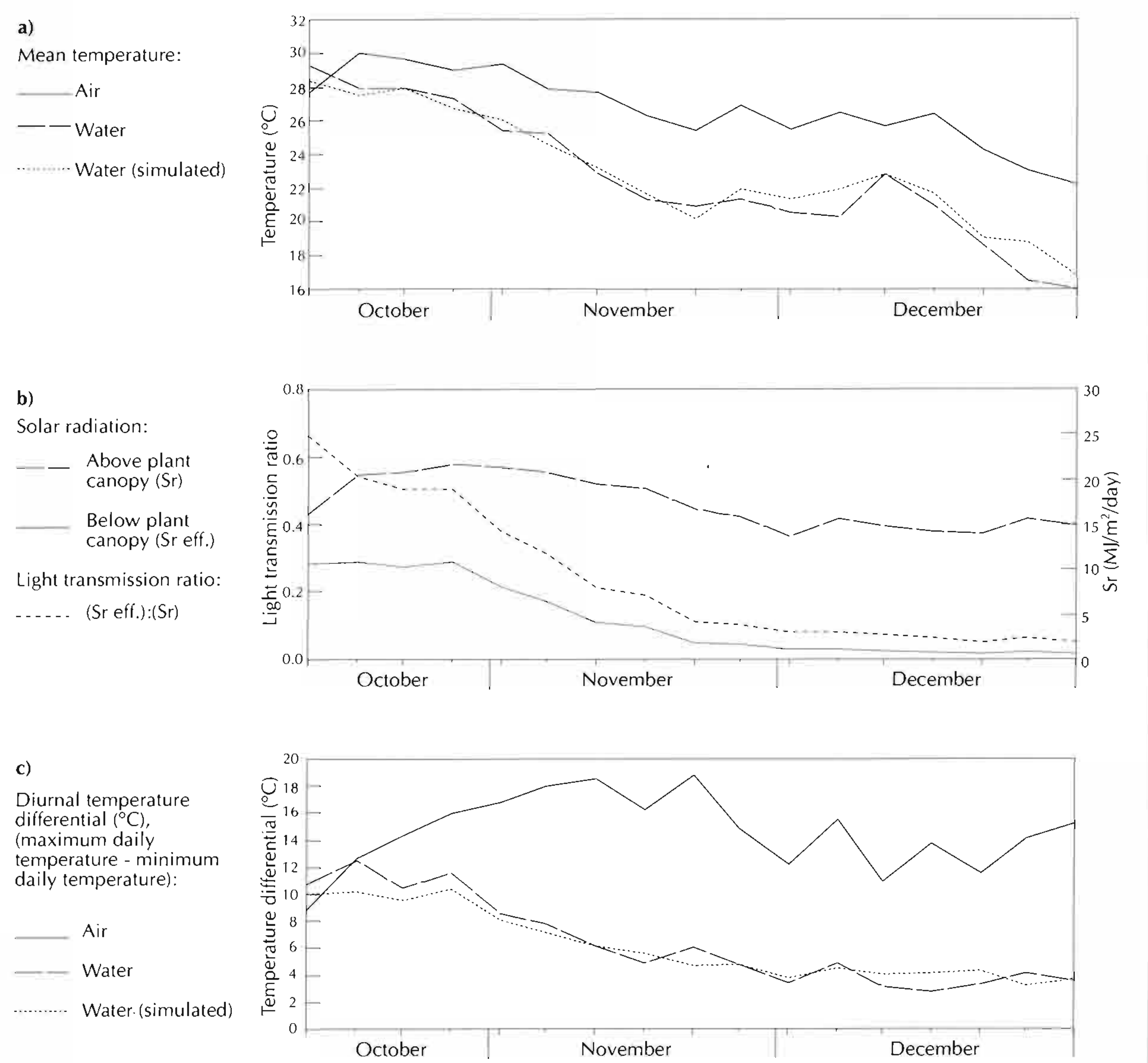
FIGURE 2
Mean grain yield and grain yield per unit crop duration of four rice varieties planted on nine dates at Fanaye, Senegal, December 1990 to August 1991



Varietal T_{sum} and T_{base} were determined by linear regression of the observed T_{sum} against duration to flowering (f). Analyses were conducted for a range of possible values for T_{opt} (20°C to 35°C, at 1°C steps). For each hypothetical value of T_{opt} and for each variety, the regressions yielded values for T_{base} and T_{sum}. Test simulations were then conducted for all resulting combinations of T_{base}, T_{sum} and T_{opt} and the resulting predictions of f were regressed against the observed f for nine planting dates. The combinations of T_{base}, T_{sum} and T_{opt} giving the best predictions were identified as the varietal constants influencing crop duration. As daily T_{max} usually exceeded T_{opt} and thus fell beyond the linear range of thermal response, daily numerical temperature means could not be used for heat summation. Instead, a daily effective temperature (T_{phys}) was calculated that ignored the segments of diurnal temperature integrals that did not fall into the physiologically responsive range (Figure 1). Night and day temperature patterns were assumed to be symmetric. T_{phys} was used for both calibrational calculations and simulations.

Model calibrations using air temperatures throughout the growth cycle yielded unreasonably high values for T_{base}, such as 17°C for Jaya. Among the observed air temperatures, only T_{min} gave significant correlations with crop duration, whereas T_{max} and T_{mean} appeared unrelated to it. This was because of exposure of the growing point to the much lower mean temperatures in the floodwater during vegetative development (Figure 3). To account for this effect, a submodel was developed to determine water temperatures as an interactive, semi-mechanistic function of minimum air temperature, relative humidity, wind speed, solar radiation and canopy LTR. The model was calibrated and verified with observed micro-meteorological data.

FIGURE 3
Five-day means of a) temperature, b) solar radiation and c) diurnal temperature, at Fanaye, Senegal, October to December 1991



For the period f from sowing to flowering, the growing point was assumed to be submerged most of the time, except in the case of the seedbed nursery, which was kept wet but not flooded. Thus, at the booting stage T_{phys} is closer to water than to air temperature. At the heading stage, on the other hand, T_{phys} is closer to air than to water temperature. For the period of maturation (m), T_{phys} is solely a function of air temperature because the panicles are well above water level.

The effect of low temperatures on the duration and yields of promising rice varieties is studied in rice garden experiments at St Louis, Senegal

The concept of T_{base}, T_{sum} and T_{opt} was tested for periods f and m but gave good results only for f (pre-flowering stages). For m, the alternative concept of Q10 = 2 (all biological processes increase by a factor of 2 when temperature increases by 10°C) was adopted on the assumption that ripening is mainly a metabolic process. This approach yielded good results if an upper limit of 28°C was set, beyond which the ripening rate was constant.

It was decided to ignore the effects of photoperiod on crop development. Due to the tropical latitude, day length varied by less than ±1 hour and the rice varieties preferred in the irrigated Sahel are without exception improved semi-dwarf varieties with low responsiveness to photoperiod.

Results and Discussion

Weather, crop duration and yield

The Fanaye site, which lies inland, has typical semi-arid, continental weather (Table 1 *overleaf*). Diurnal temperature ranges in 1991 exceeded 20°C in April and May, the hottest season of the year, while air humidity was very low. The lowest measured temperatures (10.5°C) and the highest (45.5°C) were only 2 months apart and thus were both experienced by the hot dry-season crop planted in February. The subsequent wet season (July to October) was characterized by significantly higher minimum temperatures and air humidity; diurnal temperature ranges were only 10°C to 15°C.

TABLE 1
Monthly means of 1991 weather data at WARDA's N'diaye and Fanaye sites in Senegal

Month and site	T_{min} (°C)	T_{extr} (°C)	T_{max} (°C)	T_{extr} (°C)	RH_{min} (%)	RH_{max} (%)	Wind (m/s)	Prec. (mm)	Sr (MJ/m²/d)	Ph.p. (h/d)
January										
N'diaye	16.3	(12.5)	30.5	(38.1)	39	86	2.1	1.5	16.3	11.3
Fanaye	15.9	(12.5)	29.3	(33.5)	36	77	1.3	—	15.7	11.3
February										
N'diaye	16.1	(12.0)	31.4	(36.1)	33	82	2.8	0.0	19.7	11.6
Fanaye	14.9	(10.5)	30.8	(36.5)	26	66	2.3	—	19.7	11.6
March										
N'diaye	16.9	(13.5)	32.4	(37.1)	44	96	3.2	0.0	23.3	12.0
Fanaye	16.9	(1.5)	33.9	(40.0)	27	68	2.0	—	23.6	12.0
April										
N'diaye	18.4	(15.1)	34.6	(45.1)	39	91	3.3	0.0	24.1	12.5
Fanaye	18.8	(14.0)	40.6	(45.5)	16	57	2.0	—	25.4	12.5
May										
N'diaye	18.6	(16.0)	33.0	(41.1)	43	94	3.3	0.0	22.4	12.9
Fanaye	19.7	(18.5)	40.9	(45.0)	22	73	2.0	—	26.0	12.9
June										
N'diaye	21.1	(16.0)	32.7	(43.0)	51	93	2.9	3.5	20.3	13.0
Fanaye	22.9	(19.0)	39.9	(44.5)	28	73	2.0	—	20.9	13.0
July										
N'diaye	23.2	(21.0)	32.6	(36.1)	57	97	3.1	36.8	21.3	13.0
Fanaye	24.3	(21.0)	28.4	(44.0)	42	88	2.1	—	20.1	13.0
August										
N'diaye	24.7	(22.1)	32.8	(36.1)	60	95	2.8	80.9	21.8	12.7
Fanaye	24.3	(22.5)	36.3	(38.5)	53	96	1.8	—	22.3	12.7
September										
N'diaye	25.6	(20.0)	34.0	(42.1)	61	96	2.3	84.0	20.3	12.3
Fanaye	24.4	(19.0)	35.2	(39.5)	53	92	1.6	—	20.5	12.3
October										
N'diaye	24.0	(20.0)	33.9	(40.0)	59	97	2.1	31.5	19.3	11.8
Fanaye	22.6	(15.5)	34.6	(40.0)	48	86	1.4	—	20.6	11.8
November										
N'diaye	19.9	(17.0)	33.6	(39.1)	50	96	1.8	0.0	18.3	11.4
Fanaye	18.0	(16.0)	35.6	(40.5)	32	83	1.3	—	18.8	11.4
December										
N'diaye	18.4	(14.0)	31.8	(36.1)	52	99	1.9	0.0	16.8	11.2
Fanaye	17.5	(10.5)	33.0	(36.0)	36	82	1.7	—	14.8	11.2

T_{extr} = temperature extrema; RH = relative humidity; Wind = mean daily wind speed; Prec. = precipitation; Sr = solar radiation; Ph.p. = photoperiod

By contrast, N'diaye, which is nearer the sea, has more moderate temperature extrema, higher air humidity throughout the year and stronger winds. Photoperiod was identical at both sites (11.2 hours in December, 13.0 hours in June/July). Solar radiation was more closely associated with day length than with season, indicating that cloud cover was not much greater in the wet season than in the dry season. This explains why yields were not lower in the wet season than in the dry season (Figure 2), as they tend to be in the humid tropics.

Irrigated rice is usually planted in February/March (hot dry season) and/or July/August (main wet season), although farmers' actual planting calendars are variable. At Fanaye, six varieties (Table 2) were planted on nine consecutive dates in both seasons. Mean grain yields of the four best-performing varieties — Jaya, IKP (local checks), IR 64 and IR 3941 — were constant at 8 t/ha for the March to August planting dates (Figure 2). Failure to control spider mite, however, led to high yield losses in May and July. Grain yields per unit of crop duration ranged from 60 kg/ha to 70 kg/ha if the crop was sown after February, but yields fell by 50% for crops sown from December to February. The dry-season crop experienced the hottest period of the year during the late vegetative or reproductive growth stages, which was probably responsible for the yield reductions observed. Depending on the variety, crop duration ranged between 105 and 125 days for the wet-season crop. It increased gradually to 150-190 days with earlier sowing date, due to low temperatures. Crop duration was slightly longer at N'diaye than at Fanaye.

TABLE 2
Physiological constraints influencing progress to flowering as determined for six cultivars grown at WARDA's Fanaye site in 1990-91

Variety	Type	Origin	T_{opt}	T_{base}	T_{sum}	r
Jaya	impr. *indica*	India	24	14.5	877	0.97
I Kong Pao	impr. *japonica*	Taiwan	24	13.4	878	0.99
IR 64	impr. *indica*	Philippines	24	11.8	1023	0.97
IR 3941	impr. *indica*	Philippines	23	11.7	909	0.99
KH 998	impr. *indica*		23	14.5	750	0.98
ECIA	impr. *indica*	Cuba	24	15.4	755	0.97

T_{opt} = optimum temperature °C; T_{base} = base temperature °C; T_{sum} = thermal time required for flowering (degree-days); r = regression coefficient across nine planting dates

Specific effects of micro-climate on crop duration

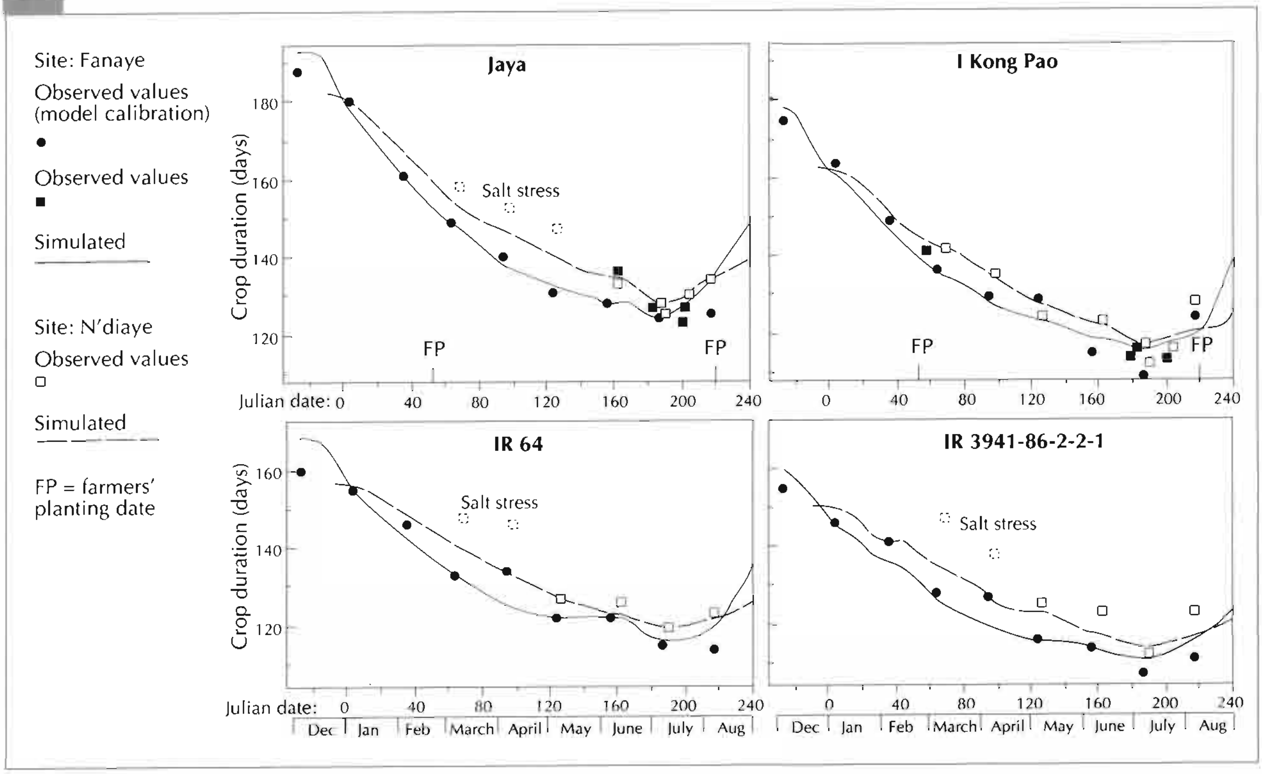
Regression analyses of cumulative mean air temperatures for the period from sowing to flowering against duration f gave no significant correlations, although this method of determining the genotype base temperature (T_{base}) has yielded good results elsewhere. Based on the concept of an upper limit of developmental responsiveness to temperature (T_{opt}), highly significant correlations were obtained between cumulative heat units and duration ($P<0.01$) for each of the six test varieties. However, the resulting values for T_{base} were between 15°C and 18°C, too high for the rice species. Instead, excellent regressions and realistic values of 9°C and 14°C for T_{base} were obtained when temperature summation was performed with minimum air temperatures. Although this method may provide good predictions of crop duration, it is questionable from a physiological point of view and applicable only to specific environments. It is commonly known that the thermal sensitivity of crop development does not depend on the time of day.

T_{base} was overestimated using mean air temperatures because of the deviating thermal conditions near the growing point. During much of the irrigated rice plant's development, the apical growing point is submerged. Mean water temperatures were 2°C to 8°C lower than those of the air at a height of 2 m once plant canopy was established (Figure 3). The amplitude of diurnal thermal variation in the water was less than a quarter of that observed in the air. However, before a dense canopy was established, temperatures in the water and the air were similar, except when dry winds cooled the water through increased evaporation.

Micro-climate-derived constants determining crop duration

To predict water temperature from weather data, a regression model was developed that reflected single and interactive effects of the LTR of the canopy, air humidity, temperature extrema, wind speed and solar radiation. Applying this model to the growth phases when the growing point was submerged gave varietal values of 11.7°C to 15.4°C for T_{base}, 23°C to 24°C for T_{opt} and 750 to 1023 degree-days for T_{sum} (Table 2). These values roughly agree with published results and proved satisfactorily predictive of seasonal crop duration at Fanaye (the site of model calibration) and N'diaye (the site of validation) (Figure 4).

FIGURE 4
Observed and simulated crop duration of four rice varieties planted at various dates at Fanaye and N'diaye, Senegal, 1991



Although T_{opt} in rice has sometimes been estimated at about 30°C (the CERES rice model sets it at 32°C), most published observations and WARDA's study indicate values of about 24°C. The six varieties investigated in the WARDA study differed more in T_{base} than in T_{opt}. Considerable genetic diversity, particularly of the T_{base} value, would improve the prospects of developing rice germplasm with a more constant growth duration under variable thermal conditions. However, broader validation of the present findings is needed to allow extrapolation to other Sahelian sites.

Interactions between the weather, the micro-climate under the leaf canopy and the rice plant's crop duration are pronounced in the Sahel. The longer crop duration at the N'diaye site compared to Fanaye (Figure 4) could not be predicted with air temperatures alone because it was caused by the stronger winds and slightly lower solar radiation, which produced colder water during the hot dry season. The model developed satisfactorily explained such effects. Such micro-climatic effects are not necessarily specific to the Sahel region.

Other factors influencing crop duration

The analysis of these results ignored non-temperature-related effects on crop duration. The exclusion of photoperiodism was justified given the latitudes of the Sahel region (a maximum of 16°N), but this would not be so for some other arid rice ecosystems.

Physiological stresses are known to delay development to flowering and to enhance ripening. Irrigated rice in the Sahel frequently experiences water stress caused by root chilling and dry winds. This stress effect is currently under investigation.

Direct-seeded rice crops mature 1 to 2 weeks earlier than transplanted crops, due to the absence of transplanting shock caused mainly by root injury and subsequent water stress. Good simulations of the duration of direct-seeded crops were achieved by subtracting 100 thermal time units from the varietal constant T_{sum}.

Improved nutrition (particularly N) can delay maturity by a few days. However, border plants (usually better nourished as they face less competition from other plants) often mature earlier than do center-plot plants. Such effects might be due to varying LTR of the canopy and thus to water temperature differentials, not necessarily to nutrition. WARDA's models accurately predicted crop duration differences of 3 days in the dry season and 1 day in the wet season for dense and thin canopies, with dense canopies maturing later. This indicates that heterogeneous maturation in the field is at least partly due to micro-climate.

Plot-to-plot variation in the maturation of given genotypes was much greater at N'diaye than at Fanaye. Plants showing salt stress symptoms matured later than the model predicted (Figure 4). Studies are under way to investigate the specific effects of the salinity and micro-climatic differences found at the N'diaye site.

Application of Results

This study has introduced two new elements to the analysis of rice crop duration: the recognition of micro-climatic effects and the varietal quantification of upper, thermal response limits for crop development. Both elements are particularly important in the Sahel, where irrigated fields are exposed to extreme evaporation and daily temperature oscillations frequently exceed the biologically effective range. The models resulting from the study are of considerable practical value for characterizing the Sahel environment, guiding rice breeding activities and developing optimal cropping calendars.

Characterization of Sahelian rice ecosystems

WARDA's Irrigated Rice Program is currently carrying out a multidisciplinary, collaborative study on the yield gap for the Sahel. Simulations of varietal crop duration and yield potential as limited by N deficiencies and climatic constraints will be conducted for all the major rice producing areas of the Sahel. The results will be compared with actual grain production levels. Climatic constraints are of primary importance in Sahelian rice ecosystems and account for a large part of the agro-ecological diversity of these ecosystems. The present study provides a point of entry into the complexity of genotype x environment interactions, which appear to be strongly linked to micro-climate. A diagnostic network consisting of WARDA and national staff and covering key ecosystems in the Sahel will be established in 1992 to further characterize these interactions.

Breeding

The development of germplasm with short and stable duration under Sahelian conditions requires a good understanding of the underlying mechanisms responsible for these traits. Certain values for T_{base}, T_{opt} and T_{sum} will indicate plant types with desirable responses to given climatic and seasonal conditions. WARDA scientists are currently characterizing 55 varieties for their thermal constants in a simplified rice garden scheme. Diallel crosses and the analysis of the varieties' parentage will provide information on the genetics of the traits. An analysis of the diversity of genotypic constants will suggest how to breed for desirable thermal-response types.

In the past, varieties were classified as short- or long-duration types without regard to the thermal variability of their cycle. Selection from advanced nurseries will in future also target the stability of crop duration as indicated by low T_{base} and a large difference between T_{base} and T_{opt}, as well as a low value for T_{sum} (necessary to achieve short duration in absolute terms). From 1992, varieties emerging from WARDA's breeding program for the Sahel will be characterized according to their response patterns to temperature.

Optimization of cropping calendars

In order to develop optimal rice-rice double cropping calendars, it is necessary to know to what extent crop duration is dependent on planting date, variety and site climate. This information can be obtained with the models developed under the project. Other determinants of cropping calendars are the availability of irrigation water, labor and other inputs, the time required for field operations, seasonal patterns of pest attack, disease and management problems, and the grain yield that can be expected for a particular planting date and variety.

WARDA's Irrigated Rice Program and scientists of ISRA, SAED, the Centre de Coopération Internationale en Recherche Agronomique pour le Développement (CIRAD) and the Center for Agrobiological Research (CABO) are jointly working on a package of models that sequentially simulate seasonal and varietal crop duration, the speed with which grain and soil dry out during and after crop maturation and the duration of the subsequent crop. The moisture content of the maturing grain is important in deciding on the timing of harvest and the rate of soil drying determines the earliest possible time for mechanized field operations. The decision support system resulting from this work will take into account the probability of local weather events and will be tested in collaboration with farmers of the Senegal river delta. The modeling studies will be complemented by socio-economic studies to ensure that the calendars recommended are acceptable to Sahelian rice farmers.

1.2 ADOPTION AND ECONOMIC IMPACT OF IMPROVED MANGROVE SWAMP RICE VARIETIES IN WEST AFRICA

Akinwumi A. Adesina and Moses M. Zinnah

Background

During the 1990-91 cropping season, WARDA conducted a study in Guinea and Sierra Leone to determine the adoption of improved rice varieties, assess the factors influencing it and estimate its economic impact. The major mangrove rice growing areas in the two countries were surveyed over a 6-month period from November 1990 to April 1991.

Methodology

In Guinea, five main mangrove rice growing districts in the Coyah region — Ballayah, Doneya, Kouyeya, Wonkifong-Central and Toguiron — were selected as study sites. These districts together have a total human population of about 6000. They also contain villages in which WARDA had tested some elite mangrove swamp rice varieties in adaptive on-farm trials during the late 1980s.

The climate of the Coyah region is humid tropical, with two distinct wet and dry seasons. The wet season starts in late April and continues until mid-November. Total annual rainfall is about 3800 mm. Vegetation is mainly secondary forest, with palm trees along the coast and mangrove trees along the tidal river banks. Studies in the Coyah region were carried out in collaboration with the Centre Canadien d'Etudes et de Coopération Internationale (CECI), which has a development project involving mangrove swamp rice farmers in the region.

The Great Scarcies region, which is located in Kambia District, Sierra Leone, was also selected for the adoption study. This is the country's major mangrove swamp rice growing area, and the home of the national Rice Research Station at Rokupr. A bilateral German/Sierra Leonean Seed Multiplication Project is also located in the study area. Three important mangrove swamp rice growing 'chiefdoms' in the Great Scarcies region — Magbema, Mambolo and Samu — were selected as study sites. The total human population of these chiefdoms is estimated at nearly 100 000. This region experiences a tropical savanna climate with distinct wet and dry seasons. The rainy season starts in May, reaches its peak in August and ends in November; the mean annual rainfall is about 3000 mm.

The study was conducted in two major phases. Phase 1 consisted of a 2-month preliminary survey of the study areas. Farmers were interviewed, individually and in groups, to collect information on their rice production techniques, cropping patterns and calendar of farm operations; during these interviews, information was also gathered on the local and improved varieties grown by farmers. Particular attention was paid to the adoption of improved mangrove swamp rice varieties. Care was taken to identify the varieties accurately by collecting panicle samples for verification by specialists at Rokupr. The preliminary survey revealed that some of the improved mangrove swamp rice varieties released by WARDA and the Rice Research Station had lost the names originally given them by their breeders as they were distributed from one farmer to another.

The villages and towns in the two study areas were then listed. From the list, a stratified random sample of 80 villages in each area was selected. The criteria used to narrow down this initial selection included:

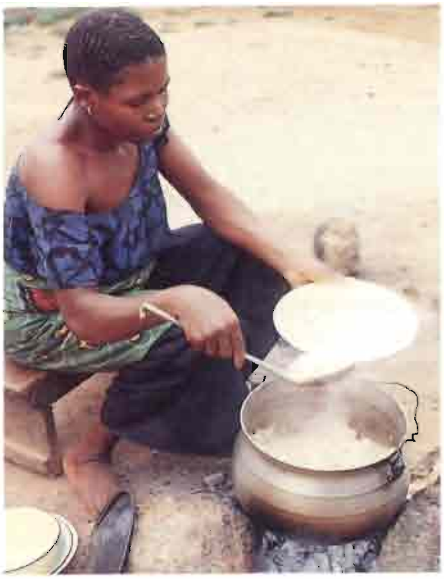
- the need to obtain a balance between villages in which WARDA had previously conducted adaptive on-farm trials and those in which it had not
- the need to represent variation in the length of the salt-free growing period (from less than 4 months to more than 6 months)

Eight sample villages in each study area were selected. All households in these villages were listed, together with information on ownership of mangrove swamp rice fields. A proportional sample of household heads was randomly selected from each village, giving 234 respondents (110 in Guinea, 124 in Sierra Leone).

Phase 2 consisted of a field survey. Three questionnaires were used, directed at farmers, researchers and extension agents. The questionnaire for farmers was designed to collect a broad range of information, including demographic/household data, farm and off-farm employment, cropping technology and practices, other crops grown besides rice, participation in training/demonstration programs, links with researchers and extension agents and membership and active participation in community organizations. Data were also collected on the preferences of farmers for a range of varietal characteristics that determine adoption, including tillering and yield, ease of threshing, ease of cooking, and taste.

Adoption

Farmers were asked to rank the 10 most important mangrove swamp rice cultivars that they grew. Three modern varieties, ROK 10, ROK 5 and Kuatik Kundur, were ranked high by farmers in Sierra Leone. Based on the frequency with which farmers cultivate these varieties, ROK 5 ranked third, while ROK 10 and Kuatik Kundur ranked fifth and seventh, respectively. In Guinea, ROK 5 was the only modern variety widely cultivated. It was ranked fifth by farmers.

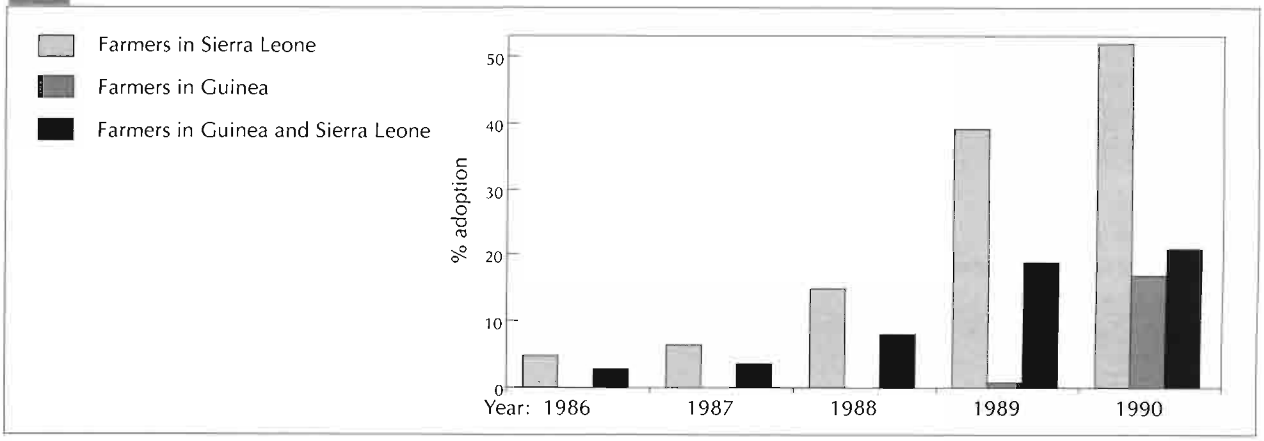


Farmers growing rice for home consumption select varieties which meet their taste and cooking preferences

ROK 5 is a medium-duration variety resulting from a cross between SR 26 and Pa Wellington. It was among the first sets of crosses made by the national scientists at Rokupr Research Station in the early 1960s. ROK 10 (Nachin 11 x Gantang) also originated from the crosses made in the early 1960s. Both varieties were released to farmers in 1978. Kuatik Kundur is a traditional rice variety introduced from Indonesia in 1977. After improvements by WARDA this medium-duration variety was recommended to national programs in 1982. All three varieties were largely unknown to farmers in Sierra Leone until they were popularized by WARDA through trials conducted in Sierra Leone and Guinea from 1981 onwards.

Adoption rates for both countries are shown in Figure 5. In Sierra Leone the number of farmers adopting at least one improved variety increased from 5% in 1986 to 39% and 52% in 1989 and 1990, respectively. In Guinea, adoption of the new varieties is a more recent phenomenon, starting with 1% of farmers in 1989. By 1990, ROK 5 was being grown by 17% of farmers, while ROK 10 and Kuatik Kundur had been adopted by 15% and 9% of sample farmers, respectively, in both countries combined.

FIGURE 5
Percentage of rice farmers who adopted at least one improved rice variety at study sites in Guinea and Sierra Leone, 1986-90

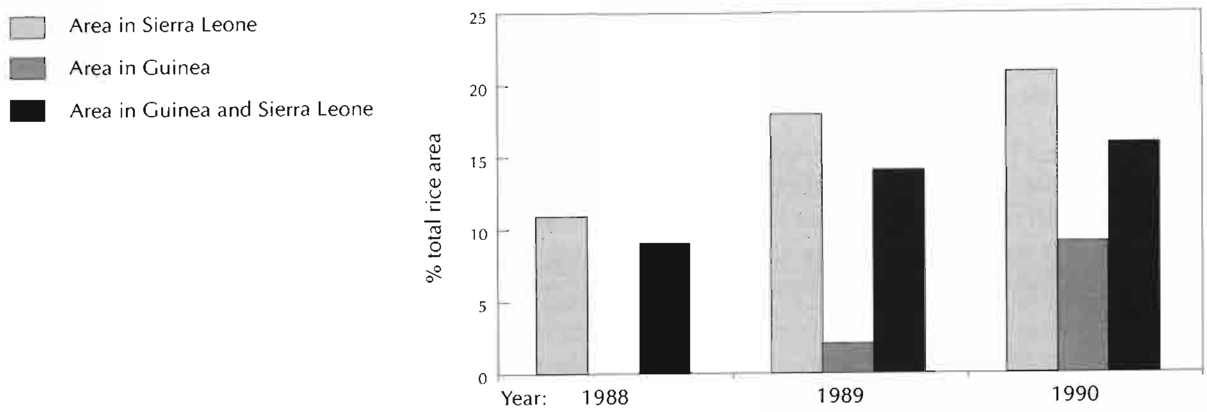


To determine the intensity of adoption, the percentage of the area planted with modern varieties out of the total area planted to mangrove swamp rice was estimated. In Sierra Leone this share grew from 11% in 1988 to 21% in 1990. In Guinea, it increased from 2% in 1989 to 9% in 1990 (Figure 6 *overleaf*).

About 90% of the farmers in Sierra Leone who did not grow any improved varieties during the 1990-91 cropping season cited lack of seed as the single most important constraint to adoption. In Guinea, 30% of the farmers cited this factor as the major constraint. The delayed adoption of the improved varieties observed in Guinea is due partly to the varietal development work having been done in Sierra Leone. Dissemination across national frontiers takes longer than dissemination within the country in which a technology is generated.

A majority of farmers in both countries said that they relied neither on the extension service nor on research centers for information on new rice varieties. Only 2% and 6% of farmers in Guinea and Sierra Leone,

FIGURE 6
Percentage of total rice area sown to improved rice varieties at study sites in Guinea and Sierra Leone, 1988-90



respectively, had been visited by extension agents during 1989 or 1990; and only 5% of the respondents in Guinea and 4% of those in Sierra Leone had attended any research field days over the 5-year period between 1986 and 1990. Neighboring farmers and family members were the major sources of technical information (Table 3).

TABLE 3
Major sources of information on improved mangrove swamp rice varieties in Sierra Leone and Guinea

Source of information	% of farmers receiving information Sierra Leone	Guinea
Neighboring farmers	58	50
Family members	33	44

Factors Influencing Adoption

Why are these varieties becoming popular with farmers in spite of the limited role of extension services and research stations? Perhaps farmers simply find them superior. To test this hypothesis, a TOBIT model was used to perform an econometric analysis of the pooled data from Guinea and Sierra Leone. The analysis revealed that factors specific to farms and farmers, such as age of farmer, farm size and participation in on-farm tests, did not account for adoption (Table 4), although they are often identified in the literature as important. Farmers' perceptions of the superiority of these elite rice varieties were the major factor determining adoption. The most important advantages they perceived were ease of cooking, threshing quality, tillering capacity and yield.

TABLE 4
TOBIT model estimates of the determinants of adoption of improved mangrove swamp rice varieties in Guinea and Sierra Leone, 1990-91

Explanatory variables	Parameter coefficient	Asymptotic standard error
Farm- and farmer-specific factors[1]		
Age of farmer	-0.0042	0.0092
Farm size	0.028	0.092
Participation in on-farm tests	-0.038	0.280
Years of experience in rice farming	0.0107	0.0087
Contact with extension agents	0.030	0.040
Intercept	-1.25	0.40**
Farmer perception of varietal trait		
Tillering	0.70	0.25**
Ease of cooking	1.27	0.28**
Ease of threshing	0.85	0.28**
Yield	0.84	0.24**
Taste	-0.15	0.28

1 Listed in order of importance
** $P < 0.01$

Tillering was seen as especially important, because of the high levels of destruction caused by crabs in the mangrove environment. High tillering is also related to grain yield, since the number of tillers and panicles produced are positively correlated. Ease of threshing was also seen as important, since this is a highly labor-intensive task.

As a result of the depletion of the mangrove forests, women and children often have to travel long distances in search of the fuelwood required for cooking. Rice varieties that cook quickly (a trait that is directly linked to the percentage amylose content in the rice grain) were regarded as a means of economizing on fuel.

Future changes in the probability of adoption and in adoption intensity

Elasticities were computed from the TOBIT model to estimate the probable percentage changes in the number of farmers adopting and in the percentage of the rice area cultivated (adoption intensity) arising from 10% changes in the traits of the varieties as perceived by farmers (Table 5 *overleaf*). Improving the ease of cooking would probably have the greatest effect. A 10% improvement in this trait would increase the probability of adoption by 6%, while the adoption intensity could be expected to rise by 5%. An improvement of 10% in the ease of threshing is likely to result in a 4% increase in adoption and a 3% increase in adoption intensity. Increasing yields by 10% would probably increase both adoption and adoption intensity by 2%.

TABLE 5
Elasticities of the probability of adoption and the expected intensity of adoption of new rice varieties in Guinea and Sierra Leone, 1990-91

	Elasticity[1]	
Varietal traits	Probability of adoption	Expected adoption intensity
Ease of cooking	0.64	0.50
Ease of threshing	0.35	0.27
Yield	0.30	0.23
Tillering	0.24	0.27

1 Elasticities are computed at the means

These results provide valuable guidelines for breeders in determining breeding objectives. They strongly suggest that breeding programs should focus on the qualitative traits of improved varieties. Farmers commonly reject varieties not because of poor yields but because of poor grain quality and difficulties with threshing. Sturdy stems and the production of many tillers also appear to be important.

Economic Impact

The economic impact of adoption at farm level was also assessed (Table 6). The percentage of income from mangrove rice that was derived from improved varieties rose substantially, but to varying degrees in the two countries. In Sierra Leone it increased from 6% in 1986 to 28% in 1990; in Guinea it increased from 3% in 1989 to 13% in 1990. Extrapolated to the eight villages surveyed in each country, the results

TABLE 6
Regional economic impact of the adoption of improved rice varieties in Guinea and Sierra Leone, 1990-91

Economic factors	1986	1987	1988	1989	1990	Total
Value of increased production (US $ millions)						
Guinea	—	—	—	0.06	0.3	0.36
Sierra Leone	0.92	1.2	2.5	4.2	4.9	13.7
Share of rice income from improved varieties (%)						
Guinea	0	0	0	3	13	
Sierra Leone	6	7	16	25	28	

indicated that the cumulative benefits from 1986 to 1990 amounted to US $487 000 in Sierra Leone and US $115 000 in Guinea.

Based on the number of agricultural households estimated to be growing mangrove rice in the two study areas, the cumulative farm-level gross benefits of the modern varieties in the Great Scarcies region of Sierra Leone from 1986 to 1990 were estimated to be about US $13.7 million. In the Coyah region of Guinea, due to delayed adoption, the cumulative economic impact was estimated to be only US $0.36 million, a figure which can nonetheless be expected to rise rapidly in the coming years.

Conclusion

Farmers' perceptions of agricultural technologies are crucial inputs in the setting of research priorities. The identification and incorporation of varietal traits that meet farmers' preferences can be expected to encourage broader and more rapid adoption of new technologies. WARDA strongly believes that the participation of farmers in the early stages of technology development is critical for the successful introduction of new rice varieties in West Africa. This study validates that belief.

1.3 INTERNATIONAL COOPERATION IN RESEARCH ON RICE BLAST

Abdoul Aziz Sy

Background

Rice blast, caused by the pathogen *Pyricularia oryzae*, is universally recognized as the principal disease affecting high yielding rice varieties. First described in China in 1673, it is important because of its widespread distribution, its impact on yield and the genetic variability of the pathogen. Estimates of yield losses resulting from blast attack in Africa over the past 20 years range from 3-15% in Sierra Leone to 64% in Togo. In the West African region, rice blast is now considered the major constraint to rice production.

Research efforts to control blast have focused on plant resistance, improved agronomic practices and chemical control. Although this has produced some promising results, the lack of durability of released varieties raises doubts about the approaches used to develop blast control measures — the restriction of the genetic base of plant germplasm, the use of fungicides with a fairly limited spectrum of action, the evaluation of germplasm under non-representative selection pressure (in terms of the level of pressure and/or the genetic diversity of rice blast) and the under-estimation of the role of biotic environmental factors.

Collaborative Research on Characterizing *Pyricularia oryzae* Populations

At a meeting hosted by the International Rice Research Institute (IRRI) in the Philippines in January 1991, scientists from WARDA, IRRI and the Centro Internacional de Agricultura Tropical (CIAT) developed a collaborative strategy to generate rice varieties with durable resistance to rice blast. The strategy is based on characterizing *P. oryzae* populations in five representative upland sites: Goiania, Brazil; Santa Rosa, Colombia; Sitiung, Indonesia; Cavinte, the Philippines; and Bouaké, Côte d'Ivoire. Institutions collaborating with the three international agricultural research centers include the Centro Nacional Pesquisa Arroz e Feijao (CNPAF) in Brazil, the Sukarami Agricultural Research Institute for Food (SARIF) in Indonesia and Washington State University, USA.

Collaborative work began in 1991. The main objectives of the first year's activities were:

- to assess the genetic diversity of *P. oryzae* populations in the five upland sites through restriction fragment length polymorphism (RFLP) analysis
- to analyse the degree of inter-fertility of different *P. oryzae* strains (special emphasis is being placed on this objective; research in this area dates back only to the 1970s, and in order to identify the mechanisms governing the breakdown of resistance in blast-resistant cultivars more information is needed on the multiplicity of physiological strains of the pathogen)
- to define the virulence and aggressiveness patterns of 1200 isolates of *P. oryzae* in relation to a series of varieties with well-known resistance profiles
- to establish the relationship between virulence patterns and molecular phenotypes of *P. oryzae* in five target environments
- to assess the diversity of experimental sites in terms of relative effectiveness (ability to distinguish cultivars subjected to the selection pressure of a differentiated *P. oryzae* population in a given ecosystem)

A better understanding of field populations of *P. oryzae* at the molecular level will enhance the ability to predict blast epidemics and to identify the most suitable cultivars for specific ecological niches. However, the limited information available on the biology and genetic diversity of *P. oryzae* populations means that it is difficult to select experimental sites which are representative of blast selection pressure.

Progress in 1991

The trials established at M'bé in 1991 involved 20 test entries, laid out according to the Marchetti experimental design, with four replications. Three spreader lines were used: Ishikari Shroke (50%), CNA 67-96 (25%) and CNA 63-83 (25%). Parasite incidence on the host was measured in terms of leaf area affected, using the Castano and Zaini 5-level scale (1 = 1%, 3 = 5%, 5 = 10%, 7 = 25%, 9 > 50%). Observations were made twice weekly for 3 weeks, starting from the appearance of the first symptoms. Samples from the test entries in each of the four replications, as well as samples from the spreader lines and from the breeders' plots, were sent to the Plant Pathology Department, Washington State University for analysis of virulence patterns and molecular phenotypes.

All the data from the five sites were provided to the IRRI collaborator. Although the analyses of these data have not yet been completed, several observations can be made. In the trial conducted by WARDA, the severity of rice blast ranged from 1% (IRAT 216) to 38% (Kinandang Patong). In BR 21, KU 115, Danau Laut Tawar, IRAT 13, IRAT 104, Moroberekan, IAC 165 and HD 14, severity ranged from 1% to 2%, while in CO 39 and Yamada Baki the severity was 24% and 20%, respectively. At a later stage, stability analyses of the data from all five international sites will be conducted, using the Eberhart and Russel model. Each site will be characterized by its environmental index as well as by the 20 rice varieties used, according to their average performance and stability parameters.

Rice blast is a major cause of yield losses in Africa

At the international level, the RFLP characterization revealed the existence of 20 different profiles for the Philippines site. The fertility of isolates from the upland sites was estimated to be 42% in the Philippines, 12% in Indonesia and 7% in Colombia. For the first time, two isolates from the same field were found to be compatible, producing viable ascospores. These data will be supplemented by information from the Côte d'Ivoire site, where the trial began later than at other sites because of the cultivation calendar.

Work Plan for 1992

In August 1991 a meeting was held in Colombia between WARDA and CIAT scientists to evaluate progress. The following collaborative activities were identified for implementation in 1992:

- *WARDA/Washington State University:* WARDA will send lyophilized DNA samples of leaves originating from different ecological niches in West Africa to Washington State University for molecular analysis, with a duplicate set sent to IRRI
- *WARDA/CIAT*: WARDA will assess different breeding lines developed by CIAT from the CIAT recurrent selection program (double haploid lines and lines showing high resistance to blast at the Colombia site) by subjecting them to the *P. oryzae* populations prevalent at key West African sites
- *WARDA/IRRI*: WARDA will conduct inheritance studies of progenies from the Moroberekan x CO 39 cross provided by IRRI

A meeting will be held at WARDA in 1992 to review progress and plan activities for the following year.

Future Collaborative Research on Rice Blast

Current research will provide information crucial to the development of effective blast control methods. Analysis of the association of alleles with multiple DNA loci will reveal whether *P. oryzae* populations are of a clone type or whether intensive exchanges or frequent recombinations have occurred. This will give further insight into the level of polymorphism and the potential variation of pathogenic populations.

If highly fertile strains of the pathogen are identified at screening sites, these could be manipulated to increase the genetic diversity of pathogen populations, improving screening efficiency and reliability. Also, if correlation between the virulence pattern and RFLP maps is established, this could lead to the use of DNA probes for epidemiological purposes, providing easier and more rational tagging and coding of *P. oryzae* physiological races. More accurate mapping of differentiated ecological niches could then be undertaken in terms of the structure and dynamics of *P. oryzae* populations. The results of this study will also facilitate the selection of sites for screening, which will be based on a systematic comparison of *P. oryzae* populations. Sites characterized by more diversified and aggressive populations should be given priority.

It is clear from the nature of this global research effort that scientists in West Africa's national programs will soon need to be fully involved in the work. National pathologists will play key roles in prospecting and mapping the pathogenic populations across the region, in sampling pathogens at key sites and in establishing the nature of host x parasite interactions.

1.4 SCREENING UPLAND RICE GERMPLASM UNDER LOW- AND HIGH-INPUT SYSTEMS

Monty P. Jones and Akinwumi A. Adesina

Background

Upland rice accounts for about 44% of West Africa's total rice production. It is grown on about 1.3 million ha (57% of the total area under rice), primarily in Côte d'Ivoire, Guinea, Liberia, Nigeria and Sierra Leone. Over 70% of the region's peasant farmers grow upland rice as a subsistence crop. Yields vary considerably from year to year, with averages ranging from 0.5 t/ha to 8.0 t/ha. Slightly higher yields are obtained in areas where soil, rainfall and management conditions are more favorable, particularly irrigated lands, hydro-morphic areas and lands bordering inland valleys. In the low-input slash-and-burn fallow rotation systems common in the region, rice is often the only crop, with the result that in many areas the soils are deficient in nitrogen and phosphorus or have a high aluminum and manganese content.

Breeding Improved Rice Varieties

Efforts to solve these problems through breeding improved upland rice varieties have been undertaken by various international and national agricultural research organizations. Over the past 20 years, for example, the International Institute of Tropical Agriculture (IITA) and the Institut de Recherches Agronomiques Tropicales et des Cultures Vivrières (IRAT) have developed early maturing (100-120 days), medium height (110-120 cm) varieties which produce reasonably high yields (3.5 t/ha) under improved management practices. Surveys conducted among farmers, however, have indicated that, despite the release of these improved materials, traditional cultivars remain the most common upland rice varieties in West Africa, occupying about 60% of the upland rice area.

Traditional African rice varieties are generally well adapted to the major stresses found in upland areas, such as drought, blast and panicle diseases. They tend to be 130 cm or taller, with long, bright or dark green leaves, long and well-exserted panicles, and thick roots. Under high levels of fertilizer application, plant height increases and severe lodging occurs because of the weak stems.

Selections from traditional varieties have produced moderately high yields in farmers' fields. Research conducted by WARDA scientists in Liberia in the early 1980s showed that, under low-input rainfed conditions, the performance of introduced varieties, particularly those from Asia, was generally inferior to that of traditional varieties. For example, no introduced varieties were found to be superior to LAC 23, a selection made from a local *Oryza sativa* population. The same pattern has been observed in Nigeria and Sierra Leone, where traditional varieties such as OS 6, ROK 3 and ROK 16 continue to rank high in yield trials and are still being grown extensively by small-scale farmers. In general, most currently recommended varieties and those popular among West African farmers have been derived primarily from selections among African varieties or from hybridization between African and exotic varieties.

Trials conducted at IRAT, WARDA and IITA and by national scientists in Liberia, Nigeria and Sierra Leone have shown that, under improved management practices, several introduced varieties have a higher yield potential than that of traditional varieties, but that in unfavorable environments they are less stable and give very poor yields. They also tend to be susceptible to major diseases and are too short to suppress weeds. Although a few varieties developed outside West Africa have been released for upland cultivation their performance remains unstable, with only one such variety, IR 442-2-58, still being widely planted in the region. However, some selections originating from crosses of African and introduced varieties, such as ROK 1 and ROK 2, give yields comparable to those of traditional varieties when grown under low-input management practices. This implies that testing large segregating breeding populations which have some local variety backgrounds may be more useful than concentrating on a limited number of introductions.

WARDA's New Approach to Varietal Development

The experiences outlined above have led WARDA to try a new approach to the on-station development of new varieties. This approach involves simultaneously breeding and evaluating improved varieties under different levels of management. The short-term objective of these trials is to develop varieties which perform at least as well as local varieties under low- and medium-input management. As the technological and infrastructural conditions under which West African upland rice farmers operate improve, farmers will need varieties that perform well under higher input levels. WARDA's medium-term objective, therefore, is to develop varieties which give stable yields equal or superior to local varieties under low-input management and which are at the same time more responsive to improved management. The improved performance of these varieties will, in turn, create an incentive to use more inputs.

In 1991 WARDA began an exploratory study to assess: the performance of elite varieties under low- and high-input management, both on farm and on station; the suitability and reliability of screening rice germplasm under low-input management; and the yield and yield stability of elite varieties in response to different levels of moisture stress, soil fertility, soil toxicity and disease and insect pest incidence. This study involved conducting the following activities during the 1991 wet season:

- on-station replicated yield trials of 14 elite varieties under low- and high-input management levels
- on-station screening of segregating F_3-F_5 populations under these two levels of management
- on-farm varietal trials of five elite varieties under farmers' management conditions at 53 locations in Côte d'Ivoire

All the on-station trials were conducted at WARDA's Main Research Center at M'bé. The on-farm trial sites were located in Gagnoa (12), Man (5), Odienne (5), Ponangdougou (15) and Touba (16) — all in the most densely populated rice growing areas of Côte d'Ivoire.

In the on-station elite variety trials, 14 short-duration varieties (IAC 164, IDSA 6, 10, 27 and 46, IRAT 144, ITA 257 and 301, WAB 32-80, 56-50, 56-57, 56-104 and 56-125 and, as the check, WABC 165) were evaluated for yield potential under low- and high-input levels of management (Table 7). The characteristics evaluated were seedling vigor, plant height, growth duration, panicles/m^2, panicle length, blast infection, yield (corrected to 14% moisture) and grain shape.

In the trials on segregating F_3-F_5 populations, 540 populations were grown under the two management levels described in Table 7. Primary plots were 0.5 x 5 m (two rows, 5 m long), with no replication. The check varieties (IAC 164, IDSA 6 and WAB 56-104) were replicated after every 20 test entries. The seeds were dibbled at a spacing of 25 x 25 cm, with two seeds/hill, and individual plants with desirable characteristics were selected. At harvesting, observations were made of days-to-maturity, plant height and disease and insect pest damage on all selected plants.

TABLE 7
Components of low- and high-input management levels

Practice	Low-input level	High-input level
Land clearing	Minimal tree cutting within experimental blocks; stumps left in place; residues removed	Trees and stumps removed manually, with tractor assistance, within experimental blocks under dry soil conditions
Land preparation	No land leveling; hand hoe used for scarification to a maximum depth of 5 cm	Disc plough used to till soil to a depth of about 10 cm; multiple passes with disc plough
Sowing	Seeds drilled in rows on 14 June 1991	Seeds drilled in rows on 13 June 1991
Spacing and plot size	25 cm between rows; plots 2.5 x 5 m (10 rows, 5 m long)	25 cm between rows; plots 2 x 5 m (8 rows, 5 m long)
Fertilizer application	Total of 40 kg N/ha applied in two equal parts at 15 and 45 days after sowing	Total of 90-40-40 kg/ha N-P_2O_5-K_2O; N applied in three equal parts during the vegetative and reproductive stages; P_2O_5 and K_2O applied as basal fertilizer
Weed control	Plots hand weeded at 15 and 30 days after sowing	Pre-emergence herbicide (Ronstar) applied 1 day after sowing at a rate of 4 l/ha; plots hand weeded when necessary
Insecticide/fungicide	No application	Furadan applied 14 days after sowing at a rate of 2 kg a.i./ha

In the on-farm varietal trials, five varieties (IDSA 10, ITA 257, WAB 56-104 and 56-125, and WABC 165) were tested. Seeds were sown in rows or dibbled in 10 x 5 m plots in each farmer's field. Entries were thus site-replicated in each area. Management followed farmers' practices, in which no fertilizers or herbicides were applied and weeds were removed by hand.

Preliminary Results

Selected results from the on-station elite variety trials are presented in Table 8 *(overleaf)*. Average plant height under low-input levels was reduced by 18%, probably because of the slower seedling emergence and growth observed under conditions of poor land preparation. These factors may also explain the differences in crop duration, which was longer by an average of 15 days under the low-input levels. No serious disease or insect pest problems were recorded during 1991, but in plants grown under the high-input level an average rating of 3 for blast incidence was recorded, compared to 1 for the low-input level.

Average grain yields were 4910 kg/ha and 1420 kg/ha for rice grown under high- and low-input levels, respectively. However, performance varied considerably between the two levels. Under the high-input level, the top three entries were WAB 56-125, IDSA 27 and ITA 301, but these ranked sixth, tenth and twelfth, respectively, under the low-input level. Similarly, the three top yielders under the low-input

TABLE 8
Grain yield, plant height and growth duration of elite varieties grown under low- and high-input management levels at M'bé, Côte d'Ivoire, 1991 wet season

Variety	Low-input level Yield (kg/ha)	Height (cm)	Duration (days)	High-input level Yield (kg/ha)	Height (cm)	Duration (days)
IDSA 46	1930	83	117	5280	105	104
IRAT 144	1920	115	115	5030	113	104
IDSA 10	1780	96	109	5030	106	95
WABC 165	1590	109	111	4610	130	98
WAB 56-104	1500	91	105	4340	108	87
WAB 56-125	1440	97	107	6050	117	107
IAC 164	1430	107	113	4540	125	107
ITA 257	1310	88	105	4660	109	89
WAB 56-50	1270	101	115	4770	120	96
IDSA 27	1250	89	114	5320	120	103
ITA 301	1120	82	135	5610	104	113
IDSA 6	1200	80	136	4660	97	115
WAB 56-57	1070	85	107	4580	108	95
WAB 32-80	1070	100	120	4340	130	103
Mean	1420	93	115	4910	114	100
CV (%)	22			14		
SE ±	294			410		

level — IDSA 46, IRAT 144 and IDSA 10 — were not among the top three under high-input levels. The non-significant Pearson correlation coefficient (r = + 0.19, P = 0.524) for grain yields at low- and high-input levels indicates little association between the two. This is also reflected in the non-significant Spearman correlation (r = 0.22, P = 0.441) of rank order. In other words, different varieties would have been selected under the two different management levels.

These results indicate that on-station screening of available germplasm at different levels of management is essential for the identification of suitable rice varieties for specific management systems.

From the on-station screening of segregating populations, 619 and 445 individual plants grown under low-input and high-input management levels, respectively, were selected on the basis of plant type, tiller number, grain characteristics and disease and insect pest resistance/tolerance. As shown in Table 9, the populations from which the largest numbers of individual plant selections were made differed for the two management levels. For example, a larger number of plants with desirable characteristics were selected from the WAB 377 (TGR 68/WABC 165) and WAB 307 (ITA 311/WAB 15-701) crosses for low-input management than from the WAB 384 (ITA 184/ROK 16) and WAB 285 (ITA 150/WAB 15-764) crosses, which were intended for high-input management. This suggests that suitable plant materials for each management level should be obtained from different crosses. However, a fairly high number of selections was also made from the WAB 376 (TGR 68/WAB 56-125) and WAB 326 (ITA 235/WABC 165) crosses under both management levels.

TABLE 9
Selection of progenies of F_3-F_5 populations grown under low- and high-input management levels at M'bé, Côte d'Ivoire, 1991 wet season

Population	Parents	Number of selections: High-input level	Number of selections: Low-input level
F_3			
WAB 376	TGR 68/WAB 56-125	31	25
WAB 377	TGR 68/WABC 165	4	99
WAB 381	ITA 184/WAB 56-57	26	40
WAB 384	ITA 184/ROK 16	20	1
F_4			
WAB 275	3290/WAB 15-675	22	9
WAB 285	ITA 150/WAB 15-764	17	11
F_5			
WAB 307	ITA 311/WAB 15-701	16	59
WAB 326	ITA 235/WABC 165	54	48

The results of the on-farm and on-station varietal trials are compared in Table 10. Yield performance under low-input levels on station was similar to that in the on-farm trials. The higher average yields obtained from the on-station, low-input plots compared to the farmer-managed plots can be attributed to the higher soil fertility levels in the newly cleared on-station plots. The yield ranking for varieties grown in the on-station, low-input plots was similar to that obtained for the on-farm plots, whereas there was little similarity in yield ranking between the on-station, high-input plots and the on-farm trials.

TABLE 10
Yields and yield rankings of elite varieties grown on farm under low-input management levels and on station under high- and low-input management levels, Côte d'Ivoire, 1991 wet season

Variety	Yield (kg/ha) On-farm low input	Yield (kg/ha) On-station low input	Yield (kg/ha) On-station high input	Yield rank On-farm low input	Yield rank On-station low input	Yield rank On-station high input
WAB 56-104	1100	1500	4340	3	3	5
WAB 56-125	1190	1440	6050	1	4	1
WABC 165	1130	1590	4610	2	2	4
ITA 257	970	1310	4660	5	5	3
IDSA 10	1080	1780	5030	4	1	2

On-station trials under low-input management levels established at M'bé, Côte d'Ivoire

Conclusion

The results from this pilot study suggest that the high-input screening methods conventionally used by breeders lead to the development and selection of varieties poorly adapted to the needs of the vast majority of the region's rice farmers. The assumption on which the conventional methods is based — that the ranking of varieties according to yield under high- and low-input conditions will be identical — is false. The types of varieties developed under high-input conditions are not the same as those developed under low-input conditions.

WARDA scientists will continue to refine the methods used for low-input screening, so that these can be applied more widely in the future. In addition, further studies will be launched to identify the factors that determine inter-varietal differences in yield performance under different management levels. Results from the latter studies will enable WARDA to develop breeding strategies and methods which more effectively target the needs of farmers with differing management capacities.

1.5 REGIONAL COOPERATION IN RICE IMPROVEMENT FOR THE MANGROVE SWAMPS

Martin Agyen-Sampong

Background

Mangrove swamp rice cultivation is one of the oldest forms of rice culture in West Africa. The system is well established in six coastal countries (The Gambia, Guinea, Guinea-Bissau, Nigeria, Senegal and Sierra Leone), where a high population density in coastal areas is combined with a high rice production potential. In these countries, about 214 000 ha of mangrove swamps are cultivated by over 100 000 farm families. Mangrove swamp rice accounts for 10% of regional rice production, with annual yields averaging 1.8 t/ha.

Research on improved mangrove swamp rice production techniques started in the 1920s, with experimental activities in the Casamance region of southern Senegal, as well as in Guinea, Nigeria and Sierra Leone. These activities, however, were isolated and poorly coordinated. Since it was founded in the 1930s, the national Rice Research Station at Rokupr, Sierra Leone has sought to develop superior varieties of rice adapted to mangrove swamp conditions. Its efforts have met with success: by the mid-1970s several high yielding, early maturing varieties such as ROK 5 had been developed and released.

In 1976, WARDA established a special multidisciplinary project at Rokupr to work with the strong national program on the development of technologies for improving mangrove swamp rice productivity throughout the region. Promising technologies were evaluated by WARDA scientists through on-farm trials in the six member countries. Farmer participation in technology development was emphasized and by the mid-1980s several new technology packages appropriate for the various mangrove swamp ecosystems had been developed. However, links between national programs remained poor, limiting the capacity for collaborative research. This problem restricted the regional spread of the new technologies, reducing their impact.

A New Network

To promote the spread of new technologies, WARDA established a networking project in 1990 with funding from the United States Agency for International Development (USAID). The network was inaugurated at a workshop of national program scientists organized by WARDA in March 1991. A Steering Committee of national scientists was selected to work with the WARDA Network Coordinator to guide operations. The main objectives of the network are to:

- maximize the transfer of skills, information and improved technologies, especially improved varieties, to the national programs working in mangrove swamp ecosystems
- strengthen national research capabilities and promote collaboration between national programs
- bring about sustainable increases in rice production in the mangrove swamp environment

The network seeks greater cost-effectiveness in research by exploiting the complementary nature of research programs across national boundaries. The pooling of resources is considered vital, since individual national programs are often severely constrained by resource limitations. Stronger links between national programs also enable researchers to avoid disciplinary stagnation and duplication of effort.

Planning Network Activities

At the inaugural meeting a master plan was developed whereby each national program assumed responsibilities in line with its comparative advantage (Table 11). WARDA's role was to provide technical support.

TABLE 11
Allocation of research responsibilities to national programs in the Mangrove Swamp Rice Network

	Capabilities of national programs					
Research areas	**The Gambia**	**Guinea**	**Guinea-Bissau**	**Nigeria**	**Senegal**	**Sierra Leone**
Soil/plant analyses	—	—	—	+	+	+
Hybridization	—	—	—	—	—	+
Screening:						
acid sulfate	—	—	—	—	—	+
salinity	+	—	—	—	—	+
diseases	+	—	—	+	+	+
insects	+	—	—	+	+	+
Varietal evaluation:						
observational	+	+	+	+	+	+
yield trials	+	+	+	+	+	+
Seed multiplication	+	+	+	+	+	+

\+ Adequate capacity to undertake an activity
— Limited capacity

Nigeria, Senegal and Sierra Leone expressed their willingness to assume leadership in plant and soil analyses. The Steering Committee recommended that Senegal should meet the needs of The Gambia and Guinea-Bissau, and that Sierra Leone should meet those of Guinea.

The national and WARDA teams at Rokupr agreed to play a leading role in hybridization, selection and screening in support of all other national programs in the network. In Sierra Leone, the aim would be to gradually transfer research activities from WARDA to the national team, in line with WARDA's strategy of devolving regional responsibilites to stronger national programs. In 1991 all national programs would conduct observational and yield trials to evaluate improved varieties. These trials would be designed to suit the particular requirements of individual programs (for example, for crop duration and stress tolerance).

Activities

Varietal improvement

In 1991 WARDA-Rokupr continued to identify higher and more stable yielding varieties from introduced varieties and advanced lines. Selections were made from observational nurseries and replicated yield trials as well as from segregating populations resulting from crosses made in the 1980s. In collaboration with the national program at Rokupr, about 450 lines from segregating populations in F_6-F_{10} generations were selected and advanced. The selections were made on the basis of agronomic characteristics and reaction to environmental stresses. The fixed lines selected will be evaluated in collaborative network regional trials in 1992. The results of this work are given in the Research Summaries section of this report, on page 78.

Seed distribution

The network distributed more than 5 t of seeds of nine improved varieties during 1991 to national institutions, rural development agencies and individual farmers. A further 12 t of seeds were produced during the 1991-92 main cropping season for distribution in 1992.

Network trials

During the 1991 season, 60 observational, multilocational and on-farm trials were undertaken in the six member countries. In the observational trials, each country selected varieties from sets of short-, medium- and long-duration materials, each set containing between 50 and 65 varieties. Varieties were assessed for phenotypic acceptability and stress tolerance (salinity, acidity and iron toxicity).

Three sets of 13 varieties each of short, medium and long duration were also made available to national scientists for multilocational replicated yield trials. In these trials, national breeders identified a number of varieties with outstanding performance in a wide range of mangrove swamp conditions.

Regional yield trials for the improvement of mangrove swamp rice varieties at Rokupr, Sierra Leone

Finally, on-farm trials of the most promising varieties observed in the previous year's yield trials were conducted in each country. The trials were managed entirely by farmers under local conditions, with the results being monitored by national scientists and extension agents. The results of this work are discussed in detail in the Research Summaries section.

Training

Training to upgrade the level of national staff and strengthen their research capabilities is an essential network activity. WARDA offers both individual and group training. Training activities in 1991 included support for two research assistants, two research fellowships, a post-doctoral fellow and several short-term visiting scientists. Three group training courses were organized, with about 15 participants each.

Monitoring tour

During the 1991 cropping season, a monitoring tour was conducted in The Gambia and southern Senegal by scientists from each of the six mangrove swamp rice producing countries. The objectives of the tour were to familiarize the participants with the diversity of mangrove swamp rice ecosystems in the sub-region, to evaluate the performance of rice varieties in network trials and to develop strategies for improving mangrove swamp rice in the areas visited.

The tour participants were pleased to observe that a number of varieties selected, bred or popularized by WARDA have gained considerable acceptance in the countries visited. Among the most popular were Kuatik Kundur, ROHYB 6, WAR 6-2-B-2, ROK 5, WAR 115-1-2-10-5, WAR 1 and WAR 77-3-2-2, which were being multiplied as foundation seed. The group was informed that large-scale multiplication would be carried out in 1992 in The Gambia. Seeds will be distributed to extension units and to non-governmental organizations (NGOs), which will evaluate the varieties in farmers' fields and multiply the seeds for distribution to farmers.

The group also observed that WAR 1 and WAR 77-3-2-2 performed consistently better than ROK 5, the current best variety, under the highly acid sulfate soil conditions of southern Senegal, even without soil amendments. Farmers interviewed at several locations preferred these two varieties because of their tall stature, high tillering capacity, large panicles, long grain and stable yields under stress conditions.

Conclusion

Since its establishment in 1990, the Mangrove Swamp Rice Network has made rapid progress in linking rice scientists in the sub-region. Their problems and needs have been collectively determined and this has encouraged collaborative research and the sharing of information and new technologies.

It is envisaged that, by the end of 1992, WARDA will have largely completed the selection of stress-tolerant, high-yielding varieties. These will be available for regional testing in network trials. The individuals trained by the network will return to their national programs with significantly enhanced knowledge of new research techniques. Finally, through the varietal evaluation trials, national programs will have had the opportunity to evaluate the most promising genetic material bred or selected by WARDA and by colleagues in other programs. Through seed multiplication and on-farm tests supported by the network, as well as through national extension agencies, the best of these varieties will be distributed to farmers.

SUMMARIES OF RESEARCH ACTIVITIES

Continuum Program

INTRODUCTION

The undulating landscape of the West African forest and forest-savanna transition zone creates diverse ecosystems along the toposequence, which are collectively known as the upland/inland swamp continuum. For rice cultivation, the continuum contains two distinct types of land: the uplands, in which the rice crop is strictly rainfed, and the lowlands or inland valley swamps, where the rice crop is periodically flooded through natural flow or irrigation. A third, less well-defined land type is the hydromorphic zone, lying between the uplands and the lowlands, in which rice cultivation is assisted by the presence of groundwater close to the soil surface. Since these ecosystems are contiguous, farm families usually have fields spread across all three. These ecosystems are thus closely connected in terms of both physical interactions and farming practices.

WARDA attaches high priority to the upland/inland swamp continuum because its large size, in terms of both area and farming population, makes it potentially the region's most productive rice growing environment. Nearly 2.5 million ha are currently sown to rice in the continuum, representing 80% of the total area sown to rice in West Africa. Of this, 69% is rainfed upland, 25% is inland valley swamp without water control and 6% is irrigated lowland.

The most important constraints to rice production in the continuum are those associated with the stability and sustainability of rice production. In the upland/hydromorphic ecosystem these include drought stress, low soil fertility and erosion. In the hydromorphic/swamp ecosystem a complex of poorly understood soil conditions, including iron, aluminum and manganese toxicity, are often critical. Major biological stresses common to both ecosystems are weeds, the diseases blast, leaf scald and brown spot, and the insect pests stem borers and diopsis. Rice yellow mottle virus (RYMV), a disease unique to Africa, poses a potentially major threat under hydromorphic/swamp conditions. Although local rice varieties are generally well adapted to low-input cropping systems, yield potential for most of these genotypes is modest and their response to improved inputs is poor.

At the upper end of the continuum the potential for impact on yields may be relatively small, but because of the large areas involved the overall effect of new technologies on regional output could be substantial. It is at this end of the continuum that the issues of sustainability are most acute, with erosion and soil fertility degradation posing severe threats under systems of continuous cultivation. Such problems can be addressed only within the context of the whole farming system. Alternative upland cropping systems, such as intercropping, crop/fallow rotations, alley farming and other improved agroforestry systems, need to be developed and/or promoted. At the lower end of the continuum the potential for impact on yields is greater and continuous rice cropping generally poses fewer sustainability problems.

Research in the Upland/Inland Swamp Continuum Program is currently conducted within five major projects:

- characterization of rice growing ecosystems
- development of sustainable, intensified rice cropping systems
- development of improved soil fertility practices
- development of integrated pest and disease management practices
- development of improved rice varieties

PROJECT 1

CHARACTERIZATION OF RICE GROWING ECOSYSTEMS

Background

The rice growing ecosystems of the upland/inland swamp continuum are highly diverse. Their potential for production is determined by the interplay of many factors, including geology, climate, soil types and hydrology, vegetation and a range of socio-economic factors.

The development of appropriate technologies for the continuum's smallholder rice farmers requires a thorough understanding of the specific constraints under which rice is grown in each ecosystem and of how farmers use their existing resources to reduce risk and optimize production. Such understanding assists in the definition of research priorities and in the identification of suitable locations for specific types of research. It also serves to guide the transfer of technologies developed in a given location to similar areas throughout West Africa.

Characterization and Classification of Rice Growing Ecosystems in Côte d'Ivoire

Laurence Becker and Roger Diallo

In 1990 WARDA implemented a macro-level characterization study in Côte d'Ivoire to determine the geographical distribution of rice and to characterize the biophysical and socio-economic factors that affect rice production throughout the country.

Past agro-ecological characterization studies at continental and national levels in Africa focused on the soil and climatic factors influencing crop production. The present study complements the earlier work by mapping current rice production in Côte d'Ivoire at a scale of 1:1 000 000, and describing the key biophysical and socio-economic determinants of rice production. By combining these factors, distinct ecosystems can be defined and classified.

From mid-1990, interviews were conducted throughout Côte d'Ivoire with local extension agents and farmers. Direct field observations were also made. The survey estimated the total rice area in Côte d'Ivoire to be 329 000 ha, of which 74% was rainfed upland and the remaining 26% lowland, including irrigated swamps and floodplains. Ten major rice ecosystems were identified — four in the forest zone and six in the savanna zone. Figures 7 and 8 show their geographical distribution. The systems are distinguished by rainfall, position in the toposequence, tillage method, rice varieties used, sowing and intercropping techniques, land tenure, gender of the rice farmer and primary objective of rice production (Table 12, and Table 13 *overleaf*).

Micro-level characterization of selected key sites in the most important ecosystems is now under way. Minimum data sets are being developed describing watersheds and the biophysical and socio-economic factors affecting production at farm and plot levels.

FIGURE 7
Distribution of lowland rice production in the major rice ecosystems of Côte d'Ivoire

+ Dioula forest immigrant
× Forest irrigated
× Savanna floodplain
□ Savanna irrigated
□ Savanna swamp
■ Yacouba forest broadcast

Each symbol represents 500 ha

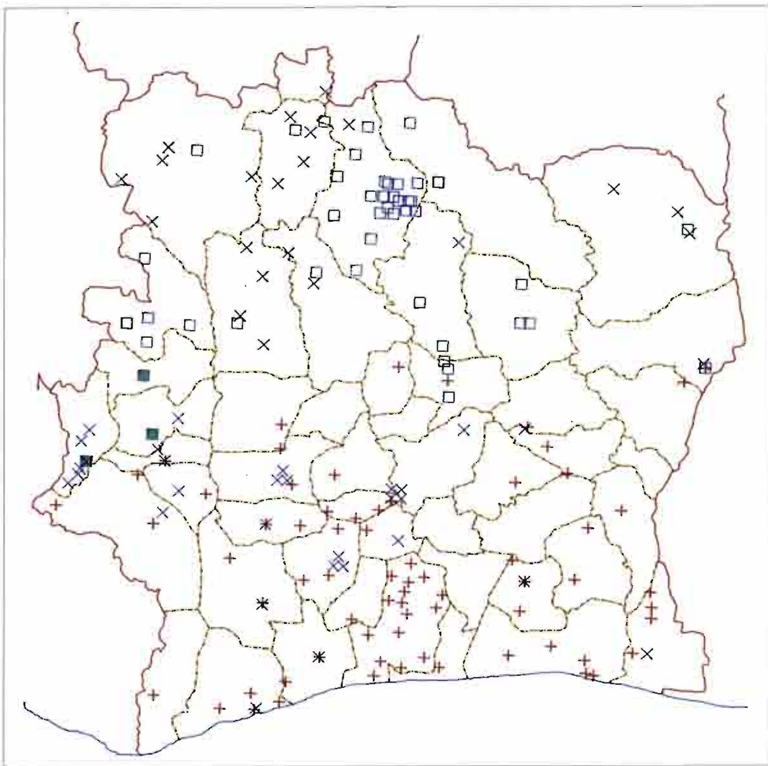
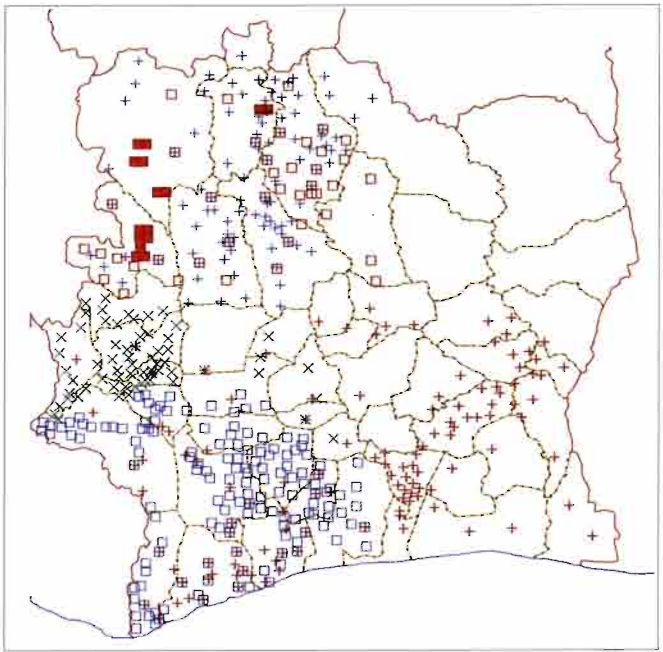


FIGURE 8
Distribution of upland rice production in the major ecosystems of Côte d'Ivoire



+ Dioula forest immigrant
□ Krou forest dibbled
■ Savanna fully mechanized
□ Savanna manual
+ Savanna mechanized tillage
× Yacouba forest broadcast

Each symbol represents 500 ha

TABLE 12
Four major rice ecosystems in the forest zone of Côte d'Ivoire

Characteristic	Krou forest dibbled	Yacouba forest broadcast	Dioula forest immigrant	Forest irrigated
% rice, Côte d'Ivoire	22	10	29	5
Rainfall pattern	Bimodal	Long monomodal	Bimodal, long monomodal	Bimodal, long monomodal
Toposequence position	Upland rainfed	Upland to valley bottom	Upland to valley bottom	Valley bottom
Tillage method	No till	Manual	Manual	Power tiller, manual
Rice variety	Traditional	Traditional	Improved, traditional	Improved
Sowing method	Dibbled	Broadcast	Dibbled (upland), broadcast (lowland)	Transplanting
Associated crops	Maize, cassava, vegetables	Maize, cassava, condiments	Maize (upland), monocrop (lowland)	Monocrop
Land tenure system	Customary	Customary	Rental	Rental
Decision maker	Female	Female, male	Male	Male
Production objective	Home consumption	Home consumption	Sale, home consumption	Sale

TABLE 13
Six major rice ecosystems in the savanna zone of Côte d'Ivoire

Characteristic	Savanna manual tillage	Savanna mechanized tillage	Savanna fully mechanized	Savanna swamp	Savanna floodplain	Savanna irrigated
% rice, Côte d'Ivoire	6	15	2	4	3	3
Rainfall pattern	Monomodal	Monomodal	Monomodal	Monomodal	Monomodal	Monomodal
Toposequence position	Upland rainfed	Upland rainfed	Upland rainfed	Valley bottom	Alluvial plain, valley bottom	Irrigated valley bottom
Tillage method	Manual	Ox-drawn plough, tractor	Tractor	Manual	Tractor	Manual, power tiller
Rice variety	Traditional	Improved	Improved	Traditional	Traditional	Improved
Sowing method	Broadcast	Broadcast	Mechanical	Transplanted	Broadcast	Transplanted
Associated crops	Maize, yam	Maize or monocrop	Monocrop	Monocrop	Monocrop	Monocrop
Land tenure	Customary	Customary	Allotment	Customary	Rental or customary	Allotment
Decision maker	Male	Male	Female, male	Female	Male	Male
Production objective	Home consumption	Sale, home consumption	Sale	Sale	Sale	Sale

At a regional workshop held in June 1991, national program scientists from Benin, Burkina Faso and Ghana expressed an interest in conducting similar studies in their countries. WARDA will assist these new studies by adapting methods developed in Côte d'Ivoire to the needs of these countries.

This work, of major importance in understanding WARDA's priority rice growing environment, will continue in 1992.

PROJECT 2

DEVELOPMENT OF SUSTAINABLE, INTENSIFIED RICE CROPPING SYSTEMS

Background

Shifting cultivation, the production system traditionally practised in the upland/inland swamp continuum, is sustainable provided fallow periods are long enough to restore soil fertility, maintain soil structure and suppress troublesome weeds. However, under increasing land pressure this system is breaking down throughout the West African region, with fallow periods being drastically shortened or eliminated altogether. Continuous cultivation leads to deteriorating soil properties and thus to declining yields. Farmers react by clearing and planting ever larger areas, reducing the fallow period still further. A cycle of land degradation begins.

Technologies that increase productivity and sustainability can help to break the cycle, but they must be appropriate for the target system if they are to be widely adopted. WARDA's research on cropping systems in the continuum is intended to ensure that the technologies developed by the Association and its national partners will:

- increase the efficiency with which renewable resources found on the farm are used (rather than increasing dependence on external inputs)
- conserve soil and water resources, enhancing their quality wherever possible
- be adopted and adapted by farmers spontaneously

Cropping systems research activities are conducted in the forest, the forest-savanna transition and the savanna zones. Currently, special emphasis is being placed on the forest zone, identified as a priority research area for WARDA.

Throughout much of the forest zone the fallow is dominated by *Chromolaena odorata*, a vigorous shrubby perennial. Research has so far focused on chemical control and biological eradication of *C. odorata*. However, little is known about the contribution made by this shrub to system sustainability.

The transition zone is characterized by a long rainy season with a high probability of dry spells, especially in June and July. In response to the risk of drought, farmers in this zone are moving downslope onto the hydromorphic lower slopes and into the valley bottoms, where water is more plentiful for a longer period of the year. Cultivating these lower lying parts of the continuum incurs increased tillage and weed control requirements — a major constraint for farmers in a system that is still based largely on the use of the hand hoe.

The savanna zone is characterized by a 4- to 5-month monomodal rainy season. Animal traction is increasingly used in the zone's upland areas but, as in the transition zone, farmers are moving downslope into the hydromorphic areas and the seasonally flooded valley bottoms. The increasing exploitation of these lowlands is leading to a more complex production system, with the lowland soils being wet tilled and rice transplanted into these soils at the height of the rainy season, after upland crops have been established. At present, animal traction is under-used in both upland and lowland areas.

Research in 1991 focused on the diagnosis of weed control practices in the upland systems of Côte d'Ivoire.

Farmer Weed Control Practices in Three Upland Rice Cropping Systems in Côte d'Ivoire

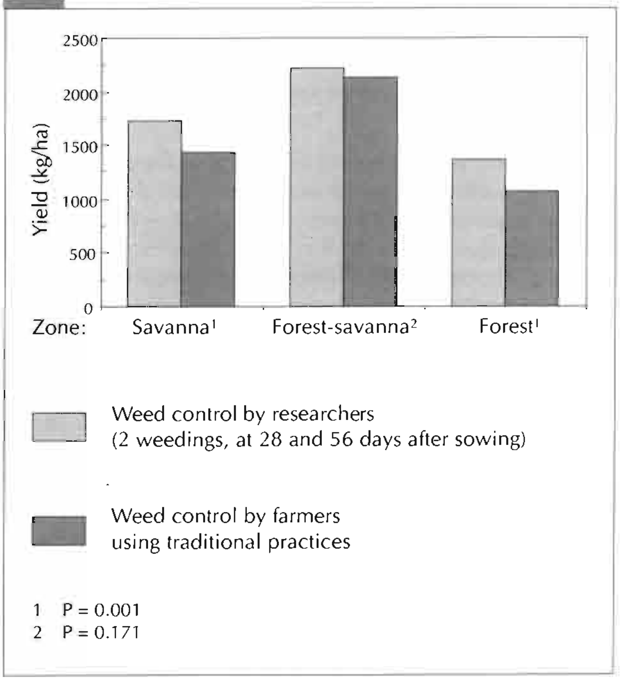
Thomas Remington

Before testing weed control interventions it is important to characterize the weed control practices already used by farmers. Characteristics of particular importance include the techniques employed (manual, mechanical or chemical), the timing and frequency of weeding, the labor allocations required and the yield losses when weeding is either not done at all or is not completed. This information can be used to identify and prioritize the research needed to develop appropriate weed control methods for rice cropping systems at different stages of intensification.

To this end, a survey was conducted of 15 upland rice farmers in three important upland cropping systems of Côte d'Ivoire. The systems selected were the humid forest zone in the south-west of the country, where weeding is carried out manually and rice is seeded directly onto hills, a system in the forest-savanna transition zone of west-central Côte d'Ivoire, where weeding is also manual but seeds are broadcast, and a system in the savanna zone of northern Côte d'Ivoire, in which weed control is carried out with animal traction and herbicide is also used.

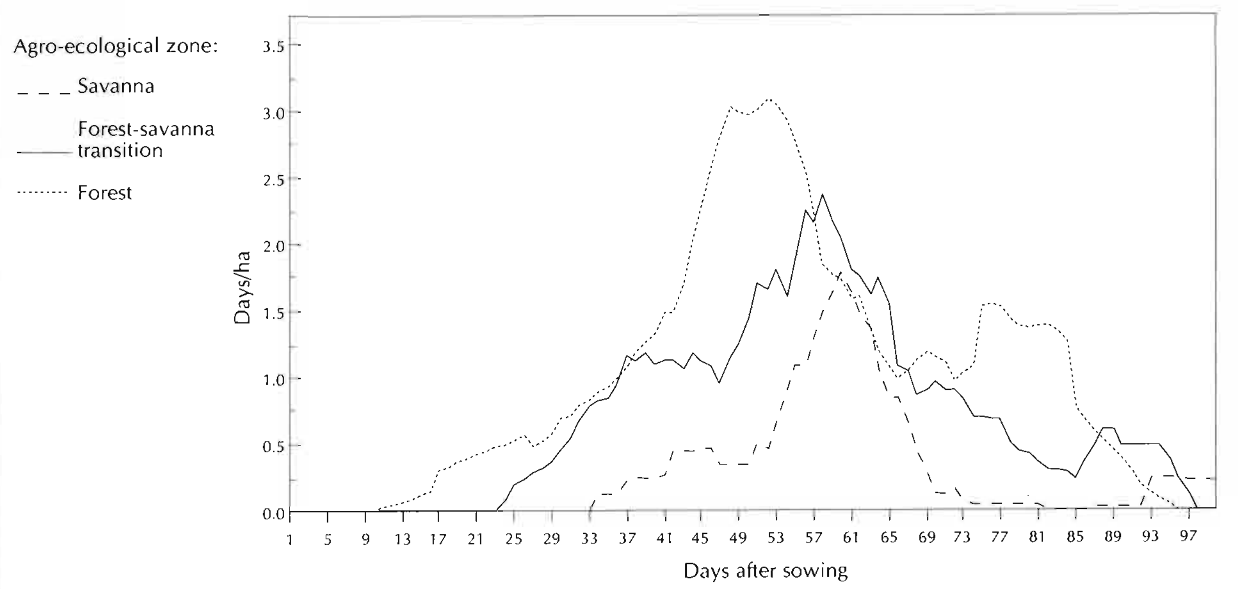
Six paired 25 m² plots were established at random in each farmer's principal rice field. One plot in each pair was weeded twice by researchers, at 28 and 56 days after seeding, whereas the other was weeded by the farmer according to his/her normal practices. Data were collected on the timing and frequency of weeding, the labor inputs, the species and weight of weeds removed and the rice yields (Figure 9, and Figure 10 *overleaf*).

FIGURE 9
Rice yields obtained by farmers and researchers using different weed control practices in three upland rice cropping systems in Côte d'Ivoire, 1991



Rice yields were lowest and farmers' labor time highest (99 person-days/ha) in the humid forest zone, where *C. odorata* is the dominant plant. Yields were highest in the forest-savanna transition zone, where 69 person-days/ha was the average time required by farmers for hand hoeing and pulling

FIGURE 10
Average time spent weeding in three upland rice cropping systems in Côte d'Ivoire, 1991



of weeds, primarily *Imperata cylindrica*. In the cotton-based cropping system of the savanna zone, hand weeding by farmers required only 28 person-days/ha, this lower allocation being due largely to the application of herbicide at planting. The herbicide, REFIT, which costs CFAF 22 400/ha (CFAF 250 = US$ 1.00), effectively replaced an early weeding. Rice yields were significantly reduced under farmer weed control practices in the humid forest and savanna zones, but not in the transition zone. The higher yields obtained in the latter zone are thought to be due to the farmers' practice of hand pulling *I. cylindrica* during the first month after seeding. This practice is called *kombo* in the local language, meaning 'giving the rice seedlings room to grow'.

Improving weed control in the forest zone depends on the development of more effective practices for managing *C. odorata*. In particular, techniques need to be developed to prevent regrowth following slashing. However, any new approach adopted must consider *C. odorata* as a multipurpose shrub as well as a weed that needs to be controlled, since it maintains soil structure and fertility and suppresses troublesome grass weeds.

Further research in the forest-savanna transition zone should focus on the effect of the depth and frequency of cultivation by animal traction on the suppression of *I. cylindrica*.

In the savanna zone there is a need to integrate more fully animal traction seeding and inter-row weeding, so as to supplant the late hand weeding currently practised and to reduce the currently high level of herbicide use.

Research in all three zones will continue in 1992.

PROJECT 3

DEVELOPMENT OF IMPROVED SOIL FERTILITY PRACTICES

Background

Position in the continuum or toposequence is perhaps the single most important physical factor affecting rice cultivation in West Africa. Rice in the continuum is grown on a wide variety of soils and land forms, ranging from areas in which moisture regime may be defined as strictly upland to areas in which the water level is highly unpredictable and areas that are usually completely waterlogged throughout the year. These differing conditions present different nutrient deficiencies and excesses or toxicities. Little work has been done on the interactions of water and nutrients at different positions in the toposequence. A better understanding of these interactions is central to diagnosing nutrient disorders and developing more effective soil management practices.

Performance of Four Rice Cultivars Grown along the Upland/Inland Swamp Continuum in M'bé Valley

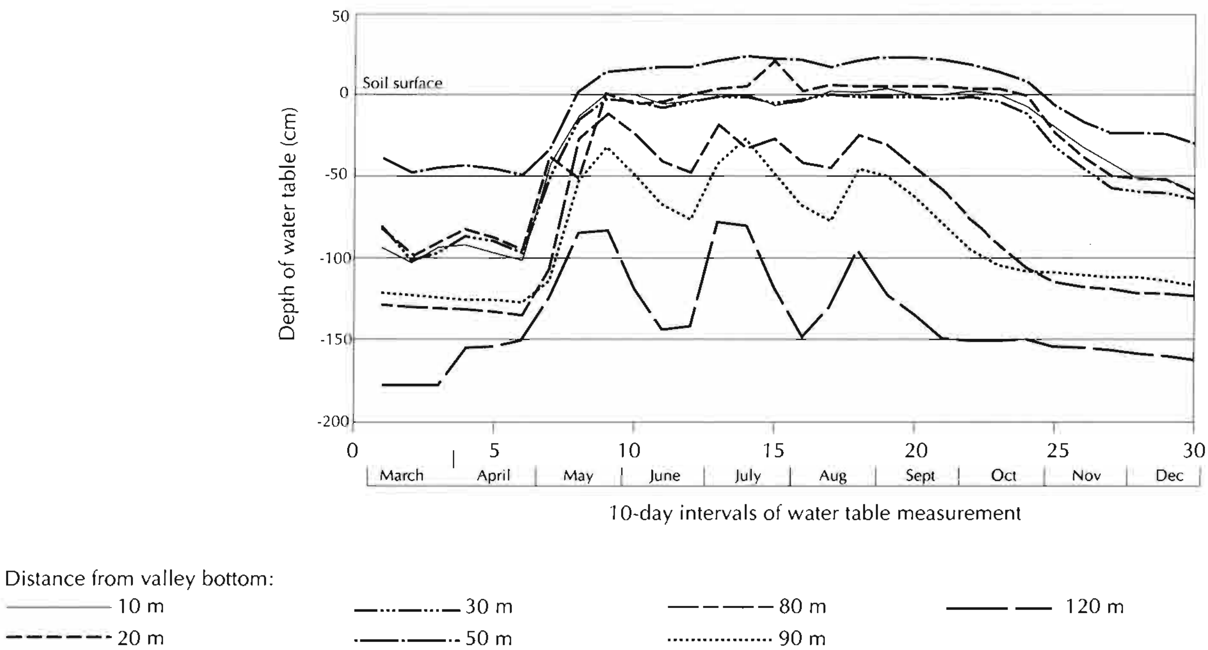
Kanwar L. Sahrawat and Sitapha Diatta

A 3-year multidisciplinary study began in 1989 to measure soil-related and other factors affecting rice growth along the continuum.

The experiment consisted of three blocks (A, B and C) each measuring 120 x 40 m, oriented vertically across the continuum with an average slope of 1-3%. Two upland cultivars (short-duration IAC 164 and medium-duration IDSA 6) and two lowland cultivars (IR 5931-110-1 and Bouaké 189, both medium duration) were grown along the continuum, with and without fertilizers. The experimental design was a split plot with a cultivar in the main plot and fertilizer in the subplot. The fertilizer doses were 150 kg/ha NPK (10-18-18) at planting and 100 kg/ha of urea applied in equal doses at tillering and at flowering. Twelve sections (each 40 x 10 m) were established, parallel to the valley bottom and at distances of 10, 20, 30, 50, 80, 90 and 120 m from it. Two piezometers were installed in each section to measure water table depths. Readings were taken three times a week from March to December. Gravimetric soil moisture was measured weekly. Rice root distribution along the continuum was scored, using a 60 x 30 cm grid with 72 squares, each measuring 5 x 5 cm.

Water table fluctuations The hydromorphic zone lay higher up the slope than in the previous year due to greater rainfall (1231 mm in 1991, compared with 961 mm in 1990). The water table in the three blocks rose rapidly in April and fell at the end of the rainy season in October (Figure 11). The lowest sections in blocks B and C remained flooded from July to October and from June to October, respectively. In block A, which was located upstream, no plots were flooded.

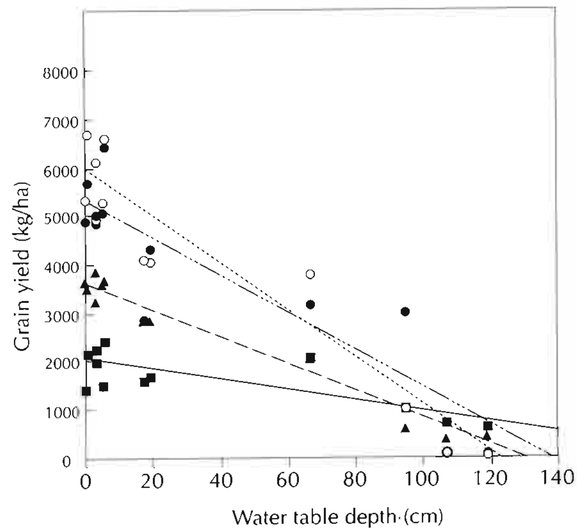
FIGURE 11
Water table dynamics along the upland/inland swamp continuum, M'bé valley (block C), Côte d'Ivoire, March to December 1991



Varietal response to position in the toposequence Regressions of grain yields against water table depth revealed a positive response to the rising water table, with IAC 164 responding least and Bouaké 189 most (Figure 12).

The lowland cultivars consistently gave the highest yields in the hydromorphic zone (Table 14). Shallow water table and high gravimetric soil moisture had a positive effect on their growth and grain yield. Of the two upland cultivars tested,

FIGURE 12
Effect of water table depth on grain yield of four rice varieties in M'be valley (block C), Côte d'Ivoire



IAC 164	$y = -10.818x + 2057$	$r^2 = 0.650$
IDSA 6	$y = -28.153x + 3653$	$r^2 = 0.886$
IR 5931-110-1	$y = -39.056x + 5345$	$r^2 = 0.749$
Bouaké 189	$y = -48.945x + 5967$	$r^2 = 0.858$

TABLE 14
Mean grain yields (kg/ha) of four rice cultivars grown along the continuum in M'bé valley, Côte d'Ivoire, 1991

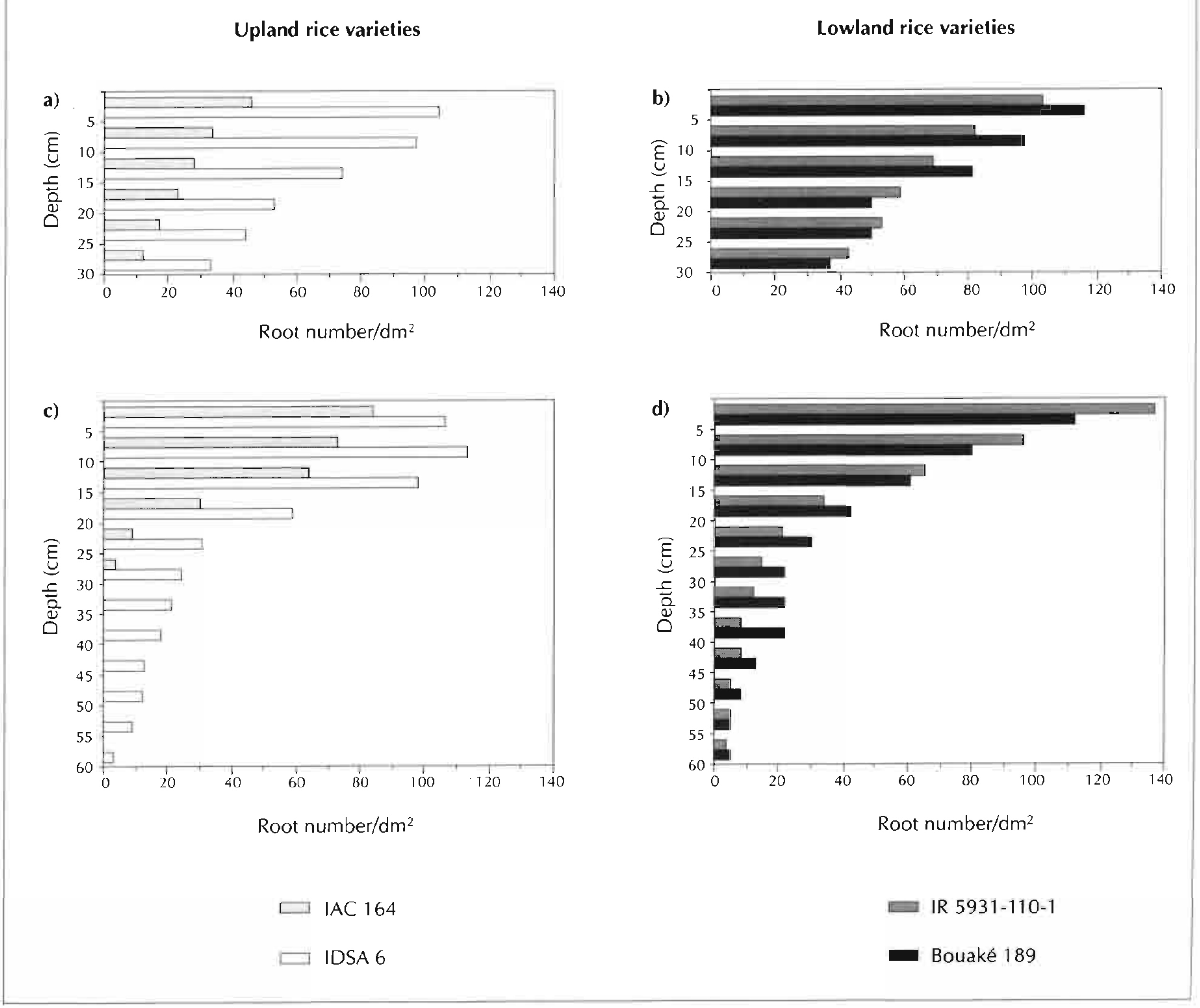
Variety	Treatment[1]	Upland	Hydromorphic area[2]	Mean
IAC 164	F0	770	1440	1100
	F1	1160	1930	1550
IDSA 6	F0	540	2040	1290
	F1	790	3150	1970
IR 5931-110-1	F0	380	3140	1760
	F1	440	4310	2370
Bouaké 189	F0	170	2750	1460
	F1	230	4230	2230
Mean	F0	460	2340	
	F1	640	3410	

1 F0 = without fertilizers; F1 = with fertilizers
2 Intermediate zone between upland and lowland in a continuum where the water table depth influences plant growth

IDSA 6 seemed to be well adapted to hydromorphic conditions but IAC 164 reacted poorly to excess water. The lowland variety IR 5931-110-1 yielded poorly in the upland zone but performed well in the hydromorphic zone. This cultivar was selected by IRRI for the upland ecosystem in Asia, but it appears better adapted to the hydromorphic zone in West Africa. Drought stress reduced the effect of fertilizer on grain yields, both in the uplands and in the upper part of the hydromorphic area.

Root distribution was also influenced by water table depth. Roots were generally concentrated in the top 30 cm of soil, but extended to a depth of 60-70 cm when the water table was over 50 cm below the soil surface (Figure 13). IAC 164 had the fewest roots, with very few extending beyond 30 cm even when the water table was deep. The roots of IDSA 6 were deeper and more dense than those of IAC 164. At all water table depths the lowland cultivars had more and deeper roots than the upland cultivars.

FIGURE 13
Root distribution of four rice varieties with a water table depth less than 50 cm (a and b) and a water table depth greater than 50 cm (c and d), M'bé valley



To evaluate cultivar performance along the toposequence, yields of each cultivar were regressed against the mean yield of the four cultivars at 39 landscape positions in the three blocks. The results obtained in 1991 confirmed those of 1989 and 1990. IAC 164 performed best (976 kg/ha) under unfavorable edaphic and climatic conditions, followed by IDSA 6 (334 kg/ha). Bouaké 189 and IR 5931-110-1 gave the highest grain yields in the most favorable edaphic conditions. Under moisture deficit conditions IAC 164 gave the most stable yields.

These results confirm the greater plasticity of upland rice plant types over a range of soil moisture regimes. This suggests that, under hydromorphic conditions where the water table depth varies greatly over the years, risk-averse farmers would prefer to plant upland types. Although farmers adopting this strategy would not maximize their yields in years when rainfall was high, they would avoid crop failure when rainfall was poor. Future physiology and genetics research will determine mechanisms and characteristics of upland rice that give yield stability. Future soils research will focus on water x nutrient interactions in the hydromorphic part of the continuum.

Iron Toxicity and the Role of Other Nutrients

Kanwar L. Sahrawat

Iron toxicity in rice is a complex disorder involving deficiencies of several other soil nutrient elements, especially potassium, calcium, phosphorus and zinc. Rice cultivars differ considerably in their manifestation of the visual symptoms of iron toxicity and the occurrence of iron toxicity in the field is often patchy. These characteristics make the disorder difficult to diagnose and to treat.

Symptoms of iron toxicity in rice plants

To study the role of different nutrients, an exploratory pot experiment was set up consisting of five treatments of a soil known to cause iron toxicity. The treatments were as follows:

- soil alone (control)
- soil + P (20 mg/2 kg)
- soil + K (10 mg/2 kg)
- soil + Zn (10 mg/2 kg)
- soil + P (20 mg/2 kg) + K (10 mg/2 kg) + Zn (10 mg/ 2 kg)

All treatments received a uniform application of N, at a rate of 200 mg/2 kg of soil at the planting, tillering and flowering stages. The cultivars tested were Bouaké 189 and *glaberrima* CG 14. Each treatment was replicated four times. The progressive development of iron toxicity symptoms was observed and the grain and dry-matter weights determined.

Rice plants grown under all treatments produced typical iron toxicity symptoms 4 to 6 weeks after emergence. The application of P, alone or in combination with other nutrients, delayed the appearance of iron toxicity by 1 to 2 weeks but did not prevent it. Yields did not increase, even when all nutrients were added together (Table 15).

TABLE 15
Grain and dry-matter weight (g/pot) of Bouaké 189 and *glaberrima* CG 14

Treatment	Bouaké 189 Grain yield	Bouaké 189 Dry matter	*glaberrima* CG 14 Grain yield	*glaberrima* CG 14 Dry matter
Control	6.5	7.2	7.7	7.2
Control + P	8.9	9.1	8.7	8.8
Control + K	6.7	7.7	7.3	8.0
Control + Zn	8.8	9.3	7.5	7.0
Control + P + K + Zn	8.2	9.3	8.4	8.3
CV (%)	18.5	14.2	9.5	11.5
SE ±	0.83	0.69	0.43	0.52
LSD (5%)	3.25	2.70	1.70	2.04
LSD (1%)	5.96	4.96	3.12	3.74

The symptoms appeared initially as tiny brown spots on the lower leaves, starting at the tip and spreading towards the base. After about 1 week the entire leaf became purplish brown. Symptoms in *glaberrima* CG 14 were less severe than in Bouaké 189.

Work in 1992 will continue to be directed at understanding the interactions of nutrients under iron toxic conditions, especially the delayed response to toxicity noted in this experiment.

Soil Nutrient Deficiency Studies

Kanwar L. Sahrawat and Sitapha Diatta

Starting in 1987, a series of trials was conducted to determine the status of mineral reserves in upland soils in the different agro-ecological zones of Côte d'Ivoire. These trials were located at Man in the forest zone, at Odienne in the savanna zone and at Bouaké in the forest-savanna transition zone.

The results showed that P was the most limiting nutrient in the forest zone, while soils in the transition and savanna zones were deficient in N. The results from M'bé, where trials covered the hydromorphic and the upland part of the continuum, indicated that N was the most limiting factor in both ecosystems. No deficiency was observed for P, K, Ca and Zn.

In 1991 an experiment was conducted to measure soil nutrient reserves after 3 years of continuous rice cultivation at M'bé in the upland, hydromorphic and lowland ecosystems. Complete fertilizer (CF) treatment (100 kg N/ha as urea, 100 kg P_2O_5/ha, 10 kg K_2O/ha as KCl, 50 kg CaO/ha as hydrated lime, 50 kg MgO/ha as $MgCO_3$, and 10 kg ZnO/ha as $ZnSO_4$) was compared with treatments in which N, P, K, Ca, Mg and Zn, respectively, were omitted, in a randomized complete Fisher block design with four replications. The cultivar IDSA 6 was planted in the upland and hydromorphic ecosystems, while Bouaké 189 was planted in the lowland ecosystem. The elements P, K, Ca, Mg and Zn were applied at planting, whereas N was applied in equal split doses at planting, tillering and flowering.

It was found that N was deficient in all three parts of the continuum, but that N deficiency symptoms were greater in the upland and hydromorphic ecosystems than in the lowland ecosystem. No deficiencies of P, K, Ca, Mg and Zn were observed in these experiments.

Future studies will determine the number of crops that can be grown before P and K deficiencies begin to occur.

PROJECT 4

DEVELOPMENT OF INTEGRATED PEST MANAGEMENT PRACTICES

Background

Crop yield losses caused by arthropod pests, diseases and weeds are generally estimated to be about 30% in West Africa. However, many rice pests and diseases occur sporadically, with the result that the entire crop may occasionally be destroyed.

Damage caused by stem borers in a rice plant

Although modern production technology can increase the food production and incomes of resource-poor farmers, it is now known that the indiscriminate use of chemical inputs can have serious effects on both the environment and human health. In addition, the intensification of agriculture among resource-poor farmers in developing countries cannot depend on the use of expensive, imported chemicals. Clearly, more economically rational and ecologically friendly approaches are needed.

It is for these reasons that WARDA has initiated an integrated pest management research project. Integrated pest management has been successfully introduced in rice production systems in Asia, where it has led to a substantial decrease in pesticide use. However, the use of pesticides on West African rice is still very low. Under these circumstances the major contribution of an integrated management approach would be to reduce the yield losses caused by pests and diseases through improving the effectiveness of traditional control practices and natural regulatory mechanisms.

Crucial to the development of acceptable integrated pest management practices for rice in West Africa is a better understanding of pest problems. This requires the identification of the most serious pests as well as the study of their biology, etiology and ecology. On this basis, cultural and biological control methods can be developed and integrated with the development and use of resistant cultivars.

The considerations guiding WARDA's approach to integrated pest management are:

- the concept of key pests
- the improvement of traditional practices
- human health and safety
- the ease with which control methods can be implemented
- the preservation and enhancement of natural control agents
- minimal disturbance of the environment

In 1991, research was conducted under eight sub-projects, focusing on:

- grain yield losses caused by insect pests in the uplands
- lowland insect pest populations and their effects on grain yields
- the effect of soil moisture on *Trichispa* damage
- resistance to blast disease
- characterization of rice blast
- rice yellow mottle virus detection and distribution
- resistance to leaf scald
- resistance to brown spot

Grain Yield Losses caused by Upland Rice Insect Pests

Elvis A. Heinrichs

The relative importance of the many pests attacking rice in West Africa is not well understood. In particular, few studies have been conducted to identify the different crop growth stages at which yield losses are caused.

In 1991, a study was launched on the abundance of insect pests and their effects on grain yields under upland conditions at M'bé. In this study, pesticides were used in heavy enough doses in the treated plots to reveal the pattern of pest damage throughout the crop cycle. The information obtained will help develop more precise control measures that minimize the use of pesticides by ensuring their application at the appropriate growth stage.

IDSA 6, a 125-day upland rice variety, was sown in 100 m^2 plots at a spacing of 25 cm within and between rows. Fertilizer NPK (10-18-18) was applied at 150 kg/ha before sowing, and urea was broadcast at 75 kg/ha 30 days after sowing. To control weeds, Ronstar was sprayed on the soil at a rate of 4 l/ha 1 day after sowing.

The insecticide treatments were:

1 No insecticidal protection (control)
2 Weekly sprays of fenitrothion at 0.5 kg a.i./ha
3 Weekly sprays, except at the vegetative stage
4 Weekly sprays, except at the reproductive stage
5 Weekly sprays, except at the ripening stage
6 Weekly sprays of fenitrothion + weekly applications of Carbofuron granules at 1 kg a.i./ha, broadcast on the soil and then incorporated

Treatments were replicated three times in a randomized complete block design. Insect counts and visual estimates of plant damage were recorded weekly. Percentage yield losses were determined by the following formula:

$$y = \frac{y^6 - y^t}{y^6} \times 100$$

where:
y^6 = yield under treatment using both fenitrothion and Carbofuron
y^t = yield of particular treatment

Deadhearts caused by stem borers were highest in treatments 1 (3%) and 3 (4%), in which there was no protection at the vegetative stage, and lowest in treatment 6 (0.5%). The most abundant insect pests, indicated by sweep net counts, were the stem borer *Diopsis longicornis* (6/50 sweeps)), the leaf-feeding beetle *Chnootriba similis* (3), the white leafhoppers *Cofana spectra* (5) and *C. unimaculata* (4) and the pollen feeder *Diaperasticus* sp. (4). Among the predaceous arthropods, spiders were the most abundant (5/50 sweeps).

Grain yield was highest (nearly 2.5 t/ha) in treatment 6 (Table 16). The lowest yields (1.54 t/ha) occurred in treatment 1, where there was a loss of 38%. Most of the insect damage occurred at the vegetative stage, resulting in low yields in treatment 3 of 1.62 t/ha, compared with yields of 2.21 t/ha and 2.25 t/ha in treatments 4 and 5, when the reproductive and ripening stages, respectively, were not protected.

TABLE 16
Grain yields of IDSA 6 under various insect control treatments in the upland ecosystem at M'bé, Côte d'Ivoire, 1991 wet season

Treatment	Yield (t/ha)	Yield loss[1] (%)
1 No protection (control)	1.54	38.2
2 Complete protection (weekly sprays)	2.02	18.9
3 No protection at vegetative stage	1.62	34.9
4 No protection at reproductive stage	2.21	11.2
5 No protection at ripening stage	2.25	9.6
6 Complete protection (weekly sprays + granules)	2.49	—
Mean	2.02	
CV (%)	6.79	
SE ±	6.08	

1 Calculated using the formula on page 54

Further studies will be conducted to determine yield losses more accurately, identify the species responsible for losses and obtain more detailed information on natural enemies.

Lowland Rice Insect Pest Populations and Their Effect on Grain Yields

Elvis A. Heinrichs

A study was conducted under irrigated lowland conditions at M'bé to determine the abundance of insect pests and their natural enemies, and to assess the effect of key pests on grain yields. The rice variety IR 5931-110-1, a 125-day variety, was transplanted into 100 m^2 plots (25 cm spacing within and between rows). Fertilizer NPK (10-18-18) was incorporated into the soil at 150 kg/ha before transplanting and urea was applied at 75 kg/ha at 30 days after transplanting. To control weeds, tamariz + herbazol was applied at 5 +1 l/ha, 15 days after transplanting. The treatments were:

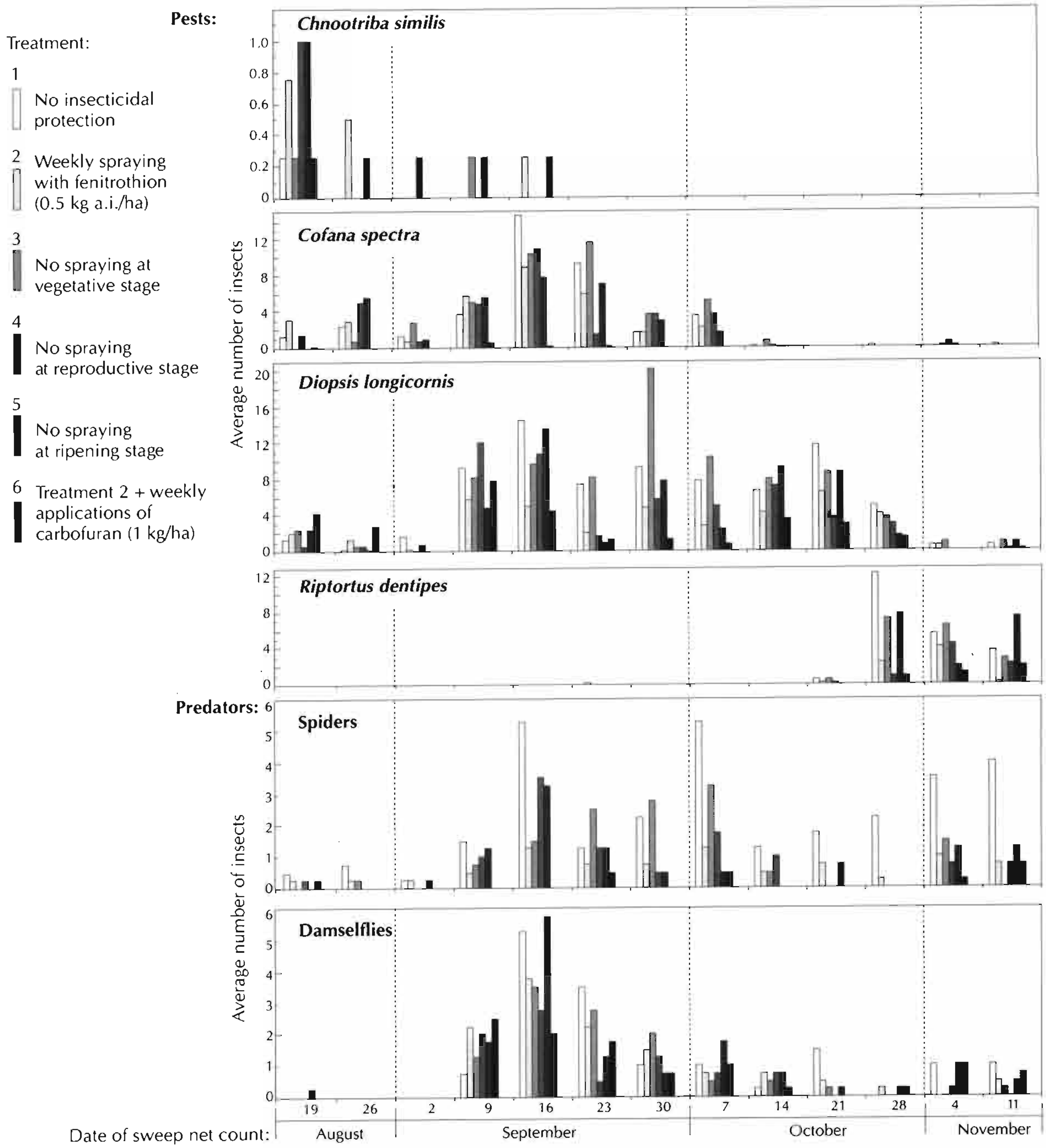
1 No insecticidal protection (control)
2 Weekly sprays of fenitrothion at 0.5 kg a.i./ha
3 Weekly sprays, except at the vegetative stage
4 Weekly sprays, except at the reproductive stage
5 Weekly sprays, except at the ripening stage
6 Weekly sprays of fenitrothion + weekly applications of Carbofuran granules broadcast into paddy water at 1 kg/ha

Each treatment was replicated four times and arranged in a randomized complete block design. Insect counts and estimates of plant damage (deadhearts and whiteheads) were made weekly throughout the cropping season. Insects were collected with a sweep net and counted in the laboratory.

A total of 36 different insect species belonging to seven orders were collected. The abundance of individual species varied throughout the crop season. With regard to plant damage, deadhearts and whiteheads were generally highest (9% and 7%, respectively) in treatment 1, with no protection, and lowest (7% and 2%, respectively) in treatment 6, with dual insecticide protection. *Maliarpha separatella* was the most abundant stem borer in the stems, confirming the results obtained in the sweep net counts.

The abundance of four major pests and two predators is given in Figure 14 (*overleaf*). The leaf-feeding beetle *Chnootriba similis* attacked the crop at an early growth stage. These attacks were followed by those of the leaf hopper *Cofana spectra*. The stalk-eyed fly *Diopsis longicornis,* a stem borer, occurred throughout the cropping season but was most abundant between 4 and 10 weeks after planting, during the vegetative and reproductive stages. The grain-sucking bug *Riptortus dentipes* occurred only in the grain development phase. The predators — spiders and damselflies — occurred throughout the cropping season. Both pest and predator populations were highest in the unprotected plots.

FIGURE 14
Sweep net counts taken at weekly intervals of rice insect pests and their predators on IR 5931-110-1 grown under different insecticide treatments in irrigated, lowland conditions in M'bé valley, Côte d'Ivoire, August to November 1991



Grain yields were highest in treatment 6 (sprays + granules) and lowest in treatment 1 (no protection) (Table 17). Yields in the unprotected treatment were 1.39 t/ha lower than those in treatment 6, representing a yield loss of 22%.

TABLE 17
Grain yields of IR 5931-110-1 as affected by insect control treatments at various plant growth stages under irrigated lowland conditions at M'bé, Côte d'Ivoire, 1991 wet season

Treatment	Yield (t/ha)	Yield loss[1] (%)
1 No protection	4.85	22.3
2 Complete protection (weekly sprays)	5.05	19.1
3 No protection at vegetative stage	5.28	15.4
4 No protection at reproductive stage	5.99	4.0
5 No protection at ripening stage	6.18	1.0
6 Complete protection (weekly sprays + granules)	6.24	—
Mean	5.60	
CV (%)	13.00	
SE ±	0.36	

1 Calculated using the formula on page 54

In spite of the application of both sprays and granules in treatment 6, some insect damage was still observed. Studies in 1992 will use a more effective insecticide treatment to obtain a more accurate estimation of yield loss. Studies on natural enemy populations will be conducted in greater detail.

Effect of Soil Moisture on *Trichispa sericea* Damage

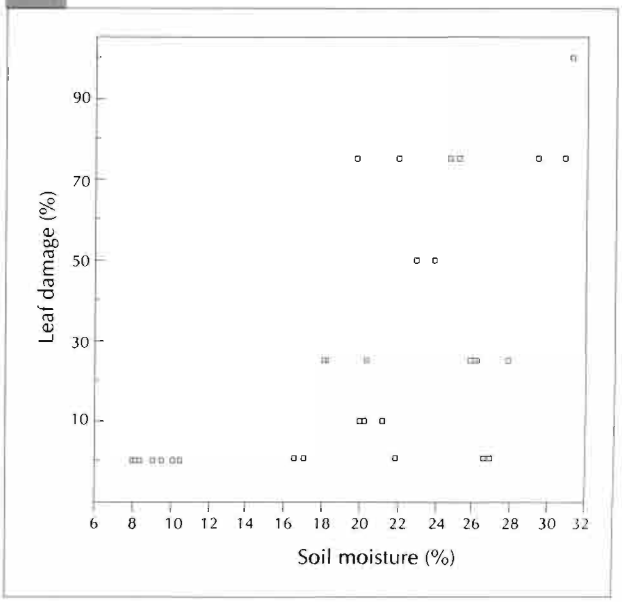
Elvis A. Heinrichs

Trichispa sericea (Coleoptera: Hispidae) feeds on the leaves of rice. Adults feed externally while the larvae mine within the epidermal layers. The damage caused varies along the toposequence, being most severe at the lower end, where water is frequently present on the soil surface. A study was conducted in 1991 to quantify this relationship.

An upland rice variety, IDSA 6, was planted in four 25 m² plots at various intervals along the toposequence. The treatments consisted of plots with fertilizer (NPK 10-18-18 at 150 kg/ha) and without fertilizer. At the peak occurrence of *T. sericea*, leaf area damaged and percentage soil moisture at a depth of 0-20 cm were recorded. Sampling was carried out in 10 areas (each 1 m²) in each plot, from the valley bottom up the toposequence to an area in the hydromorphic ecosystem where no *T. sericea* damage occurred.

T. sericea damage was significantly correlated with soil moisture percentage in both fertilized and unfertilized plots ($r^2 = 0.47$, $P < 0.001$) (Figure 15). Leaf damage ranged from 0% to 100% and soil moisture from 8% to 32%. High leaf damage occurred only at moisture levels above 18%. The mechanisms involved were not determined, but it appears that upland rice plants growing in standing water constitute attractive hosts for *T. sericea*. The humid environment in wet areas may be attractive to ovipositing *T. sericea* adults.

FIGURE 15
Relationship between soil moisture (0-20cm depth) and leaf damage caused by *Trichispa sericea* on unfertilized rice variety IDSA 6, along the continuum, M'bé, Côte d'Ivoire, 1991 wet season



Trichispa sericea damage is most severe in the lower lying areas of the upland/inland continuum, where the water table is highest

Studies in 1992 will continue to quantify the relationship between moisture levels and *T. sericea* damage and to determine the effect of leaf damage on rice yields. This will reveal the importance of *T. sericea* at different levels of the toposequence, enabling an assessment to be made of the need to develop specific *T. sericea* management strategies.

Key Site Identification and Sources of Durable Resistance to Blast

Abdoul Aziz Sy, Monty P. Jones and Elvis A. Heinrichs

In spite of extensive research to develop control methods, rice blast continues to be a major problem in rice growing areas throughout the world. The genetic variability of the pathogen, *Pyricularia oryzae*, has enabled it to overcome the resistance introduced into rice cultivars by breeders. WARDA's research on blast during 1991 concentrated on identifying and characterizing locations where blast pressure is sufficiently severe to conduct field evaluation of germplasm (key site identification). The objective is to determine the genetic variability of the rice blast pathogen present. Breeding for resistance can then be targeted at developing cultivars with durable resistance to all the pathogen races commonly found in West Africa.

The 1991 studies were conducted at both upland and irrigated lowland sites. Upland studies took place at Farako-Bâ in Burkina Faso and at Man and M'bé in Côte d'Ivoire; 36 rice cultivars were tested at each site. Studies under irrigated lowland conditions were conducted at Karfiguela in Burkina Faso, and at Man and M'bé. At both the upland and lowland sites, cultivars were replicated four times and plots were arranged according to Decreasing Inoculum Trial for Evaluation of Resistance (DITER) standards, with main plots of 10 m^2. The degree of blast pressure was assessed on the basis of both incidence (I, percentage of diseased plants) and severity (S, percentage of leaf area destroyed).

In terms of incidence, pressure under upland conditions was highest at Farako-Bâ, but in terms of severity it was highest at Man. Both incidence and severity were lowest at M'bé. This may be because rice has been cultivated for only a few years at the WARDA experimental site at M'bé, whereas it has been cultivated for many years at Farako-Bâ and at Man. In terms of incidence and severity, the most resistant upland entries at Man were CG 14, WAB 56-125, CG 20, IAC 164, ITA 329, ITA 333, WABC 165, WAB 56-14 and WAB 99-1-1. Over all sites, the most resistant entries (I < 50% and S < 10%) were WAB 56-14 and WAB 32-55. Under irrigated lowland conditions, the mean incidence of leaf blast was 94% and 42% at Karfiguela and M'bé, respectively, while mean severity was 2% and 6%. At M'bé the incidence of neck blast, based on an evaluation of 4400 panicles of cultivar IDSA 6, ranged from 7% to 42%, with a mean of 11%.

Studies in 1992-94 will emphasize further identification of key sites for use in breeding programs, blast resistance heritability, the use of the molecular approach in blast epidemiology and the development of blast-resistant cultivars

Characterization of Rice Blast

Abdoul Aziz Sy

In January 1991, a collaborative study involving CIAT, IRRI and WARDA was launched to characterize populations of the rice blast fungus, *Pyricularia oryzae*. The major objectives of the study are to assess the genetic diversity of *P. oryzae* populations in various regions of the world, to investigate the inter-fertility of these populations, to determine the virulence pattern of molecular phenotypes, and to characterize upland sites for screening and evaluation.

Studies were conducted in Colombia, the Philippines and Côte d'Ivoire. At M'bé, 20 entries were evaluated in microplots using the design developed by Marchetti. Test entries were separated by three rows of the resistant cultivar, and plots were bordered with spreader rows planted at each end of the rows of test entries and the resistant cultivar. Disease levels were recorded twice a week using the Castano and Zaini rating scale.

The results indicated a range of disease severity from 1% for IRAT 216 to 38% for Kinandang Patong. Cultivars BR 21, KU 115, Danau Laut Tawar, IRAT 13, IRAT 104, Moroberekan, IAC 165 and HD 14 all had low values of between 0.5% and 1.8%, while CO 39 and Yamada Baki had values of 24% and 20%, respectively.

The characterization study will continue in 1992 at M'bé, using a newly developed blast nursery facility to increase blast pressure. Scientists at Washington State University will conduct molecular analyses of blast samples from West Africa provided by WARDA. Both WARDA and CIAT will evaluate cultivars developed at CIAT and assist IRRI in the evaluation of progeny from the cross of blast-resistant Moroberekan with CO 39. These collaborative studies will provide information on the polymorphism and variability of blast pathogen populations and on the use of DNA probes for epidemiological purposes. The studies will also provide criteria for the selection of blast screening sites. National research programs will collaborate in the mapping of blast pathogen populations in West Africa.

Rice Yellow Mottle Virus Detection and Distribution at M'bé and Gagnoa

Abdoul Aziz Sy, Elvis A. Heinrichs and Monty P. Jones

The problem of RYMV disease has repeatedly been reported, primarily in lowland areas of Burkina Faso, Côte d'Ivoire, Niger, Nigeria and Sierra Leone. Susceptibility is evident in several recommended cultivars, including Jaya, BG 90-2 and Bouaké 189. Despite evidence that this disease is spreading and increasing in importance throughout West Africa, relatively little research is being done on it by national programs. WARDA and national scientists recently identified RYMV as one of their major research priorities.

Rice yellow mottle virus in a farmer's irrigated lowland field, M'bé

In 1991, potential screening sites for RYMV were identified and germplasm screening began. All experiments on station at M'bé and on farmers' fields in the M'bé area were surveyed for incidence and severity of the disease. Eighty entries of the African Rice Yellow Mottle Virus Evaluation and Screening Set (ARYMVESS) from the International Network for Genetic Evaluation of Rice (INGER) were assessed at the Institut des Savannes (IDESSA) at Gagnoa. WARDA breeding lines and other selected entries were also evaluated at IDESSA. Twenty entries were evaluated under lowland irrigated conditions at M'bé. Entries with RYMV symptoms were subjected to serological diagnosis consisting of gel diffusion on an agar medium.

The results indicated that RYMV pressure at Gagnoa and M'bé was low. Among the 80 ARYMVESS entries which were screened at Gagnoa, only 21 were infected with RYMV, with the percentage of infected plants ranging from 2.7% to 16.6%. In the second trial conducted at Gagnoa, IRAT 104, IRAT 170, Bouaké 189, BG 90-2, WAB 56-125, IR 3143-2-8-6 and TOX 3107-53-1-2-2 had typical RYMV symptoms. Observations in another trial conducted by IDESSA indicated that, in cultivars IM 16 and Jaya, 75% and 80% of the plants were infected, respectively. In the various experiments at M'bé, Bouaké 189, TOX 3118-6-E2-3-2 and ITA 322 were observed to be infected. In the irrigated lowland evaluation of 20 entries, disease pressure was extremely low,with the percentage of infected plants ranging from 1.2% to 16.9% at 115 days after sowing.

In 1992 evaluation of germplasm for resistance to RYMV will continue at the same sites and at additional sites where pressure is greater.

Screening for Sources of Leaf Scald Resistance

Abdoul Aziz Sy and Monty P. Jones

In parts of West Africa leaf scald (*Gerlachia oryzae/Monographella albescens*) has become a serious disease of both upland and lowland rice. In 1991 a study was conducted to evaluate the IDESSA station at Man as a screening site for leaf scald and to determine the resistance of selected cultivars.

Two trials were conducted, one each under upland and irrigated lowland conditions. The former consisted of 36 cultivars, the latter of 20. In both trials cultivars were planted in 10 m^2 plots, with each cultivar replicated four times.

Leaf scald pressure was high in both ecosystems. In the upland trial incidence ranged from 42% for CG 14 to 69% for ITA 254 at 84 days after sowing. In the lowland trial, at 81 days after sowing incidence ranged from 80% to 100%, with ITA 304, ITA 308, ITA 310, ITA 312, ITA 316 and ITA 320 showing 100% incidence. The lowest incidence, 80%, occurred in ITA 326. Mean severity ranged from 18% in ITA 326 to 28% in ITA 310. These results confirmed that leaf scald pressure at Man is high enough to provide a reliable site for evaluating cultivars.

In 1992, a set of 30 entries will be screened simultaneously at Man, at Karewa and Ndop in Cameroon and at Uyo in Nigeria.

Screening for Brown Spot Resistance

Abdoul Aziz Sy and Monty P. Jones

Brown spot (*Dreschlera oryzae*/teleomorph *Cochliobolus miyabeanus*) has been reported in all the major rice growing areas of Africa, Asia and the Americas. The economic importance of this disease was demonstrated by its role in the Bengal famine of 1942, when rice yield losses were as high as 90% in some areas. In West Africa, brown spot has been ranked by WARDA and national scientists as the second most important rice disease after rice blast.

In 1991 a study was conducted under lowland irrigated conditions at the IDESSA station at Man to evaluate the usefulness of the site for screening purpose and to assess the resistance of selected cultivars. Observations were made on 20 cultivars replicated four times in a randomized complete block design. The severity of brown spot, based on the percentage of leaf area destroyed, was recorded at 81 days after sowing.

Severity ranged from 2% for ITA 322 to 30% for ITA 306. Other entries with a low severity rating were ITA 316 (3.5%), ITA 320 (4.3%) and ITA 324 (3.3%). However, there was low brown spot pressure at Man, precluding the use of this location as a key site for screening.

Further studies in 1992 will concentrate on the identification of key sites for screening. The effect of agronomic factors such as tillage, soil fertility and water regime on disease incidence and severity will also be investigated.

PROJECT 5

DEVELOPMENT OF IMPROVED RICE VARIETIES

Background

Improved rice varieties with higher and more stable yields are needed for both the major ecosystems of the upland/inland swamp continuum — the upland/hydromorphic and the hydromorphic/lowland ecosystems. Work based at WARDA's Main Research Center at M'bé, Côte d'Ivoire, focuses on the development of upland rice varieties, while that based at IITA in Ibadan, Nigeria concentrates on the development of varieties adapted to the rainfed and irrigated lowlands. Research at both locations emphasizes the targeting of varieties to specific niches in a systems approach that takes into consideration environmental and socio-economic factors, as well as biotic and abiotic stresses.

Upland rice breeding activities in 1991 focused on the selection of plants with resistance or tolerance to major stresses, including blast, grain discoloration, leaf scald, sheath blight, drought and acid soils. Observational and yield trials were conducted in Côte d'Ivoire on promising selections under two levels of management in a wide range of environmental conditions at Man, Odienne and M'bé. Man is in the humid forest zone and has a monomodal rainfall pattern, Odienne is in the savanna zone and also has a monomodal rainfall pattern, and M'bé is in the forest-savanna transition zone and has a bimodal rainfall pattern. During 1991 rainfall at the three locations was 1540 mm, 1490 mm and 940 mm, respectively.

Lowland breeding activities in 1991 focused on yield stability under this ecosystem's highly variable conditions, as well as on yield gains. Plants were selected for resistance or tolerance to the following major disease and insect pest problems: blast, grain discoloration, sheath blight, RYMV, stem borers and gall midge. Among the major abiotic stresses studied were drought tolerance , flooding and water stagnation, submergence and iron toxicity.

Screening for Adaptation to Upland Conditions

Monty P. Jones

WARDA's upland/inland swamp continuum program has now evaluated over 4000 varieties/lines received from Asia, Latin America and Africa. These materials were screened in on-station trials between 1985 and 1991 for their adaptation to upland/hydromorphic conditions. About 30 promising varieties were selected for further yield trials or for use in the crossing program. In addition, new materials with desirable traits are constantly being developed by WARDA and other institutions. These too must be evaluated.

During 1991, 328 new introductions from Asia, Latin America, and INGER-Africa and 112 fixed lines harvested in bulk from 1990 pedigree nurseries were evaluated at Man, Odienne and M'bé. The test entries were established in single plots consisting of four rows, 5 m long and 25 cm apart. Seeds were drill-planted at the rate of 60 kg/ha. Fertilizer N was applied at the rate of 60 kg/ha in three equal doses. P_2O_5 and K_2O were applied as basal fertilizer at 40 kg/ha. Weeding was done manually or combined with Ronstar at 4 l/ha, 1 day after sowing. A total of 188 lines were selected for further study based on seedling vigor, plant type, growth duration and reaction to drought and diseases, notably leaf and neck blast, sheath rot and glume discoloration.

Crop stand was good throughout the growth cycle at M'bé. At Odienne the entries were severely affected by termites during the vegetative phase and by periodic drought stress, blast, glume discoloration and high spikelet sterility. At Man, there was severe leaf scald and leaf and neck blast attack. Only a few entries (WAB 181-37, TOX 1889-6-102-1-1-3 and CT 6947-7-1-1-1-7-M) showed consistently good performance at all three locations. The 188 selected lines will be entered in yield trials in 1992.

Screening Promising Upland Rice Selections for High and Stable Yield Potential

Monty P. Jones

To identify high and stable yielding varieties for the uplands, yield trials are being conducted of promising varieties and advanced lines selected from the previous season.

In 1991 two observational yield trials, comprising 149 entries, four preliminary yield trials and two advanced yield trials, each consisting of 20 entries, were conducted at M'bé, Man and Odienne to evaluate the performance of rice varieties under a range of environmental conditions. The two advanced yield trials consisted of early- and medium-duration entries, while the four preliminary yield trials had entries of very early, early, medium and late duration. The observational yield trials were established using single plots (2 x 5 m), with the check varieties WABC 165 and IDSA 6 replicated after every 20 test entries. For the preliminary and advanced yield trials a randomized complete block design was used, with 3 x 5 m plot sizes and four replications. Seeds were drill-planted in rows spaced 25 cm apart. Fertilizer was applied at a rate of 60-40-40 (N, P_2O_5, K_2O) kg/ha, with N applied in three equal doses, and P_2O_5 and K_2O applied basally. The herbicide Ronstar was also applied, at a rate of 4 l/ha, 1 day after sowing.

From the observational yield trials 18 varieties and advanced lines were selected that had outyielded the best check plots by 4% to 22%. A further 28 entries were selected for good seedling vigor, earliness, plant height, grain quality and resistance/tolerance to blast, sheath rot, glume discoloration and drought. The highest yielding entries (1890-4050 kg/ha) were WAB 99-25, WAB 99-21, WAB 181-18, CNA 4136, WAB 56-57 and IRAT 144.

In the replicated preliminary and advanced yield trials, grain yields were higher at M'bé than at Man and Odienne (Tables 18 and 19). Leaf and neck blast, sheath rot and glume discoloration were the major diseases recorded at Man and Odienne. Drought stress and termite damage were also severe at Odienne, where most of the entries showed poor adaptation. The highest yielding entries were WAB 99-25, WAB 99-21, WAB 181-18, CNA 4136, WAB 56-57 and IRAT 144 at M'bé; WAB 99-5, WAB 99-16, WAB 181-18, WAB 56-125, WAB 32-133 and IDSA 46 at Man; and IDSA 10, WAB 56-39, WAB 96-1-1, WABC 125, WAB 99-7 and WAB 56-104 at Odienne. Entries that showed moderate tolerance (scores from 1 to 3) to drought stress at Odienne were IRAT 291, WAB 99-16, ITA 301 and CNA 6711. Entries that showed moderate resistance (scores from 4 to 5) to blast at both Odienne and Man were WAB 56-104, WAB 99-7, IRAT 229, IRAT 209, CNA 6656, WAB 96-8, WAB 181-46, NDR 97 and IDSA 6.

TABLE 18
Performance of the three highest yielding and check varieties in preliminary yield trials of short-duration entries conducted under upland conditions at Man, Odienne and M'bé, Côte d'Ivoire, 1991 wet season

Entry	Grain yield (kg/ha)	Plant height (cm)	Days to maturity	Stress resistance rating[1] Leaf blast	Neck blast	Glume discoloration	Drought stress
Man (forest zone, monomodal rainfall)							
WAB 99-7	2700	100	104	2	4	2	1
WAB 99-17	2520	93	108	4	6	3	1
CNA 762 069	2450	99	107	2	4	1	0
WABC 165 (check)	2300	110	105	1	2	2	0
Mean of 20 entries	2380	98	105	3	5	2	1
CV (%)	17						
SE ±	195						
Odienne (savanna zone, monomodal rainfall)							
WABC 165 (check)	910	102	102	5	3	3	5
WAB 99-7	830	88	103	3	1	3	5
WAB 56-104	820	87	100	3	1	5	7
Mean of 20 entries	840	89	105	5	3	3	7
CV (%)	48						
SE ±	174						
M'bé (transition zone, bimodal rainfall)							
WAB 99-25	3860	116	97	2	1	1	0
WAB 99-21	3810	110	94	1	1	2	0
WAB 181-18	3690	114	108	1	1	1	0
WABC 165 (check)	3130	123	101	1	1	2	0
Mean of 20 entries	3310	114	99	2	1	2	0
CV (%)	17						
SE ±	100						

1 Scored according to the Standard Evaluation System for Rice developed by IRRI (0 = no damage, 9 = dead plant)

TABLE 19
Performance of the three highest yielding and check varieties in advanced yield trials of short-duration entries conducted under upland conditions at Man, Odienne and M'bé, Côte d'Ivoire, 1991 wet season

Entry	Grain yield (kg/ha)	Plant height (cm)	Days to maturity	Stress resistance rating[1] Leaf blast	Neck blast	Glume discoloration	Drought stress
Man (forest zone, monomodal rainfall)							
WAB 56-125	2700	97	114	1	1	1	0
IDSA 46	2520	91	114	3	3	3	1
WAB 32-133	2450	107	109	3	6	2	0
WABC 165 (check)	2430	114	114	1	2	1	0
Mean of 20 entries	2250	100	112	2	3	2	0
CV (%)	17						
SE ±	195						
Odienne (savanna zone, monomodal rainfall)							
WABC 165 (check)	1230	106	103	3	1	3	6
WAB 56-104	880	83	98	3	2	4	5
ITA 257	835	86	99	3	3	3	5
Mean of 20 entries	550	93	107	4	3	3	5
CV (%)	77						
SE ±	172						
M'bé (transition zone, bimodal rainfall)							
CNA 4136	4090	122	98	0	1	1	0
WAB 56-57	3960	107	93	0	1	1	0
IRAT 144	3760	114	101	1	1	1	0
WABC 165 (check)	3480	116	96	0	1	1	0
Mean of 20 entries	3250	113	100	0	1	1	0
CV (%)	18						
SE ±	300						

1 Scored according to the Standard Evaluation System for Rice developed by IRRI (0 = no damage, 9 = dead plant)

Selected varieties/lines will be promoted for further yield trials during 1992 and the most promising lines will be nominated for regional trials in 1993.

Screening Upland Materials for Drought Tolerance

Monty P. Jones and Kanwar L. Sahrawat

Drought tolerance is perhaps the single most important attribute for stabilizing rice grain yields in farmers' fields in the upland and hydromorphic parts of the continuum. Past efforts to screen large numbers of entries for drought tolerance under field conditions have had only limited success because of climatic variability. There is an urgent need to develop a simple and reliable technique for mass screening throughout the year.

In the 1991-92 dry season, 1500 entries were screened for tolerance to drought stress at various growth stages, either as varieties per se or as potential donors. The use of controlled sprinkler irrigation in drought tolerance trials, as developed by IRRI, was also assessed. The entries were of improved and traditional *Oryza sativa* and *O. glaberrima* origin. They were sown in single 1 m rows with the tolerant (OS 6) and susceptible (IR 20) check varieties repeated after every 20 test entries. The sprinkler irrigation system created three water regimes (10 mm, 5 mm and 2.5 mm per day) for 15 days, after which irrigation was stopped and the plants were subjected to drought stress for 30 days. A second set of the same 1500 entries was grown separately and irrigated at 10 mm per day for 45 days, after which it was subjected to drought stress for 30 days during the reproductive phase. Each entry was replicated once at each moisture level.

After 22 days of drought stress, scores for drought tolerance ranged from 3 to 9 (1 = normal plant growth, 9 = all plants apparently dead). Only 2% of the entries were rated as tolerant at the vegetative phase, while 20% appeared moderately tolerant or moderately susceptible. These results underline the need to develop varieties with greater tolerance to drought. Among the best entries were some traditional varieties of *O. glaberrima* and *O. sativa*, namely D4, D8, INC 4, 63-83 and SAKOU, and two promising advanced lines, WAG 100-B-21-H1 and WAB 297-B-B-4-H2.

These screening activities will continue in 1992.

Upland Rice Germplasm Characterization and Improvement

Monty P. Jones

Since 1984, over 1000 traditional cultivars of *Oryza sativa* (469) and *O. glaberrima* (532) have been collected by WARDA from the West African region. To date, these have not been characterized beyond initial observations of plant height, duration and yield potential. There is a need to complete the characterization of this germplasm, as well as to collect and characterize wild relatives with the A genome. It is also necessary to further evaluate and select promising lines from the 586 F_3-F_7 populations which are available from WARDA crosses.

During 1991, a total of 416 accessions of *O. sativa* (368) and *O. glaberrima* (48) origin were characterized for 48 morpho-agronomic traits. All entries were sown in single plots consisting of four rows, each 5 m long, with a 25 x 25 cm spacing and one seedling per hill. The fertilizer applications were 60-40-40 (N, P_2O_5, K_2O) kg/ha for high-input treatments and 40 kg N/ha for low-input treatments.

Most entries were of intermediate to tall stature (120-140 cm) and early to medium duration (110-130 days). Some entries, including a few *O. glaberrima*, had good plant type that suppressed weed growth. Grain size and shape varied considerably, with some entries having long, slender and translucent grains. Panicles were generally large. Over 100 F_4-F_7 individuals were selected from the segregating populations and 103 fixed lines were bulk harvested for further studies during 1992 (Table 20).

TABLE 20
F_3-F_5 populations with a large number of agronomically desirable traits, screened at M'bé, Côte d'Ivoire, 1991 wet season

Population	Parents	Desirable traits
WAB 376 (F_3)	TGR 68 WAB 56-125	Good grain shape Improved plant type High tillering Resistance to diseases and drought Medium stature
WAB 384 (F_3)	ITA 184 ROK 16	Improved plant type Large, well-exserted panicles Resistance to blast and glume discoloration
WAB 326 (F_5)	ITA 235 WABC 165	Improved plant type Good grain characteristics Heavy panicles

Donor parents of *O. sativa* and *O. glaberrima* origin have been identified and included in the hybridization block for crossing aimed at combining tolerance/resistance to drought stress, blast and acidity with improved characters needed for adaptability, high yields and yield stability.

This work will continue in 1992.

Farmer Perceptions of Improved Upland Rice Varieties in Côte d'Ivoire

Akinwumi A. Adesina and Monty P. Jones

The results of recent adoption studies conducted by WARDA in the mangrove swamp rice environment show that farmers' perceptions of varietal specific traits strongly condition adoption behavior (*see* page 23).

In 1991, an interdisciplinary survey was conducted to study farmers' perceptions of the agronomic and qualitative traits of five improved rice varieties tested by WARDA in on-farm trials in Côte d'Ivoire. The range of varietal attributes surveyed included: tillering capacity; plant height; panicle length and shape; panicle weight; panicle exsertion; duration; drought, disease and insect pest tolerance; yield; and ease of threshing and milling. Some 52 farmers participated in the on-farm tests carried out in five locations representing the forest, the forest-savanna transition and the savanna agro-ecological zones of Côte d'Ivoire. Farmers and their spouses were interviewed at different growth stages of the crop and during post-harvest operations.

The survey results (Table 21) indicate that farmers rated their traditional varieties as having several highly desirable traits, including tillering capacity, height and panicle exsertion. Tillering capacity is especially important to farmers, who have noted its close correlation with high yields. About 35% of farmers rated traditional varieties as having 'very good' tillering capacity, while 60% rated them as 'good'. The best improved variety for this trait was WABC 165, which 12% of farmers rated as possessing 'very good' tillering capacity and an additional 64% of farmers rated 'good'. Plant height is considered important because of the panicle method of harvesting commonly practised by women. Women complained that short varieties are more difficult to harvest and said that they preferred varieties between 1 m and 1.3 m tall. The improved varieties WABC 165 and WAB 56-125 were preferred by 96% and 58% of farmers, respectively, as having desirable plant height. However, IDSA 10, a variety with large grains, appreciated by some farmers, and the variety ITA 257 were judged 'too short' by 58% and 61% of farmers, respectively.

TABLE 21
Farmer preferences for the traits of five improved and local varieties tested in on-farm trials, Côte d'Ivoire, 1991

	% of farmers in survey[1]					
Traits	**IDSA 10**	**ITA 257**	**WAB 56-104**	**WAB 56-125**	**WABC 165**	**Local**
Tillering capacity						
very good	2	2	2	2	12	35
good	46	35	34	46	64	60
weak	35	35	37	21	5	1
poor	17	28	27	31	19	4
Plant height						
too tall	0	0	0	0	0	25
tall	5	6	17	58	96	73
too short	58	61	35	7	2	2
medium height	37	33	48	35	2	0
Panicle exsertion						
very good	0	0	2	4	12	37
good	15	51	54	90	88	62
average	14	14	25	6	0	0
poor	71	35	19	0	0	1
Ease of threshing						
very easy to thresh	5	0	2	4	15	0
easy to thresh	87	65	79	88	79	92
difficult to thresh	8	35	19	8	6	4
very difficult to thresh	0	0	0	0	0	4
Number of grains per panicle						
high	56	70	65	60	96	100
medium	40	22	31	38	4	0
low	4	8	4	2	0	0

1 N = 52

Good panicle exsertion is important because panicles are harvested singly, using hand knives. Poor exsertion increases the time spent by women harvesting as they have to separate the flag leaf from the panicle axis before cutting. About 36% of farmers judged their traditional varieties as having 'very good' exsertion. WABC 165 and WAB 56-125 were judged by 88% and 90% of respondents, respectively, as having 'good' exsertion.

The survey showed that local rice varieties have several desirable traits much appreciated by farmers. Evaluation of farmers' perceptions will continue in 1992, with the results being fed back into WARDA's rice breeding activities.

Breeding Improved Varieties for the Irrigated and Rainfed Lowlands

Baij N. Singh

Irrigated lowlands About 150 000 ha of the humid lowlands of West Africa are irrigated with good water control. The yield potential of such systems is high, over 5 t/ha. The appropriate plant type for this ecosystem is the semi-dwarf *indica*, similar to IR 8. Leaf and panicle blast, RYMV, stalk-eyed fly, stem borers and African gall midge are the major diseases and insect pests. The cultivars BG 90-2, ITA 212, ITA 222 and ITA 306, all widely grown in this ecology, are highly susceptible to these stresses.

During 1991 a total of 280 fixed lines were tested at IITA in three replicated yield trials, including an advanced yield trial, a preliminary yield trial and an observational yield trial. The objective was to select lines that are both high yielding and resistant to the major stresses. All lines were simultaneously screened for leaf blast, RYMV and gall midge in different screening nurseries.

In the advanced yield trial, TOX 3058-52-2-2-3-2 and TOX 3084-136-1-3-1-2 showed an acceptable level of resistance to blast and had significantly higher yields than ITA 212. Other promising lines were TOX 3109-73-4-5-4-1, TOX 3133-74-1-2-2-2 and TOX 3226-7-1-3-2-, which showed resistance to blast and yielded 4 t/ha. Some 16 entries were promoted from the preliminary to the advanced yield trial, and 49 entries from the observational to the preliminary yield trial. This work will continue in 1992, when promising lines will be evaluated in regional trials across West Africa.

Rainfed lowlands Rice is grown on about 600 000 ha of rainfed inland valley swamps in the West African region. Iron toxicity, drought, waterlogging, weeds, diseases and insect pests are the major problems on the swamp fringes. The specific varietal requirements for this ecosystem have not been adequately understood in the past, with the result that varieties which are suitable for the irrigated lowland areas are often grown under rainfed conditions. Farmers prefer to grow varieties such as FARO 15, Gambiaka, Gissi 27 and Suakoko 8 in lowland ecosystems. These varieties tend to be tall and have a relatively modest yield potential of between 2.5 t/ha and 3.0 t/ha. Varieties of intermediate height with good seedling vigor and resistance to major stresses are needed. Particularly important is the ability to compete with weeds, which are a major problem in this ecosystem.

During the 1991 wet season, several trials were conducted on station at IITA and on farm at Wuya, near Bida, Niger State in Nigeria. About 238 entries were tested in four replicated yield trials. In the advanced yield trial, 28 entries were transplanted and grown in four replications in a hydromorphic field under rainfed conditions. A preliminary yield trial consisting of 50 short-duration entries was grown in three replications. Another preliminary yield trial of 50 medium-duration entries was grown in three replications under hydromorphic conditions. Lastly, an observational yield trial of 110 unreplicated entries was grown. Piezometers were used to monitor the level of the water table.

Rainfall was well distributed and no drought stress was observed. In the advanced yield trial, ITA 342 had the highest yield, 5.4 t/ha (Table 22). Other promising lines were TOX 3133-75-1-2, TOX 3100-32-2-1-3-5, TOX 3552-84-1-2-3 and TOX 3100-44-1-2-3-3, all of which had yields of about 4.7 t/ha. These varieties also showed resistance to leaf blast and RYMV when they were screened separately in inoculated nurseries.

In the short-duration preliminary yield trial, two entries, TOX 3440-166-2-2-3 and TOX 3027-43-1-E3-1-1-1, had the highest yields, reaching 5.4 t/ha, and showed good resistance to both blast and RYMV. In the medium-duration preliminary yield trial, TOX 3118-47-1-1-2-3-2 and TOX 3562-15-3-3-2 had the highest yields, reaching 6.0 t/ha and 5.6 t/ha, respectively.

From the two preliminary yield trials, 56 entries were promoted to the advanced yield trial for testing in 1992. Another 51 selections were made from the observational yield trial and advanced for preliminary yield trial testing. The most promising advanced breeding lines from the advanced yield trial will be tested in regional trials organized through the Lowland Rice Breeding Task Force during the 1992 wet season.

TABLE 22
Grain yield and agronomic characteristics of entries in the rainfed lowland advanced yield trial at IITA, Ibadan, Nigeria, 1991 wet season

Entry	Grain yield (t/ha)	50% flowering (days)	Plant height (cm)	Tillers per hill (no.)	Leaf blast[1]	RYMV[1]
ITA 342	5.4	120	99	11	3	4
TOX 3133-75-1-2	4.8	109	110	10	1	3
TOX 3100-32-2-1-3-5	4.8	107	108	12	2	1
TOX 3552-84-1-2-3	4.7	106	106	10	1	1
TOX 3100-44-1-2-3-3	4.7	108	119	11	2	3
TOX 3052-39-1-2-1	4.5	107	105	9	2	1
TOX 3100-73-4-4-2-5	4.5	106	95	13	3	5
ITA 328	4.5	113	110	12	2	0
Suakoko 8	4.0	112	139	8	2	0
ITA 212 (check)	3.7	102	100	10	6	2
IR 46 (check)	3.7	106	105	13	3	1
Mean	4.1	107.0	105.0	10.0		
CV (%)	16.9	1.56	3.8	10.4		
LSD (5%)	0.97	2.34	5.7	1.5		

1 Scored according to the Standard Evaluation System for Rice developed by IRRI (0 = no damage, 9 = dead plant)

Breeding for resistance to rice yellow mottle virus Screening for RYMV-resistant donors started in 1982 at IITA, where several upland cultivars, including LAC 23, Moroberekan, OS 6 and 63-83, were identified as resistant. Since 1984 a large number of crosses have been made and resistant lines with lowland backgrounds have been recovered. Some of the resistant lines, such as TOX 3217-69-3-1, ITA 328 and ITA 316 have shown rice yield potentials of up to 4.6 t/ha.

During the 1991 wet season, 1128 lines (including the elite lowland lines in yield trials) were artificially screened in a screenhouse. Some 140 lines were found to be resistant or moderately resistant. These lines were re-tested during the 1991 dry season and will be tested in regional yield trials during the 1992 wet season.

Breeding for tolerance to African rice gall midge African rice gall midge (*Orseolia oryzivora*) has recently become a major pest in Nigeria and Burkina Faso. This species differs from the Asian gall midge, with the result that many resistant Asian lines have shown susceptibility to it. A breeding program using some moderately resistant donors was begun by IITA in 1988, with segregrating generations subsequently grown in 'hot spot' farm field sites. Screening for resistance is being carried out in collaboration with the National Cereals Research Institute (NCRI) at Badeggi, Nigeria.

On-farm trial conducted at Okot Obong, Nigeria to assess Cisadane rice resistance to African rice gall midge

During the 1991 wet season, a yield trial consisting of 32 tolerant lines was grown at IITA and Badeggi, as well as at hot spot locations at Adani and Abakaliki. Infestation in the screenhouse at Badeggi varied from 8% to 44%, and at Abakaliki from 1% to 16%. Among the tolerant lines, Cisadane had the highest yield, 4.4 t/ha, followed by BW 348-1, which yielded 4.2 t/ha (Table 23). Cisadane was also observed as tolerant at a hot spot screening site at Okot Obong, Akwa Ibom State, Nigeria. The line OB 67, which had earlier been observed to be moderately resistant, was found to be highly susceptible, both in on-farm trials in Gadza valley, near Badeggi, Niger State, and at Ikwo in Enugu State.

Cisadane seed is being multiplied in the current 1991-92 season and will be widely tested in farmers' fields during the 1992 wet season in Nigeria. A trial of elite lines organized through the Lowland Rice Breeding Task Force will also be conducted, in collaboration with national programs.

Breeding for tolerance to iron toxicity Iron toxicity can be a major problem in inland valley swamps, into which iron leaches from the surrounding upland fields. The problem is prevalent in both irrigated and rainfed lowlands. High iron content stunts the growth of rice plants, the leaves of which show bronzing or yellowing symptoms. In previous work at Suakoko, Liberia, resistant varieties such as Gissi 27 and Suakoko 8 were identified. However, these varieties are tall plant types prone to lodging and have a modest yield potential of only 3 t/ha. They have been used as donors by WARDA and IITA in crosses with lines of improved plant types such as IR 5. Breeding lines are available for yield testing.

During the 1991 wet season a preliminary yield trial with 14 entries and an observational trial with 862 lines were grown at an on-farm site at Edozhigi, near Bida, Niger State. The irrigation water had 4.1 ppm water-soluble ferrous ions, which caused severe bronzing, yellowing and stunting of plants.

In the preliminary yield trial, TOX 3050-46-E2-3-3-3 and TOX 3100-12-2-1-3-5 were least affected by iron toxicity. In the observational trial, 25 lines with a score of 1 and 67 lines with a score of 3 were considered promising.

Tolerant lines will be tested in regional trials organized by the Lowland Rice Breeding Task Force during the 1992 wet season.

TABLE 23
Grain yield and agronomic characteristics of entries in the irrigated lowland trials conducted at IITA, Ibadan, Nigeria to assess resistance to African rice gall midge, 1991 wet season

Entry	Grain yield (t/ha)	50% flowering (days)	Plant height (cm)	Tillers per hill (no.)	Leaf blast[1]	RYMV[1]
Cisadane	4.4	126	117	10	3	4
TOX 4136-30-2	4.4	130	114	10	4	8
BW 348-8	4.2	115	126	10	4	9
TOX 3876-56-1-2	4.1	115	107	11	5	8
TOX 3971-14-1-3	4.1	116	117	10	7	9
TOX 3962-28-1-1	3.9	115	102	11	4	8
ITA 212 (check)	3.8	115	106	9	6	9
RP 1045-25-2-1	3.7	131	121	9	7	9
ITA 312	3.6	111	95	11	6	9
ITA 306	3.4	115	103	10	7	9
ITA 338	3.3	116	115	12	2	7
OB 677	3.3	111	104	9	9	9
Mean	3.0	123.5	116.4	9.8		
CV (%)	23.9	3.8	13.2	2.8		
LSD (5%)	1.8	2.83	9.9	2.09		

1 Scored according to the Standard Evaluation System for Rice developed by IRRI (0 = no damage, 9 = dead plant)

Breeding lowland varieties tolerant to waterlogging Waterlogging can be a major problem in floodplains and valley bottoms with poor drainage systems. In some areas, farmers grow rice on ridges to reduce the effects of waterlogging. Early and/or deep flooding can cause submergence, leading to complete crop failure. In response to this threat, farmers grow tall, photoperiod-sensitive rice varieties, which are susceptible to lodging and have low yield potentials. It is therefore desirable to incorporate tolerance to waterlogging and submergence in improved plant type backgrounds with photoperiod sensitivity.

During the 1991 wet season, 615 advanced lines were screened in an on-station trial conducted at IITA; FR 13A was used as a tolerant check and IR 42 as a susceptible check. Ten days after transplanting, water depth was increased to 40-50 cm and it was maintained at that level for 45 days, after which it was slowly reduced. Twenty-nine entries with a score of 1 (highly tolerant) and another 153 entries with a score of 3 (moderately tolerant) were rated as superior to the checks.

These lines will be further tested in replicated yield trials in the next season. Highly tolerant lines will also be grown in regional trials and lines selected from segregating populations will be further evaluated in 1992.

Screening for drought tolerance Drought is one of the major yield loss factors for rice grown in the hydromorphic areas fringing the inland valley swamps. Lines with deep rooting systems and the ability to penetrate the hardpan are needed for these conditions.

After the 1991 rains, 978 direct-seeded lines were screened for drought tolerance at the vegetative stage using methods which had been developed at IRRI. The crop was grown for 30 days with irrigation; after this period no irrigation was provided. Scores for drought tolerance were given 35 rainless days later, when the check variety, IR 20, was almost completely dry. Ninety transplanted elite lines were also screened.

The lines showing a high degree of tolerance were ITA 235, TOX 3142-7-2-3-4, TOX 3055-10-1-1-1-2 and OS 6.

Screening for drought tolerance under hydromorphic lowland conditions will continue in 1992.

Screening for resistance to the stalk-eyed fly The stalk-eyed fly (*Diopsis* spp.) is a major insect pest of both lowland and upland rice in Africa, causing deadhearts during the vegetative stage of the rice plant. Deadhearts reduce panicle numbers and grain yields.

During the 1991 wet season, 415 improved breeding lines were screened under artificial infestation in the screenhouse at IITA. Flies were collected regularly from the field and released in the screenhouse. Tiller infestation counts were taken at 30, 45 and 60 days after transplanting.

Infestation varied from18% to 74%. Maximum infestation was recorded at 45 days. Only eight entries were found to be moderately resistant to *Diopsis* attack; 80% of the lines were found to be susceptible. Among the least infested lines were WAB 56-195, TOX 3142-2-2-1, TOX 3440-171-1-1-1-1 and Moroberekan.

Plants with no damage were grown to maturity. These lines will be tested again during the 1992 wet season.

Screening for resistance to stem borers Stem borers are major insect pests of rice in West Africa. The white stem borer (*Maliarpha separatella*), striped stem borer (*Chilo* spp.) and pink stem borer (*Sesamia* spp.) are the most common. In addition to deadheart and whitehead damage, which are visible, white stem borer larvae also feed in the stem without causing any visible symptoms.

During the 1991 wet season, 112 elite lines were screened for resistance to stem borers. Rice stems were dissected to count larvae in the tillers.

M. separatella was found to be the major pest species, with tiller infestation as high as 94% in ITA 120. Tatung 16, which was used as the resistant check on the basis of earlier results, proved less resistant than previously thought, with 53% infestation. Lines with the lowest levels of infestation (between 32% and 39%) included ITA 325, ITA 372, ITA 402, ITA 218 and ITA 318.

These and other resistant lines will be further tested in 1992.

Selecting from segregating populations Hybridization followed by pedigree selection is the major breeding method applied by WARDA for the genetic improvement of plants for the lowlands. In the past, crosses at IITA were made mainly between *indica* types, with the result that potentially useful traits for dealing with the variability of the African lowlands have not been incorporated.

During 1991, a total of 239 lines in the F_2 population from crosses which had been made in 1988 were grown in irrigated and hydromorphic plots, and individual plant selections were made. Another 6500 pedigree lines (F_3-F_8) were grown first in the leaf blast screening nursery and only those lines with resistant or moderately resistant types were transplanted. Another 1458 F_3 lines were grown for selection in waterlogged fields. Selections were made between and within progeny rows. The preferred characteristics of the selected plants included high tillering capacity, erect leaves, high number of grains per panicle, long grain and resistance to blast, sheath rot and stem borers. Semi-dwarf types were selected for irrigated lowlands, while plants of intermediate height were selected for rainfed areas. The three best plants were harvested from the segregating lines, while uniform lines were bulked for observation yield trials to be conducted in 1992.

Sahel Irrigated Rice Program

INTRODUCTION

Since the 1920s, when irrigated rice production systems were first introduced in the Sahel, rice has become a major staple in Sahelian countries. Between the mid-1960s and the mid-1980s, total rice production in the zone grew by 0.4% annually, while consumption rose by 5%.

Many Sahelian countries are making efforts to fill this growing gap by increasing irrigated rice production, which, in theory at least, has great potential in the zone. Several bilateral development projects have adapted irrigated rice technologies in the Sahel, introducing a number of varieties of Asian origin. In the 1970s and 1980s, WARDA played an active role in the Sahel by coordinating the regional selection and testing of germplasm. WARDA also conducted resource management research, with the emphasis on green manures, weed management and the development of socially appropriate and technically efficient water management systems.

However, the impact of WARDA's research was limited by the lack of a truly zonal focus. In late 1990, WARDA restructured its program to better address irrigated rice needs in the entire Sahel zone. It was considered essential to reach a better understanding of the diversity of the Sahelian growing environment and to broaden the genetically narrow, and therefore biologically vulnerable, base of rice germplasm currently found in the zone. Two research projects were initiated: the agro-ecological and socio-economic characterization of irrigated rice ecosystems and the improvement of rice germplasm. These projects will be augmented in 1992 with a regional network for diagnostic research and germplasm development.

WARDA's research for the Sahel is based at two contrasting sites: N'diaye, near the coast, with a relatively mild climate, and Fanaye, further inland, which experiences harsher conditions with greater diurnal and seasonal temperature fluctuations and lower rainfall. The N'diaye site also provides opportunities to expose plants to saline soil conditions.

PROJECT 1

CHARACTERIZATION OF IRRIGATED RICE ECOSYSTEMS

Background

Preliminary studies in early 1991 revealed that Sahelian rice ecosystems, often uniform in appearance, are in fact highly diverse. To characterize the Sahel environment in greater detail an approach was developed which combines on-station research, regional surveys, collaborative studies with national programs at key sites and crop simulation studies.

The work was planned in three phases: the development of simulation models, the collection of information throughout the region and agro-ecological field studies.

Yield gaps in the region will be quantified in collaboration with IRRI and the Center for Agrobiological Research (CABO.) The gaps will be compared with biological, chemical, physical, genotypic and cultural production constraints specific to seasons and sub-regions. The agro-ecological characterization project is closely linked to the other priority project for the Sahel, the improvement of germplasm. Indeed, the two projects are mutually reinforcing: a thorough characterization of existing rice germplasm in the Sahel is required to understand current production systems, and the characterization of the ecosystems will help guide and improve future breeding efforts.

Effects of the Harmattan Wind on Rice Crop Canopy

Michael Dingkuhn and Kouamé Miézan

The harmattan, a dry, dust-laden wind, is characteristic of the Sahelian dry season, which lasts from December to June. It is thought to be a serious constraint to rice production, although it is not clear exactly how it reduces yields.

The objective of this study was to characterize stresses to the rice crop caused by the harmattan and other meteorological conditions during the Sahelian dry season. Physiological, agronomic and micro-meteorological observations were made in the continuous cropping, rice garden trials at WARDA's sites at N'diaye and Fanaye. The results are reported on pages 17-22.

Observations in 1991 indicated that dry winds drastically reduce floodwater temperature, causing gradients of up to 15°C between the crop's root zone and the air. Low water temperatures increase the duration of the dry-season crop and thus its water use. Large temperature differences between roots and leaves inhibit water absorption while transpiration is high, resulting in water deficits despite flooding. Drought stress was manifested by leaf rolling, low leaf water potential, stunting and the death of entire leaf generations. Cold injury was most severe in deeply flooded plots. Leaf desiccation caused by the harmattan resulted in chlorophyll degradation and tissue death in the upper leaf strata and leaf tips, giving a bleached appearance to the canopy. The vertical gradient of chlorophyll in the canopy was inverted, with detrimental effects on crop growth and grain yields. Jaya, the local variety, was susceptible to leaf desiccation, but some recent WARDA selections, such as BG 400-1 and BW 293-2, proved more resistant. Under rice-rice double cropping, dust deposits on leaves were also associated with spider mite attacks. Spider mites affected topmost and flag leaves and severely reduced yields.

A more detailed study on micro-climate x variety interactions and their diurnal effects on leaf water potential, stomatal conductance and net photosynthesis will be conducted in 1992.

Rice Seedling Growth under Adverse Environmental Conditions

Michael Dingkuhn

Rapid crop establishment is essential under Sahelian rice-rice double cropping because of the late and variable maturity of the dry-season crop. Plant establishment, whether in the seedbed nursery or in wet direct-seeded fields, is affected by thermal, chemical and biological constraints, most of which are interactive and depend on cultural practices.

To characterize the effects of these stresses during crop establishment, observations were made in the seedbeds of various field trials in 1991. The records taken included microclimatic parameters, shoot elongation and dry matter, the electric conductivity of the floodwater, bird attack and root nematode infestation.

Chilling can be caused by cold soil and water in the early dry season, whereas heat stress sets in just before the main rainy season. Covering seeding nurseries with straw for 10 days after sowing in the wet season reduced heat injury and increased seedling survival. The microclimate under the straw had smaller thermal oscillations and lower mean temperatures than the atmosphere. Covering the seedbed for the dry-season crop, however, led to almost total crop failure because low night temperatures were maintained under the straw for most of the day, resulting in cold stress.

A multivariate analysis of the behavior of six varieties at the Fanaye site showed seedling elongation depended exclusively on daily minimum temperature ($r = 0.93^{***}$) and not on maximum or mean temperature, solar radiation, air humidity or wind speed. The main biological constraints to seedling establishment were birds and, if the seedbed was used continuously, root nematodes. Nematodes could be controlled with the systemic insecticide, Furadan. *Hirschmaniella oryzae* was the predominant nematode species. Furadan, however, promoted seedling growth even in the absence of nematodes, suggesting a growth-regulating function. Under conditions of sodic salinity at N'diaye, crop establishment was better when seeding was carried out directly into semi-saturated soil than with transplanting. Frequent drainage and delayed application of N fertilizer favored seedling growth in saline soils.

Research on the interactions between the genotype, cultural practices and the physio-chemical and biological micro-environment will continue in 1992.

Direct Seeding and Transplanting under Sahelian Conditions

Michael Dingkuhn

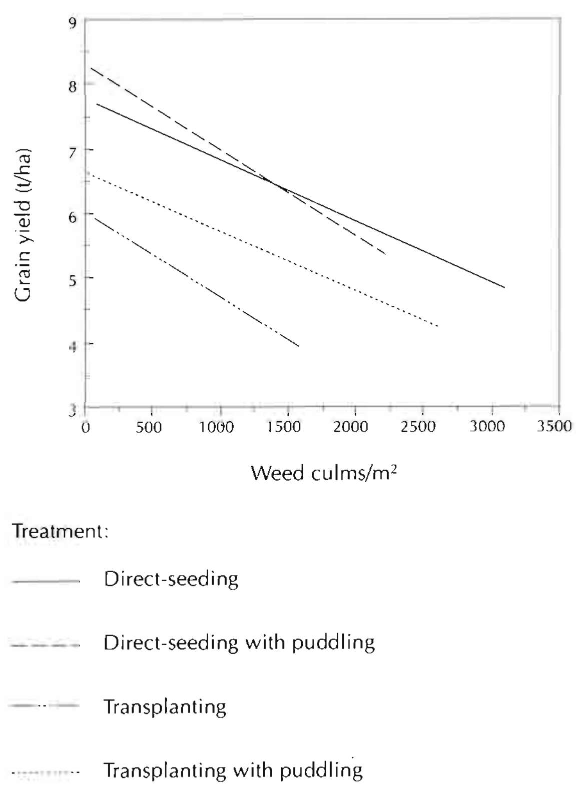
Direct seeding of rice is the most common practice in the delta and middle valley of the Senegal river, whereas in the upper valley and most other Sahelian environments transplanting is predominant. Direct seeding is associated with mechanized, dry field preparation, poor leveling and heavy weed infestation. Studies in Asia have shown that, in well-managed fields, direct-seeded flooded rice has a greater yield potential than transplanted rice. Similar studies are needed in the Sahel.

To determine the yield potential of direct-seeded and transplanted rice as affected by weed infestation and soil preparation, the short-duration variety I Kong Pao (IKP) was grown at WARDA's Fanaye site in the 1991 hot dry and wet seasons. The soil was a heavy clay (*hollalde*). The experimental design was a three-factorial, randomized complete block with six replications. Leveling and water management were optimum.

Fertilizer was applied at a rate of 120 kg N/ha, 60 kg P/ha and 60 kg K/ha. Factors studied were the crop establishment method, weed control, puddling and crop yield.

Yields varied between 4.5 t/ha and 8 t/ha. Direct-seeded rice consistently outyielded transplanted rice by 1 t/ha to 2 t/ha, a difference of 22% across all treatment pairs and seasons. Puddling increased yield by about 1 t/ha in the first (dry-season) trial but had no effect in the second season. Chemical weed control increased yield by 19% in the dry season and 18% in the wet season. Sedges constituted 93% of the weed population. Puddling reduced weeds by about one-third, but weed populations were more than twice as great in direct-seeded than in transplanted rice. Yield reductions were roughly proportional to the weed populations at panicle initiation stage, with a reduction of about 100 kg/ha per 1000 weed culms/m^2 (Figure 16).

FIGURE 16
Linear regressions of grain yield at maturity on weed population (mainly *Cyperus* spp.) at panicle initiation stage for direct-seeded and transplanted I Kong Pao rice, Fanaye, Senegal, in the hot dry season, 1991



Despite greater weed problems, direct-seeded rice had significantly higher yields than transplanted rice. Whether this potential would materialize in farmers' fields, however, depends on the economics of improved field and crop management practices. These issues will be examined in research to be initiated in 1992.

Trends in Soil Properties under Intensive Rice Cropping

Michael Dingkuhn and Kouamé Miézan

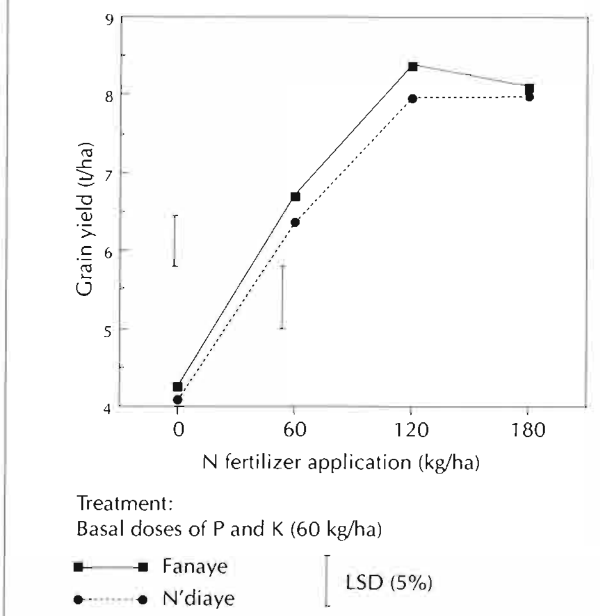
In the Sahel, rice grain yields are extremely variable over both time and space. Yields of over 10 t/ha were obtained with the short-duration variety IR 3941-86-2-2-1 in the early wet season of 1991 in WARDA's rice garden trials. This may be compared with farmers' yields which ranged between 0.1 t/ha and 9 t/ha. Instability of yields may be due to rapid soil degradation under intensive rice cropping, besides other factors such as field and crop management and climatic stresses.

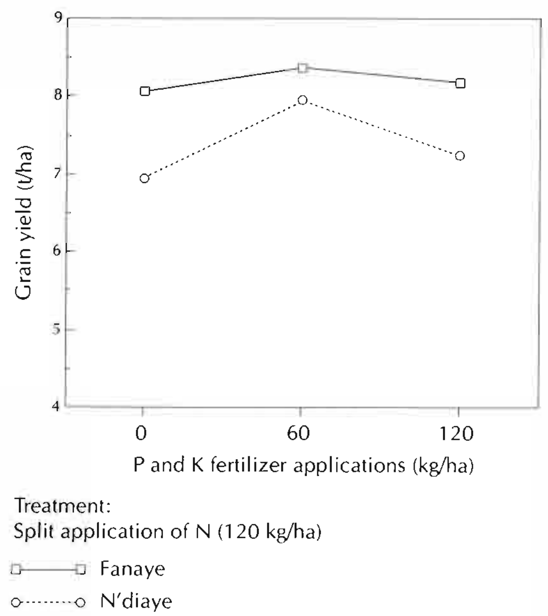
To study trends in soil properties under rice-rice double cropping, continuous cropping trials were established at N'diaye and Fanaye in early 1991. The trials are replicated, cover a broad range of NPK inputs and follow the rice-rice double cropping scheme as practised in Niger and envisaged by most national programs in Sahelian countries. Treatments and plots remain constant across seasons and years. High yielding cultivars are used to create a high demand for nutrients. Soil samples are taken for physical and chemical analysis at the beginning of each season.

The 1991 results indicated that N was the most yield-limiting element at both the N'diaye and Fanaye sites, while P and K inputs had no effect on yield (Figure 17). Another continuous cropping trial is being conducted in the form of the rice garden trials at Fanaye and N'diaye (*see* pages 17-22).

The results of soil analyses will be available in 1992, when complete analysis of all results will be made. These continuous cropping experiments will be further extended. WARDA will initiate collaborative trials with national programs at other key Sahel sites. A survey on rice soil properties and cropping history for the region is planned for 1992 and 1993. These activities will provide the basis for developing more sustainable rice-based cropping systems in the Sahel.

FIGURE 17
Grain yield of rice cultivar Jaya as affected by fertilizer inputs, at the beginning of a continuous cropping trial, Fanaye and N'diaye, Senegal, 1991 wet season





PROJECT 2

DEVELOPMENT OF IMPROVED RICE VARIETIES

Background

The irrigated rice technology introduced into the West African Sahel in the 1920s came from Asia. Traditional cultural practices and cultivars for irrigated rice were unknown in the zone. Rice germplasm specifically adapted to the socio-economic, physical and biological realities of the Sahel is urgently needed. Besides having a yield potential sufficiently high to justify the high land development and irrigation costs of schemes in the Sahel, new germplasm for the zone must contribute to system sustainability by being able to tolerate atmospheric stresses and adverse soil properties and to resist the weeds, parasites and pathogens prevalent in the Sahel. In addition, seasonal crop duration must suit the cropping calendars of farmers and grain quality must match consumers' preferences.

WARDA's task in the Sahel is to identify and develop rice germplasm that combines these traits. After a number of years in which efforts had been directed mainly towards increasing yield potential, the Sahel program restructured its varietal selection efforts in 1991 to emphasize stable crop duration and yields under variable thermal conditions and in saline soils. To reflect these conditions, varietal selection was performed simultaneously at the N'diaye and Fanaye sites.

Observational Yield Nurseries for the Hot Dry Season

Kouamé Miézan

The national programs of most Sahelian countries promote rice-rice double cropping to increase production per unit area and thus maximize returns to the high initial investment costs of irrigation. Some 70% of rice farmers in Niger practise rice-rice double cropping on the limited irrigated ricelands, but the larger irrigated areas of Mali and Senegal are less intensively cropped. This is due mainly to time constraints resulting from the delay in flowering of the dry-season crop caused by low temperatures. For example, IR1529-680-2 in Niger and BG 90-2 in Mali mature 30 to 60 days later in the dry season than in the wet season.

To identify varieties with appropriate duration, plant type and yield potential, 52 short-duration lines were selected from initial and observational nurseries during the 1990 wet season and transplanted to the hot dry-season nursery of 1991. Plots measured 18 m^2 and were not replicated.

Duration from seedling to 50% flowering ranged from 90 to 135 days. The line IR 9752-71-3-2 had the shortest duration. Twelve entries had similar duration compared with a local short-duration check, I Kong Pao (IKP) (96 to 100 days). Entries from Latin America, particularly the ECIA series from Cuba, had medium duration, but yielded up to 10 t/ha. Most entries were not appropriate for the hot dry season, having a duration of over 125 days. Lines with shorter duration and good yield potential were retained to verify their performance in the 1992 hot dry-season nursery.

Preliminary Wet-Season Yield Trials

Kouamé Miézan

Over the past 17 years, WARDA has screened over 10 000 entries of various origins for their suitability to Sahelian conditions. Most rice cultivars now grown in the Sahel were obtained through WARDA-coordinated trials conducted in the 1970s and 1980s. However, the genetic base of Sahelian rice germplasm is still narrow. It requires broadening to reduce its vulnerability to pests and diseases and to enable varieties to perform better under the adverse climatic conditions of the Sahel.

To identify superior wet-season lines, two preliminary yield trials were conducted in 1991, using 17 short-duration and 24 medium-duration selections from earlier observational and preliminary yield nurseries. Short-duration I Kong Pao (IKP) and medium-duration Jaya served as local checks. Identical trials were conducted at the Fanaye and N'diaye sites in a replicated, randomized complete block design. Yield was determined from a bordered area of 6.16 m^2.

The short-duration entries, IR 32307-107-3-2-2, C 1322-28, IET 9702, 35322-PN-LMS-1-KP-1, IR 32419-44-2-3-2 and SKL 17-69-11 were consistently among the top 10 yielders at both trial sites. Among the medium-duration entries, only IR 28118-138-2-3 and IR 28128-45-3-3-2 consistently gave higher yields (9.5 t/ha at Fanaye and 7.5 t/ha at N'diaye) than the local check, Jaya. Within each set, there was no correlation between crop duration and yields.

A significant margin for further reducing duration without sacrificing yield potential appears to exist, probably because of the abundant solar radiation in the Sahel. This potential will be further explored to ease the currently tight double-cropping calendar in the region. The trial will be repeated in 1992 to provide a better assessment of the 1991 entries.

Advanced Wet-season Yield Trials

Kouamé Miézan

In a typical Sahelian country, only one or two rice varieties are grown on over 90% of the irrigated land. In Senegal, medium-duration Jaya (*indica*) and short-duration I Kong Pao (*japonica*) are still the most common varieties despite requests from farmers for alternatives, especially shorter-duration materials. New introductions have not matched existing cultivars in yield level, stability or grain quality.

To identify new germplasm with at least the same yield potential and stability as I Kong Pao (IKP) and Jaya, but with better grain quality, eight short-duration and seven medium-duration lines were selected from preliminary yield nurseries for two advanced yield trials in the 1991 wet season. Identical trials were conducted at Fanaye and N'diaye. The trials were laid out in a randomized complete block design with four replications. Entries were transplanted into 16.6 m^2 plots with a yield area of 6.16 m^2.

Among the short-duration materials, IR 13240-108-2-2-3 gave the highest mean yields (6 t/ha compared with 5 t/ha for IKP) in both test sites. The line IR 31785-58-1-2-3-3 was outstanding at Fanaye but yielded poorly at N'diaye. Its low yield at N'diaye was probably due to soil salinity, to which it is susceptible, whereas IKP is moderately tolerant. Short-duration lines with above-average and less site-dependent yields were TOS 103, ITA 230 and TNAU 7893. Medium-duration lines ITA 306, BG 400-1 and BW 293-2 yielded over 8.5 t/ha at Fanaye and over 6 t/ha at N'diaye, compared with 7.5 t/ha and 4.5 t/ha for Jaya at the same sites.

These results show that higher yielding alternatives to IKP and Jaya can be developed in the medium term. Simultaneous and repeated evaluation at the two ecologically contrasting sites has given promising results. It has proved possible to combine advanced yield trials with salinity tolerance screening. In 1992 lines advanced from these trials will be tested at other Sahelian sites in collaboration with national scientists.

Germplasm Characterization for Saline Ecosystems

Michael Dingkuhn and Kouamé Miézan

One of the most severe soil-related constraints to irrigated rice production in the Sahel is sodic salinity, associated with either soil alkalinity or acidity. Marine salinity occurs throughout the coastal areas, especially in the Senegal river delta. Salinization due to the evaporation of irrigation water is important inland.

To develop screening methods for salt tolerance and to characterize the salt tolerance of local and improved germplasm, screening trials were conducted in 1991 at the N'diaye site, where the pH ranges from 4.5 to 5.5. The effects of salinity on yields, the susceptibility of plants at different growth stages, and varietal performance under constant floodwater salinity were investigated.

On 16 plots with naturally varying salinity, the local variety I Kong Pao (IPK) had a yield reduction of 1.5 t/ha per unit increase of electric conductivity of the floodwater (mS/cm) in the reproductive stage ($P<0.01$). Salinity was greatest during crop establishment (between 1 and 7 mS/cm) depending on the treatment) and gradually decreased with irrigation. In a replicated trial with 29 varieties, conductivity was kept constant at 3.5 mS/cm for the test treatment and at 0.5 mS/cm for the control. The seedling and reproductive stages were most affected by salt treatment, with yields reduced by 44%, 100-grain weights by 20%, and sterility doubled. However, straw yield and tiller and spikelet number were not affected. The supposedly salt-tolerant checks Pokkali and Nona Bokra were among the five worst performing varieties; the allegedly susceptible check IR 28 was among the five best. WARDA's selections for the Sahel zone, IR 3941-86-2-2-1, IET 6279 and IR 64, and the local checks IKP and IR 28 performed best under saline conditions. The lines IR 13240-108-2-2-3 and IR 31785-85-2-2 were extremely susceptible to salinity.

Salinity had different effects on growth, tillering and grain filling, depending on the variety. Varietal response differed profoundly from that in South East Asia, probably because the greater evaporation rate in the Sahel leads to greater transpiration-driven uptake of salt.

The trials will be repeated in 1992 under dry and wet conditions and will be complemented by physiological studies.

Identification of Underlying Mechanisms Responsible for Temperature Tolerance

Michael Dingkuhn and Kouamé Miézan

The Sahelian climate constitutes a very different rice-growing environment to the warm and humid regions in which rice originated. Minimum temperatures below 12°C in the cold season inhibit growth and development, while maximum temperatures up to 50°C impede spikelet fertility and grain quality. However, the environmental stresses are inadequately described on the basis of air temperatures alone. To study the effects of environmental stresses on growth, development and yield, a rice garden trial which involved seven varieties at N'diaye and six at Fanaye was initiated in November 1990. The varieties were transplanted in a continuous, replicated, monthly planting scheme. Growth rates of the plant organs, tillering, crop phenology and leaf chlorophyll content are measured monthly; weather and the microclimate under the canopy are continuously monitored. Crop performance is related to the meteorological conditions during the month preceding each measurement cycle.

The preliminary results show that water and air temperature, air humidity, wind, dust and solar radiation interact to determine microclimate and crop performance. Factors that are genetically influenced include water stress resulting from soil-water-air temperature gradients, leaf desiccation at the top of the plant, internode elongation, chlorophyll and N distribution within the canopy and spikelet fertility. Much of the seemingly erratic, year-to-year and season-to-season performance previously observed for rice in the Sahel appears to be due to the micro-environment and to variety-specific traits associated with temperature tolerance. A multivariate analysis of the data from these trials will provide selection criteria for germplasm with better yield stability, particularly for the hot dry season.

The trials will continue in 1992.

Mangrove Swamp Rice Network

INTRODUCTION

For over 15 years, WARDA has developed improved rice varieties and distributed them to small farmers in West Africa's mangrove swamps. To consolidate advances made in this period, the Mangrove Swamp Rice Network was established in 1990 (*see* page 39). Research activities ceased to be organized along project lines. However, the network's activities in 1991 can be grouped under two headings, agro-ecological characterization and varietal improvement.

AGRO-ECOLOGICAL CHARACTERIZATION

Background

The aim of the agro-ecological characterization work is to facilitate more effective targeting of varietal development and technology transfer. Studies were initiated during 1991 in The Gambia, Guinea-Bissau, Sierra Leone and the Casamance region of Senegal to characterize mangrove swamp ecosystems in order to define soil constraints, identify safe periods for rice cultivation and delineate recommendation domains for improved rice technology packages.

Effect of Soil Variability on Mangrove Rice Production

Mabèye Sylla and Charles A. Dixon

In many mangrove swamp areas, high rice productivity is constrained by soil salinity and sulfate acidity. These problems have recently become more severe because of declining rainfall.

A geostatistical approach was used to study the dynamism and spatial changes in soil constraints at 12 locations representing the range of salinity and acid sulfate conditions in mangrove swamps within the region. At each location, soil variability induced by different degrees of tidal submergence within a toposequence perpendicular to a river was studied. Changes in soil salinity, acidity and iron and aluminum contents over time were determined at four representative physiographic units along each toposequence. Trials for evaluating rice responses to liming and fertilizer (nitrogen and rock phosphates) were established at the same locations.

Considerable variability existed in soil pH and electrical conductivity, as well as in iron and aluminum contents, both within and across sites. At all locations, particularly along the Great Scarcies in north-western Sierra Leone, iron was a greater constraint to rice production than aluminum. Rice yields varied from 1.2 t/ha to 4.9 t/ha according to soil constraints. Response to soil amendments was most significant in areas on the edge of the mangrove swamps, where these give way to inland valley swamps.

Studies in 1992 will examine methods for alleviating aluminum and iron toxicities. The results will provide guidelines for future varietal improvement research and for the dissemination of improved crop management practices.

VARIETAL IMPROVEMENT

Background

Varietal improvement made satisfactory progress during 1991, with the identification of some very promising lines from segregation populations and from regional yield trials. The trials conducted by the six national programs participating in the network identified a number of high yielding varieties which showed tolerance to environmental stress and had a high level of acceptability by both farmers and consumers. Seeds of nine improved rice varieties were distributed for multiplication by national institutions and farmers.

Screening Mangrove Swamp Rice Varieties for Tolerance to Environmental and Biological Stresses

Robert Guei

Declining rainfall in recent years has forced farmers in some of West Africa's mangrove swamp areas to abandon rice cultivation altogether, in the face of rising levels of salinity, iron toxicity and blast incidence. Although some improved lines are available, there is an urgent need for additional shorter duration, higher yielding and more stress-tolerant rice varieties.

In order to develop short-duration varieties tolerant to salinity, acidity/iron toxicity, blast and RYMV and to identify parents for hybridization blocks, 306 newly selected/bred lines from WARDA were tested in screenhouse conditions in collaboration with national scientists at the Rice Research Station at Rokupr, Sierra Leone. Seedlings were grown in concrete troughs containing saline, iron toxic and acid sulfate soils. For each stress, scores were given to 12-week-old plants and to mature plants, using the IRRI standard evaluation system.

Twenty-eight varieties were classified as being moderately tolerant to salinity and seven as tolerant. Among the tolerant varieties were two WARDA lines, WAR 72-1-1-1-4 and WAR 87-10-2-3-1-1-3. Six varieties were considered moderately tolerant to iron toxicity; four (IR 31787-85-3-33-2, IR 10781-143-2-3, IR 51-282-8 and BR 143-2B-3-1-3) were considered tolerant. Thirty-three varieties, including 17 WARDA lines, were found to be tolerant to acid sulfate conditions.

Screening for disease tolerance showed that most of the currently available improved varieties, including WAR 1, ROHYB 6, WAR-2-b-2, CP 4, WAR 52-384-3-2 and WAR 100-6-2-1, were tolerant to blast. Eleven varieties, including ECIA 136-2-2-1-4, CARIBEL 13-5-1 and WAR 100-2-15-1, had multiple tolerance to salinity, acidity and blast (Table 24). However, none of the lines screened showed tolerance to RYMV.

TABLE 24
Varieties with multiple stress tolerance, Rokupr, Sierra Leone, 1991

Varieties	Stress reactions[1]				
	Salinity	Iron toxicity	Acidity	Blast	RYMV
KAU 25331	T	MS	MS	T	S
WAR 72-1-1-1-4	T	MT	T	S	S
WAR 52-384-3-2	MT	MT	MS	T	S
WAR 81-2-1-2	MT	MS	MS	T	S
WAR 100-5-6-1	MS	MS	MT	T	S
WAR 100-2-15-1	MT	S	S	T	S
WAR 87-10-2-2-9	MT	MT	MS	MS	S
ECIA 136-2-2-1-4	MT	MS	MT	S	S
CARIBEL 13-5-1	MT	MS	MT	S	S
IR 25912-63-2-2	MT	S	S	T	S
BW 295-4	S	MT	MT	S	S
WAR 87-10-2-3-1-1-3					

1 S = susceptible; MT = moderately tolerant; T = tolerant

Rice varieties are screened for environmental stresses in concrete troughs containing saline, iron toxic and acid sulfate soils at Rokupr, Sierra Leone

Varieties found to be tolerant in these trials will be grown in the field for further evaluation in 1992. Results will be made available to other national programs. Outstanding varieties will be used as donor parents in crosses.

Developing New Rice Varieties for Mangrove Swamp Farmers

Robert Guei

The many stresses to which rice grown in the mangrove swamps are exposed pose a considerable challenge to plant breeders. Some moderately stress-tolerant and high yielding WARDA varieties, such as ROK 5, WAR 1, WAR 77-3-2-2, ROHYB 6, WAR-6-2-B-2 and Kuatik Kundur perform satisfactorily under multiple stresses. However, worsening environmental conditions resulting from inadequate rainfall have necessitated the development of more stable, shorter duration varieties with tolerance to a wider range of stresses. Since 1978, WARDA scientists have made crosses between stress-tolerant local varieties and high yielding introduced varieties, followed by selections in advanced generations.

In 1991, further selections were made in the segregating populations of F_5-F_9 generations. To identify well-adapted varieties with appropriate growth duration, selections were carried out in three salt-free zones representing short-, medium- and long-season mangrove swamps. Selections were based on plant stature, leaf erectness, tillering capacity, disease resistance, crab and lodging resistance, panicle size and tolerance to iron toxicity, salinity and acidity.

Some 450 lines were selected, of which 350 were advanced for inclusion in the INGER African Mangrove Swamp Rice

Observational Nursery (AMSRON) trials. Of the remaining 100 fixed lines, 20 outstanding varieties of very short duration and 40 of medium duration were identified. The selected varieties, including WAR 98-6-2-1, WAR 98-6-10-1 and WAR 140-3-2, have very large panicles, a stiff culm, erect flag leaves and late senescence. Most also showed high tillering capacity and at least moderate levels of tolerance to iron toxicity.

Further selections will be made in 1992. Selected fixed lines will be distributed to national programs for *in situ* evaluation to test their adaptability and yield potential across more diverse conditions. Through this procedure, more than 500 improved mangrove swamp rice lines will become available to farmers in the region by 1994.

Regional Multilocational Testing of Promising Rice Varieties

Martin Agyen-Sampong and Robert Guei

In the past 6 years, WARDA has developed some promising varieties for adaptive testing throughout the mangrove swamps of West Africa. Adaptive testing was an important activity of the Mangrove Swamp Rice Network in 1991.

Multilocational varietal trials were designed to evaluate the performance and adaptability of WARDA-bred/selected varieties across a range of mangrove swamp ecosystems. National programs in the six network member countries tested three sets of 13 varieties each of short-, medium- and long-duration at 25 sites. The grain yields from the varieties tested were compared with those from various local checks. Among the short-duration varieties, four WARDA-bred lines in the WAR 100 series showed consistently superior performance at all the test sites (Table 25). Three of these lines (WAR 100-2-15-1, WAR 100-2-12-1 and WAR 100-2-11-1) produced average yields of more than 4 t/ha across sites. Among the medium-duration materials tested, three of the WAR 87 series were found to be the most adaptable, with consistently superior yields across test sites. Eleven of the 13 medium-duration varieties tested outyielded the checks by 20-40%. Among the long-duration varieties, which were tested only in Sierra Leone, Guinea and Nigeria, ROHYB 6, WAR 74-15-1-3, WAR 73-1-M2-1 and WAR 100-6-1-1 were phenotypically acceptable and consistently outyielded the local checks.

To further confirm the adaptability of these lines, multilocational trials will be conducted at a larger number of sites in 1992 in all six countries. In addition, national breeders will advance several of the most outstanding varieties to farmer-managed trials during 1992.

TABLE 25
Varieties with mean yields higher than 3 t/ha in regional multilocational trials, 1991

Varieties	Mean yield (t/ha)
Short duration	
WAR 100-2-15-1	5.8
WAR 100-2-12-1	5.2
ECIA 136-C-2	4.5
WAR 100-2-11-1	4.2
WAR 100-3-2-1	3.7
IR 21855-5-3-2-1-2-2-1	3.3
B 4140C-PN-186-28-KP-2	3.3
Medium duration	
BW 295-4	5.6
WAR 87-10-2-3-3	5.0
WAR 52-384-3-2	4.8
RTN 16-2-1-1	4.5
WAR 81-2-1-2	4.5
IBW 295-5	4.3
WAR 87-10-2-2-9	4.0
BG 400-1	4.0
Long duration	
WAR 100-6-1-1	3.5
WAR 73-1-M1-1	3.1
WAR 73-1-M2-1	3.0
WAR 74-15-1-3	3.0
BR 20-3B-1	3.0

Farmers' Evaluation of Improved Mangrove Swamp Rice Varieties

Martin Agyen-Sampong and Robert Guei

Due mainly to the weak agricultural extension services, improved rice seeds are still not generally available to most mangrove swamp farmers in Sierra Leone. Collaborative on-farm adaptive trials conducted by WARDA-Rokupr and national programs have resulted in limited dissemination.

To accelerate and broaden the assessment of improved rice varieties, while at the same time promoting the wide-scale distribution of improved seeds to farmers, a regional program of on-farm trials was initiated in 1991 by the Mangrove Swamp Rice Network.

Ten varieties bred or selected by WARDA were distributed to the six national research programs participating in the network, as well as to other public and private rural development agencies. In addition to the WARDA varieties, nine high yielding local varieties were tested in non-fertilized farmer-managed trials at a total of 24 sites in the six countries. The objectives of these trials were to assess the performance of the varieties and their acceptability by farmers and to promote adoption.

Varieties which had been developed by WARDA were among the highest yielding entries at all trial sites. The excellent performances of WAR 77-3-2-2 and ROK 5 were particularly evident in The Gambia, where they outyielded farmers' local checks by 58% and 52%, respectively. In Nigeria the varieties WAR 77-3-2-2, WAR 1 and ROHYB 6 outyielded local checks by 44%, 44% and 15%, respectively, while in Guinea WAR 77-3-2-2, ROHYB 6 and ROK 5 outyielded the local checks by 37%, 32% and 27%, respectively (Table 26).

The short-duration varieties WAR 77-3-2-2 and WAR 1 showed better adaptability and performance even in the marginal areas. Like ROHYB 6 and Kuatik Kundur, they were preferred by farmers because of their high yields and their tillering capacity, their tolerance to salinity and their good taste. They were also generally preferred by farmers cultivating in areas affected by high salinity and iron and aluminum toxicity.

In 1992, on-farm testing of improved and local varieties will be extended to more sites in the six network countries, in collaboration with national scientists.

REGIONAL AND INTERNATIONAL COLLABORATION IN RESEARCH

INTRODUCTION

The goal of WARDA's collaboration with other research agencies is to achieve the most efficient means of generating, adapting and transferring improved rice technologies throughout West Africa. The diversity in the region's major rice producing environments is too great, and WARDA's resources too small, for the Association to achieve this objective working alone. Possessing the regional mandate for rice research in West Africa, WARDA is responsible for organizing the planning of research on a regional basis to improve both its efficiency and its effectiveness.

WARDA must also work closely with the other international agricultural research centers whose work is relevant to the West African rice sub-sector. Lastly, it has the leading role in identifying sources of assistance in advanced research institutions outside the region and in coordinating and harnessing their inputs for the benefit of both regional and national research groups.

WARDA's collaborative activities in 1991 were mainly with national rice research programs and other international

TABLE 26
Mean grain yields and percentage gain of WARDA improved varieties over local checks in on farm trials in 1991

Variety	Guinea Yield (t/ha)	Guinea % gain	Nigeria Yield (t/ha)	Nigeria % gain	Sierra Leone Yield (t/ha)	Sierra Leone % gain	Senegal Yield (t/ha)	Senegal % gain	Gambia Yield (t/ha)	Gambia % gain
WAR 77-3-2-2	2.5	37	2.3	44	3.3	15	2.0	18	3.9	58
WAR 1	—	—	2.3	44	2.6	22	2.0	16	2.5	35
ROK 5	2.7	27	1.3	15	4.2	30	1.7	10	3.4	52
ROHYB 6	3.0	32	1.3	15	3.0	17	—	—	—	—
Kuatik Kundur	3.4	41	2.0	33	3.4	26	—	—	—	—

agricultural research centers. Links with advanced institutions outside the region are at an early stage of development, and will not be reported in detail here.

Partnerships with National Programs

In 1989 and 1990 WARDA established two advisory Working Groups with national scientists to develop a new vision of collaboration with national programs. In this new vision West Africa's rice science infrastructure is seen as a single, integrated system with interdependent parts. WARDA recognizes that agro-ecological zones and ecosystems extend beyond political boundaries, so that technologies generated in one country will generally be applicable to others in the region. National programs differ widely in their relative strengths across scientific disciplines and within each major rice production environment. This diversity, combined with the potential for substantial spillover benefits, means that regional research can be made more cost-effective through the sharing of tasks according to comparative advantage.

To develop more cost-effective regional collaboration, WARDA acted as a catalyst in assessing the relative strengths and weaknesses of national programs, defining their most appropriate roles within the regional system and developing work plans accordingly.

Task Forces are the primary unit through which collaborative research activities are planned and executed. They consist of scientists in the region who are working on similar problems in similar rice growing environments. A WARDA scientist serves as the Coordinator of each Task Force.

Three Task forces were formed in 1991, focusing on mangrove swamp rice, continuum characterization and upland rice breeding. At the same time, contacts were made with national scientists as a prelude to the formation of four additional Task Forces early in 1992. These will cover lowland rice breeding, integrated pest management, Sahel rice breeding and cropping systems.

The Task Forces formed in 1991 launched activities in four areas:

- *Coordination of research work plans:* Leading national programs in specific disciplinary areas were assigned responsibility for assisting others and for sharing more advanced research tasks with WARDA.
- *Access to information:* National scientists were provided with more complete and rapid access to information in areas relevant to their particular research activities. This was done with support from the Library and Documentation Service of WARDA's Training and Communications Division.
- *Technology assessment:* Available technologies developed either by national programs or by WARDA were assessed and plans developed to transfer and test them more systematically and with better targeting.
- *Assistance to national programs:* Procedures were developed for targeting technical, material and financial assistance to national programs to strengthen the regional rice research system.

Seven planning meetings were held with national scientists during 1991, as follows:

- *Mangrove Swamp Rice Network, Rokupr, Sierra Leone, 11-13 March:* National scientists from Senegal, Gambia, Guinea, Guinea-Bissau, Sierra Leone and Nigeria participated in a research planning workshop. They identified and prioritized the major constraints to rice production in the mangrove swamps, evaluated the contribution each national program could make in a regional effort to overcome these constraints, and developed a collaborative work plan for 1991.
- *Steering Committee of the Mangrove Swamp Rice Network, Rokupr, Sierra Leone, 11-13 April:* The committee met to review proposals prepared by national scientists requesting support for activities carried out within the network master plan. On the basis of the plan, a regional trials program was agreed and later implemented in each collaborating country.
- *Crop and Resource Management Research Working Group, Bobo-Dioulasso, Burkina Faso, 13-14 May:* Scientists from Burkina Faso, Côte d'Ivoire, Ghana, Guinea-Bissau, Mali and The Gambia met WARDA Program Leaders and scientists to review WARDA's plans for collaborative research on cropping systems, soil fertility, socio-economic factors and agro-ecological characterization. A proposal to form a Task Force for crop and resource management was discussed.
- *Continuum Characterization Task Force, Bouaké, Côte d'Ivoire, 3-5 June:* In collaboration with IITA and the Winand Staring Center, WARDA held a meeting with national scientists from Benin, Burkina Faso, Cameroon, Côte d'Ivoire, Ghana and Nigeria involved in continuum characterization work. Participants reviewed the methods used in this research and its results and identified areas for future collaboration.

- *Varietal Improvement Research Working Group, Kindia, Guinea, 11-13 September:* National scientists from Guinea, Liberia, Nigeria, Senegal, Sierra Leone and Togo met with WARDA Program Leaders and scientists to review collaborative research in rice breeding. WARDA breeders and crop protection specialists put forward proposals for discussion. National scientists strongly recommended that the activities of INGER be fully integrated into the Task Force structure.

- *INGER-Africa Workshop, Bouaké, Côte d'Ivoire, 30 September-3 October:* WARDA and IRRI sponsored the 1991 INGER-Africa workshop held in Bouaké. Representatives from 15 national programs throughout Africa met to review results from the past season, to plan trials for 1992 and to discuss improvements in INGER's current structure and operations.

- *Upland Rice Breeding Task Force, Bouaké, Côte d'Ivoire, 3-4 October:* Scientists from Benin, Burkina Faso, Cameroon, Côte d'Ivoire, Ghana, Guinea-Bissau, Liberia, Nigeria, Senegal, Sierra Leone, The Gambia and Togo met in Bouaké in an inaugural Upland Rice Breeding Task Force planning meeting. The participants presented country reports, reviewed the major technical and institutional constraints faced by their respective breeding programs and developed plans for task sharing during the 1992 season.

Collaboration with Other International Agricultural Research Centers

A major step towards improved coordination of rice research in Africa was achieved in October 1991 when a tripartite Memorandum of Understanding between WARDA, IITA

The Varietal Improvement Working Group visits an experimental field in Kindia, Guinea and IRRI was signed. The memorandum sets out a plan according to which the three international centers will share responsibilities for rice research in Africa up to the year 2000. WARDA's tasks include responsibility for all rice breeding in West Africa (in partnership with IITA for inland valley ecosystems) and full responsibility for maintaining Africa's rice germplasm collection by 1995.

The following collaborative research projects have been developed with IRRI, IITA and other international centers:

- *Upland rice improvement:* In discussions held at IRRI from 7 to 12 January 1991, WARDA, IRRI and CIAT developed plans to pool their effors in five collaborative projects: the characterization of blast populations and population dynamics using RFLP or DNA fingerprinting techniques; the identification of P-efficient and aluminum-tolerant germplasm to determine the mechanisms for aluminum tolerance and P uptake; the examination of root penetration and root structures in upland rice; expanded germplasm exchange and the exchange of a common set of indicator lines to characterize key testing sites; and the exchange of literature, especially in the area of rice plant protection. A follow-up working meeting was held at CIAT from 28 to 30 August 1991.

- *Lowland rice improvement:* With the transfer of responsibility for all rice breeding work to WARDA in 1991, IITA terminated its rice breeding activities at its headquarters in Ibadan, Nigeria. To make the most efficient use of existing research facilities, IITA offered WARDA the use of the vacated experimental areas, offices and laboratory space. WARDA's lowland breeder was subsequently posted to the IITA campus in early 1991.

- *Sahel rice improvement:* WARDA and IRRI are collaborating to strengthen rice breeding efforts in the Sahel. IRRI is helping WARDA to reconstitute its germplasm collection in Senegal, part of which was lost in the 1980s. Rapid exchange of breeding lines and special donors has begun, with the focus on materials suitable for direct seeding and tolerant to temperature extremes and salinity. Until cold and salt screening facilities are developed at N'diaye, IRRI will continue to assist WARDA by screening materials under controlled conditions in the Philippines and Korea.

TRAINING AND COMMUNICATIONS

OVERVIEW

Anthony Youdeowei

During 1991 the Training and Communications Division continued to reorganize its operations in order to establish a more solid foundation for its activities, particularly for the purposes of providing technical support to the national programs of WARDA member states.

In late 1990, the WARDA Board of Trustees accepted a recommendation from management that group training activities in 1991 be suspended and the emphasis placed instead on adequate preparation for a full program of activities in 1992. Thus most of the group training activities reported here outline the progress made in developing training course curricula and designing the 1992 training schedules.

Individual training activities at WARDA are organized by the Research Division. These activities, traditionally less well developed at WARDA than group training, have been strengthened considerably in recent years, in accordance with the Association's strategic plan of 1987.

In the Communications Unit, efforts were intensified to establish a fully operational library and rice science information dissemination service and to provide support to national libraries. These activities were aimed at facilitating the flow of rice science information in the region and linking scientists in West Africa with rice scientists elsewhere.

Collaborative training and communications activities with various international, regional and national institutions were established and strengthened. The Technical Centre for Agricultural and Rural Cooperation (CTA) and the International Development Research Centre (IDRC) continued to provide financial and technical support for specific activities.

2.1 WARDA'S APPROACH TO DEVELOPING GROUP TRAINING COURSE CURRICULA

Anthony Youdeowei

In 1989 a United Nations Development Programme (UNDP) proposal to support WARDA's training activities was prepared. The project document was based on a review of WARDA's group training courses conducted since 1973, on follow-up studies of participants conducted in 1978, 1982 and 1987 and on a survey of the rice science training needs of the national programs of WARDA member states.

The project document identified the training needs considered crucial to strengthening the capacity of national research systems in rice research, as well as possible areas of collaboration between WARDA and relevant government agencies. On the basis of these needs, the document specified training course topics. However, it did not provide details of the curricula for these courses. In addition, most of the courses identified had not been run by WARDA and therefore no curricula were available. Thus, prior to project implementation, it was necessary to develop curricula and training materials for the new courses, as well as to review the contents of existing courses in order to ensure they met the needs identified in the survey.

This feature article describes the philosophy and procedure adopted by WARDA in developing course curricula and training materials, and outlines the courses designed during 1991.

Philosophy and Procedure

To fulfill its aim of strengthening a growing West African capability in the science, technology and socio-economics of rice production, WARDA works in close partnership with national programs in both its research and its training activities. The concept of partnership underpins the procedure adopted in the development of training course curricula and materials. To tap the expertise and skills available within the region, and to target future training courses to the needs of national programs, the concept of using expert panels has been adopted. The increased involvement of national staff in all stages of course development

Expert panel members from WARDA and national, regional and international organizations collaborate in designing the curriculum for WARDA's group training course on Scientific Writing for Agricultural Research Scientists will provide them with the opportunity to develop their own capabilities in organizing and managing training courses. Members of the expert panels are selected according to discipline and experience and are invited to WARDA for consultations lasting 4-5 days. At the start of these meetings, they are briefed on the philosophy underlying WARDA's training strategy and on the specific aims of the course under discussion.

Courses Designed in 1991

Five expert panels were convened in 1991 to develop the group training courses scheduled for 1992. Panel members were drawn from national, regional and international organizations, as well as from WARDA. The tasks of the panels included detailed development of course curricula, identification of resource persons to teach specific course modules, production of course timetables, recommendation of an appropriate time of year and venue for each course and compilation of lists of training materials required. The courses designed covered topics related to research, production and technology transfer. The panel reports of these courses were discussed in detail and they formed the basis of the group training schedule for 1992 (Table 27).

TABLE 27
Group training courses designed during 1991

Course	Description	Panel
Computer Applications and Statistical Analysis in Agricultural Research	To be conducted at the ICRISAT Sahelian Center, Niger; 4-week course; for young agricultural scientists in national programs; English; 16 participants	O.E. Asiribo (Nigeria, Ahmadu Bello University) E.W. Richardson (WARDA) R.D. Stern (ICRISAT)
Water and Irrigation Management for Rice Production	To be conducted at the IIMI Center, Burkina Faso; 4-week course; for national research, extension, training and project development personnel, especially in rice irrigation; French; 20 participants	J.C. Legoupil (IIMI) I. van der Wolf (WARDA) A. Youdeowei (WARDA)
Crop Protection	To be conducted at WARDA; 6-week course; for national research, extension, training and project development personnel, especially those involved in rice crop protection; French/English; 26 participants	A. Akinsola (WARDA) O.A. Egunjobi (Ondo State University, Nigeria) Y. Mbodj (ISRA) G. Nyoka (WARDA)
Upland Rice Production	To be conducted at WARDA; 2-week course; for national research, extension and project development personnel involved in upland rice production; French/English; 20 participants	R. Agboh-Noameshie (CONGAT) M. Jones (WARDA) L. N'Cho (IDESSA) T. Remington (WARDA)
Scientific Writing for Agricultural Research Scientists	To be conducted at IITA, Ibadan, Nigeria; 2-week course; for young agricultural scientists in national programs; French/English; 30 participants (15 French/15 English)	J. Faye (RESPAO) M. Jeanguyot (CIRAD) J. Mukanyange (CTA) M. Otu-Bassey (AASE) P. Stapleton (IBPGR) C. Tahiri-Zagret (University of Abidjan, Côte d'Ivoire) A. Youdeowei (WARDA)

Conclusion

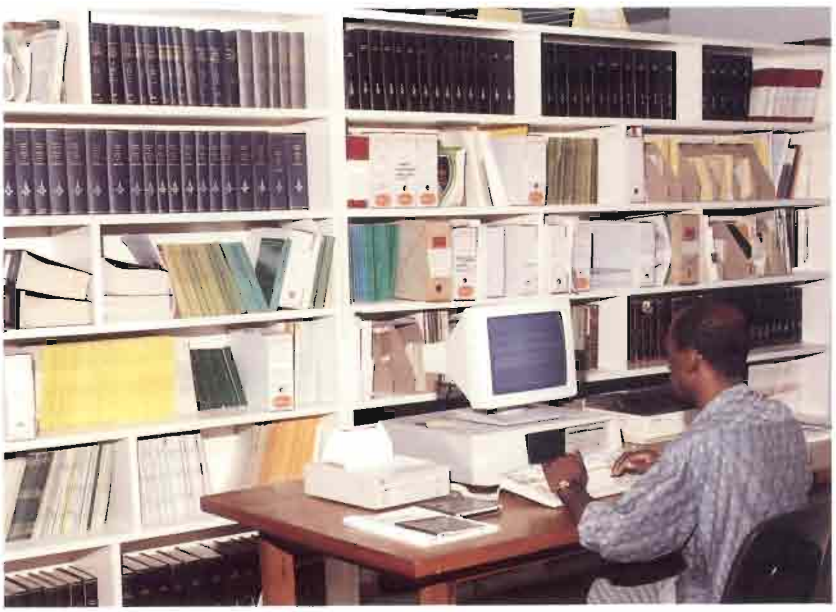
Through the use of the expertise available within the West African region for the design of training courses, WARDA has developed course curricula which meet the identified needs of national rice programs and has strengthened its working relationships with personnel in these programs. This approach not only gives WARDA greater access to resource persons for the various courses but also improves the capacity of national programs to organize and manage their own training courses.

2.2 INFORMATION RETRIEVAL AND DISSEMINATION SERVICE TO RICE SCIENTISTS IN WEST AFRICA

Alassane Diallo

Before planning and implementing their own research on a specific problem, scientists often need access to information on relevant research conducted in the past. In West Africa's resource-poor national research systems, such information is frequently difficult to obtain.

To meet the information needs of West Africa's rice scientists, WARDA's Library and Documentation Center has established a retrospective literature search service. This service, which is a component of the West African Rice Information System (WARIS), uses WARDA's in-house bibliographic databases, as well as external databases received on diskettes or CD-ROM. In response to requests received from WARDA and national scientists, bibliographic information is retrieved from the databases and printed out or downloaded onto diskettes.



WARDA's Library and Documentation Center carries out retrospective literature searches for WARDA and national program scientists, using CD-ROM agricultural databases

In 1991 an increasing number of requests for exhaustive literature searches were received by WARDA. Over 50 major searches were made. The subjects of these searches and the names of those making the requests are as follows:

Temperate stresses and their effects on irrigated rice: Chilling, cold tolerance, low and high temperature, heat (Dr K. Miézan and Dr M. Dingkuhn, WARDA, Senegal)

Wind, dust and atmospheric stresses affecting rice (Dr M. Dingkuhn, WARDA, Senegal)

Salt and other chemical stresses affecting irrigated rice (Dr K. Miézan and Dr M. Dingkuhn, WARDA, Senegal)

Nutritional stresses affecting irrigated rice in West Africa (Dr M. Dingkuhn, WARDA, Senegal)

Acidity in lowland rice varieties: Screening techniques and inheritance (Mr A.H. Hilton-Lahai, Rice Research Station, Rokupr, Sierra Leone)

Variability in the resistance to sodium chloride salinity within rice (Mr A.H. Hilton-Lahai, Rice Research Station, Rokupr, Sierra Leone)

Weeds and their effects on upland rice (Dr S.Y. Dogde, Direction de la Recherche Agronomique, Togo)

Control of rice blast disease caused by *Pyricularia oryzae* (Dr E.D. Imolehin, NCRI, Nigeria)

Control of sheath blight of rice caused by *Rhizoctonia solani* (*Thanatephorus cucumeris*) (Dr E.D. Imolehin, NCRI, Nigeria)

Epidemiology of sheath blight of rice caused by *Rhizoctonia solani* (*Thanatephorus cucumeris*) (Dr E.D. Imolehin, NCRI, Nigeria)

Water-borne diseases associated with rice cultivation in WARDA member states (Mr D. Sanni, WARDA)

Insect pests of rice in West Africa (Dr E.A. Heinrichs, WARDA)

Snails (Gastropoda) as pests of rice (Dr H. Madsen, Danish Bilharziasis Laboratory, Denmark)

Phosphate adsorption and desorption in the soils of West Africa (Dr K.L. Sahrawat, WARDA)

Phosphate fixation and release (Dr K.L. Sahrawat, WARDA)

Phosphate response of rice (Dr K.L. Sahrawat, WARDA)

Residual effects of phosphate in cropping systems, especially rice-based cropping systems (Dr K.L. Sahrawat, WARDA)

Long-term and residual effects of phosphate fertilization on rice (Dr K.L. Sahrawat, WARDA)

Small farmer household economy and farming systems in West Africa (Dr A. Youdeowei, WARDA)

Rapid rural appraisal (Dr T.R. Remington, WARDA)

Azolla and rice (Dr P.J. Matlon, WARDA)

Malaria and rice cultivation (Dr J. Dossou-Yoro, OCCGE, and Dr Y. Yapi, CEMV, Côte d'Ivoire)

African rice gall midge (*Orseolia oryzivora*) (Dr B.N. Singh, WARDA)

Incidence of blast in Gramineae other than rice (Dr S. Yacouba, CNRST/INERA, Burkina Faso)

Nutrient disorders of rice in West Africa (Dr K. L. Sahrawat, WARDA)

Lowland rice breeding and varietal improvement (Dr B.N. Singh, WARDA)

Oryza glaberrima (Dr K. Miézan, WARDA, Senegal, Dr S. Monde, Rice Research Station Rokupr, Sierra Leone and Dr K. Alluri, IITA)

Mangrove soils (Mr M. Sylla, ISRA, Senegal)

Diagnostic Rice Integrated System (DRIS) (Mr M. Sylla, ISRA, Senegal)

Index of Similarity on Soil (Mr M. Sylla, ISRA, Senegal)

Environmental classification and agro-ecological zoning (Mr M. Sylla, ISRA, Senegal)

Forms and properties of controlled-release nitrogenous fertilizers (Dr K.L. Sahrawat, WARDA)

Rice-rice double or multiple culture, restricted to tropical irrigated rice (Dr M. Dingkuhn, WARDA, Senegal)

Rice cultivation in Niger and labor constraints (Dr M. Doual, Berlin, Germany)

Silica content of irrigated rice in Africa and Asia (Dr M. Dingkuhn, WARDA)

Genotype x environment interactions (Dr K. Miézan, WARDA, Senegal)

Women in rice farming systems (Miss N. Fofana, CIRES, Côte d'Ivoire)

Agricultural sustainability (Dr A. Adesina, WARDA)

Ex-ante economic analysis of rates of returns to research (Dr A. Adesina, WARDA)

Structural adjustment policies in Africa (Dr A. Adesina, WARDA)

SUMMARIES OF TRAINING ACTIVITIES

Group Technical Training

Preparations for 1992 training courses A major training activity during 1991 was to prepare group training courses for 1992. These preparations are described on pages 84-86.

Following a planning phase, detailed arrangements had to be made. National governments were approached for permission to organize training courses in particular countries (Benin, Burkina Faso, Niger, Nigeria, The Gambia and Togo). In each country, national scientists and WARDA alumni were identified and asked to act as training coordinators or Associate Trainers. Negotiations were also undertaken with regional and international agricultural research institutions such as SAFGRAD, ICRISAT, IIMI and IITA to provide various forms of local logistical support. A detailed schedule of courses and a training workplan for 1992 were then prepared and produced.

These activities resulted in the successful planning of the courses outlined in Table 28.

Development of training materials Notes and other materials developed during the group training courses in 1990 were assembled and organized into training manuals, edited, and prepared for publication.

During 1991, a Training of Agricultural Trainers Course Instructor's Manual was published in both English and French. The English edition was subsequently used for the in-country Training of Trainers (TOT) course in The Gambia and Nigeria. The editing and design of two other training manuals have reached an advanced stage. These manuals are scheduled for publication in 1992.

Organization of in-country Training of Trainers courses During the TOT course held in Fendall, Liberia in 1990, participants from individual countries were encouraged to plan in-country TOT courses for their home countries.

In 1991, WARDA undertook aggressive follow-up action in Ghana, Nigeria, Sierra Leone and The Gambia. Nigeria and Gambia responded favorably, successfully organizing their own in-country TOT courses. The Gambian course was attended by 20 participants, including three women, and

TABLE 28
Schedule and collaborators for group training courses in 1992

Course	Date	Location	Collaborators
Computer Applications and Statistical Analysis in Agricultural Research (English)	January 1992	Niamey, Niger	ICRISAT Sahelian Center
Water and Irrigation Management for Rice Production (French)	March 1992	Ouagadougou, Burkina Faso	IIMI
Training of Trainers (French)	June 1992	Cotonou, Benin	IITA, national programs
Crop Protection (English/French)	July/August 1992	WARDA, Bouaké	—
Upland Rice Production (English/French)	September 1992	WARDA, Bouaké	—
Scientific Writing for Agricultural Research Scientists (English/French)	November 1992	Ibadan, Nigeria	IITA

was held at The Gambia College, Brikama, from 7 to 18 October. Three training participants on the Fendall course (Wilhelmina Colley, Lamin Njie and Mohammed Jammeh) acted as resource persons for this course. The Nigerian course was held at the NCRI substation at Moor Plantation, Ibadan from 15 to 30 November 1991. There were 15 participants, including four women, and the resource persons were Benjamin Okobbaro, Joseph Ojo and Bidemi Olajide, who had all been participants in the Fendall course.

In these in-country TOT courses, WARDA assisted in the following areas:

- modification of the original course curriculum to suit particular countries
- advice on the procurement of training materials
- identifying and approaching local sources for funds
- development of a course program
- evaluation of the course

Participants in the in-country Training of Trainers course held in The Gambia in 1991

Complementary group training courses Under the UNDP project, WARDA is required to organize additional training courses to complement those described in the project document. Efforts were made in 1991 to meet this requirement through the organization of four courses with funding from sources other than the UNDP grant.

Three training courses were organized for the Mangrove Swamp Rice Network in 1991:

- Mangrove Rice Production
- On-Farm Adaptive Research Methodology
- Seed Production

The Training Unit assisted with program organization, technical backstopping and course evaluation.

In collaboration with the Semi-Arid Food Grain Research and Development (SAFGRAD) project and the African Association of Science Editors (AASE), a bilingual course on Scientific Writing for Agricultural Research Scientists was held from 15 to 30 November 1991 at the Fondation Pan Africaine pour le Développement Economique, Social et Culturel (FOPADESC) in Lomé, Togo. There were 20 participants from 12 WARDA member states (15 francophone and five anglophone). Three participants were women.

The six resource persons (three men and three women) for this course were: Paul Stapleton from the International Board for Plant Genetic Resources (IBPGR), Rome, Italy; Martine Seguier-Guis from the Centre de Coopération Internationale en Recherche Agronomique pour le Développement (CIRAD), Montpellier, France; Joy Mukanyange from CTA, Ede, The Netherlands; Rokia Ba Touré, from the Institut du Sahel (INSAH), Bamako, Mali; Alain Poiri, from the University of Abidjan/International Development Research Centre (IDRC), Ottawa, Canada; and Anthony Youdeowei from WARDA.

Financial support was obtained from CTA, CIRAD, IDRC and the West African Farming Systems Network Program supported by the United States Agency for International Development (USAID). An end-of-course evaluation concluded that the course was highly beneficial to the research work of participants in their national programs.

Women in Development: Trainer Intern Program for West African Women A project document for this program was developed and finalized in early 1991 and the first candidate for the program, Zainabou Cole from The Gambia, was recruited.

During this initial year of the program, Mrs Cole underwent on-the-job training in all aspects of the development and management of technical training courses and participated fully in organizing and managing itinerant courses.

This project has generated considerable interest internationally. The search for funding to support it continues.

Individual Research-Related Training

Introduction WARDA provides research-related training mainly to young West African scientists seeking to deepen their knowledge in specialized areas of rice research and to gain experience by working with scientists at WARDA. There are four main categories of trainees: research scholars, post-doctoral scientists, research assistants and visiting scientists.

Research scholars Under the research scholar program, WARDA awards fellowships to outstanding African students pursuing MSc and PhD degrees in a range of rice-related subjects. Scholars conduct their field work under the supervision of WARDA scientists, who work closely with the students' university committees. The program is supported by the African Development Bank (AfDB) and USAID.

Three West African research scholars worked at WARDA in 1991:

- *Moses Zinnah*, a Liberian student studying for his PhD in extension education at the University of Wisconsin, USA under the supervision of Professor Lin Compton, completed field work he had begun in 1990. He investigated the factors influencing the adoption of improved rice varieties in the mangrove swamps of Sierra Leone and Guinea and assessed the economic impact of adoption at farm level. Dr Akinwumi Adesina, a WARDA economist based at Bouaké, Côte d'Ivoire, supervised the design and execution of the field work. Mr Zinnah's research was supported by a USAID grant. Analysis of the data and writing the PhD thesis started in 1991. Completion of the write-up and defense of the dissertation are planned for early 1992.
- *Mabeye Sylla,* a Senegalese student working for his PhD degree in soil science at the Agricultural University of Wageningen in The Netherlands, under the supervision of Professor Dr N. van Breemen, began research to characterize the diverse mangrove swamp rice ecosystems of West Africa. Mr Sylla is conducting his field work in The Gambia, Guinea-Bissau, Senegal

and Sierra Leone with financial support from USAID, under the supervision of Dr Martin Agyen-Sampong, entomologist and Mangrove Swamp Rice Network Coordinator, and Dr Kanwar Sahrawat, soil scientist. In each country, secondary data on climate, soils, vegetation and flooding have been analysed to provide a basis for the selection of key sites. Intensive soil surveys and field experiments are being conducted at each key site across transects representing the full range of soil conditions adjacent to rivers and estuaries. Data collection and analysis will be completed in late 1992. The results will be used to guide future varietal improvement research and to better target the technology transfer activities of national extension services. This work will be completed in 1993.

- *André Ouattara,* an Ivorian national preparing his Doctorat de troisième cycle at the Centre Ivorien de Recherches Economiques et Sociales (CIRES), began his field work under the supervision of WARDA's Continuum Program economist, Dr Akinwumi Adesina, and Dr Kouadio Yao of CIRES. He is conducting an ex-ante analysis of new rice production technologies in the Guinea savanna zone of northern Côte d'Ivoire. Data for his thesis are being collected through surveys of farmers in the Korhogo region. He will identify the major constraints to adoption across different types of rural households and estimate the potential impact of new technologies on household incomes and rice marketing. The effects of national policies on adoption rates and patterns will also be determined. Mr Ouattara plans to complete his thesis write-up in early 1993. His field work is being supported by a grant from AfDB.

Post-doctoral scientists Under the post-doctoral program, recent PhD recipients come to WARDA for 2-year assignments. Preference is given to West African scientists, but young scientists from other parts of the world are also considered. The program is designed to play a major role in strengthening WARDA's current research activities, identifying possible future staff members, building national capacities and expanding the network of rice scientists within West Africa and worldwide.

Two post-doctoral scientists worked in WARDA research programs in 1991:

- *Dr Laurence Becker,* an American national and Rockefeller Foundation Research Fellow, began his work in early 1990 immediately after being awarded his PhD in geography from the University of London. He worked within WARDA's Continuum Program, characterizing and classifying the major rice cropping ecosystems in Côte d'Ivoire. Dr Becker interviewed farmers and extension officers throughout the country's 185 sous-préfectures to characterize rice-based cropping systems according to physical, technical and socio-cultural factors. Combining these data with field observations and secondary information on soils, climate and vegetation, Dr Becker defined and mapped 10 distinct rice cropping ecosystems. The results of this major study will be used by scientists in WARDA and in the Côte d'Ivoire national program to select key sites for more in-depth characterization and to locate trials for promising rice technologies.

- *Dr Robert Guei,* an Ivorian national who recently completed his PhD in plant breeding at Kansas State University, USA, joined WARDA's Mangrove Swamp Program in early 1991. Dr Guei has been responsible for making selections from segregating populations resulting from crosses made by WARDA in the late 1980s. He has selected materials in areas chosen for their high levels of biotic and abiotic stresses. Dr Guei also played a leading role in planning and implementing the first year of regional trials of advanced rice cultivars in collaboration with national breeders through the Mangrove Swamp Rice Network. He helped prepare training materials and served as a trainer on several courses organized by the network for national program scientists and technicians. His work has been supported by a grant from USAID.

Post-doctoral fellow, Dr Robert Guei, an Ivorian national, working as a member of the WARDA Mangrove Swamp Rice Network in Rokupr, Sierra Leone

Research assistants WARDA provides on-the-job training for research assistants on specific research techniques. Participants in this AfDB-supported program are young scientists or technicians who have degrees but have not yet had much work experience. Two research assistants, both from Sierra Leone, are receiving in-service training at WARDA-Rokupr. Robert Chakanda is engaged in the evaluation of segragating populations, while Charles Dixon is involved in the characterization of mangrove swamp soils.

Visiting scientists This program provides opportunities for more experienced scientists to conduct specialized research on a range of rice science topics. Participants are expected to work relatively independently and to make a substantive contribution to WARDA's research efforts. Two national scientists, Albino C. Emabalo from Guinea-Bissau and Aoussa Diallo from Guinea, visited the Soils Laboratory of the Department of Agricultural Research in Yundum, The Gambia, from 18 November to 15 December 1991. They gained practical experience in the use of equipment and advanced techniques in soil physical and chemical analysis, including the determination of electrical conductivity and soil pH. Another Guinean scientist, Sékou Diawara, visited the ISRA station at Djibélor, Senegal, from 11 November to 7 December 1991 to work with the ISRA Farming Systems Division. He studied techniques for conducting on-farm trials and agro-economic surveys to identify research priorities.

REGIONAL AND INTERNATIONAL COLLABORATION IN TRAINING

Collaborative training activities were strengthened with national groups and international organizations. Activities undertaken with national groups were as follows:

- *Nigeria:* Work on the West African edition of the *Farmers' Primer for Rice Growing*, undertaken in collaboration with NCRI, was completed. The book was sent for printing in late 1991 and publication is scheduled for early 1992. WARDA also worked closely with the national program in organizing a follow-up in-country TOT course in November 1991.
- *The Gambia:* A follow-up in-country TOT course was successfully organized in October 1991 by the national research system, which collaborated closely with WARDA in planning and implementation.
- *Côte d'Ivoire and Togo:* Resource persons from the national programs in these countries were used extensively in the planning of group training courses for 1992.

Activities undertaken with international organizations were as follows:

- *International Rice Research Institute (IRRI):* In August Dr Ike Navarro, a training specialist from IRRI, assisted WARDA in the development of a training course on the Genetic Evaluation and Utilization of Rice. He attended the Mangrove Swamp Rice Network training course on Mangrove Rice Production and interacted closely with the scientists there in course planning.
- *International Irrigation Management Institute (IIMI):* Arrangements were finalized with IIMI, Ouagadougou, Burkina Faso for the organization of the training course on Water and Irrigation Management for Rice Production, scheduled for March 1992. WARDA worked closely with IIMI in planning the content and overall administration and management of the course.
- *International Crops Research Institute for the Semi-Arid Tropics (ICRISAT):* WARDA worked with Dr Roger Stern, Biometrician, Dr B. Ndunguru, Chairman of the Training Committee, and Alieu Jagne, Regional Administrator at the ICRISAT Sahelian Center, in planning a group training course on Computer Applications and Statistical Analysis in Agricultural Research, scheduled for January 1992.
- *Technical Centre for Agricultural and Rural Cooperation (CTA):* Strong collaboration has now been established between WARDA and CTA in training and publications activities. CTA provided a resource person, five training fellowships and training materials for the Scientific Writing for Agricultural Research Scientists course. CTA also collaborated with WARDA in co-publishing the TOT manual in French.
- *Centre de Coopération Internationale en Recherche Agronomique pour le Développement (CIRAD):* CIRAD provided and supported two resource persons, both women (Michelle Jeanguyot and Martine Seguier-Guis) to plan and organize the course on Scientific Writing for Agricultural Research Scientists.
- *Institut du Sahel (INSAH):* Rokia Ba Touré, of INSAH, Bamako, Mali, was a resource person for the Scientific Writing for Agricultural Research Scientists course.
- *Semi-Arid Food Grain Research and Development (SAFGRAD) project and African Association of Science Editors (AASE):* WARDA collaborated successfully with both these organizations in planning and organizing the group training course on Scientific Writing for Agricultural Research Scientists.

SUMMARIES OF COMMUNICATIONS ACTIVITIES

Publications Unit

WARDA's in-house publishing capabilities remain very weak. However, determined efforts were made during 1991 to produce or originate publications in both French and English.

Six issues, totalling 48 pages, of the *WARDA Development Update* were published. The objective of this newsletter is to report progress in the development of WARDA's Main Research Center and Headquarters at M'bé in Côte d'Ivoire. There were 10 issues, totalling 68 pages, of *WARDA News*, a monthly internal newsletter which reports events at WARDA. Five issues of *Trainerlink*, the special newsletter which focuses on training activities, were published, with a total of 38 pages. In addition to these publications, the Unit produced 12 brochures/leaflets, with a total of 108 pages, and 12 books/booklets, with a total of 599 pages.

The major books/booklets published in French and English during the year were as follows:

- *Annual Report 1990*
- *Program of Work and Budget 1992*
- *Group Technical Training at WARDA 1992*
- *Rice Challenge* (French)
- *A Program of Partnership*
- *WARDA: Breaking New Ground*
- *Training of Agricultural Trainers Course Instructor's Manual* (French)

A series of very positive reports on WARDA were published in local, regional and international newspapers and magazines. Copies of these reports were reproduced as a booklet entitled *WARDA in the World Press*.

In addition to the publications produced in 1991, a 25-minute video on WARDA entitled 'Breaking New Ground' was produced. The video was presented at the International Centers Week in Washington, USA in October 1991. A accompanying booklet was also published. Both the video and the booklet have been distributed to WARDA donors as well as to selected international organizations, agencies and individuals.

International identifier codes for WARDA's publications were obtained from Unesco, Paris. These codes enable WARDA's publications to be listed in the world's bibliographic databases.

Library and Documentation Center

Significant progress was made in 1991 in upgrading the library resources and providing information and documentary services to scientists. The WARIS project was implemented and links with institutions providing global agricultural information services were strengthened. In the first phase of the WARIS project, equipment and library materials were purchased in order to provide improved and better targeted services to WARDA and national scientists.

The equipment purchased included a Hewlett Packard Laser Jet III printer, a Micro Design Micro Copy 1000 Microfiche reader-printer and two Toshiba XM-3201B CD-ROM drives.

The main library holdings acquired during the year are summarized in Table 29.

TABLE 29
WARDA library acquisitions during 1991

Type of document	Number acquired
Books	564
Periodicals	2009
Annual Reports	106
Catalogs/pamphlets	195
Reprints/photocopies	3650
Others	84

An attempt was made to fill gaps in key journal and book collections. Several journals were received on an exchange basis with other international organizations and libraries.

WARDA's databases were further developed during the year. The West African Rice Bibliographic Database (WARBI) and the Periodical Database of WARDA (PERIO) now contain 12 900 and 1190 records, respectively. In addition, the Union Catalog of Serials held at international agricultural research centers and containing 5400 serial titles, was installed, enabling requests for photocopies of articles not available in the library to be more efficiently targeted to the information services of other international centers. WARDA's computer access to external databases was also improved.

WARDA received updates of the following agricultural databases on CD-ROM: AGRICOLA (1970-present, updated quarterly); AGRIS (1986-present, updated annually); CAB Abstracts (1984-present, updated annually); KIT Abstracts/TROPAG & RURAL (1975-present, updated quarterly); and SESAME (1980-1990 and 1991 editions).

In addition to these CD-ROM databases, WARDA subscribed to Current Contents on Diskette (Agriculture, Biology and Environmental Sciences), a service which gives immediate access to the most up-to-date bibliographic data from thousands of journals and books worldwide. Each week, a new Current Contents on Diskette issue is delivered to be loaded and read on the computer.

The computerized WARDA mailing list, which now holds about 2500 addresses, was used to distribute WARDA's publications.

Current Contents at WARDA was published monthly. About 150 copies of each issue were distributed in WARDA member countries, together with two photocopy request forms. Scientists were able to obtain up to 50 photocopied pages free-of-charge from the WARDA library by filling in and returning the request forms.

In addition to book circulation services, over 350 publications and 33 356 photocopied pages of journal articles and book chapters were sent out on request. The libraries at IRRI, CTA and the Agricultural University of Wageningen were particularly helpful in providing materials not available at WARDA.

Over 50 major searches were made on internal and external databases, to meet the information needs of WARDA and national rice research scientists (*see* page 87).

Translation and Conference Services Unit

The Translation and Conference Services Unit facilitated communication within WARDA and, more importantly, relationships with other institutions and with national scientists. The documents translated by the unit are presented in Table 30.

TABLE 30
Documents processed by the Translation and Conference Services Unit, 1991

Type	Number of documents translated	Number of pages
Administrative documents	196	389
Publications		
Annual Report 1990	1	80
Reports of meetings	39	404
Training manuals and lecture notes	4	601
Newsletters	15	47
Occasional publications	4	57
Rice research documents	25	277
Miscellaneous documents	3	253
Total	318	2028

The unit also assists with the organization of conferences through the coordination of interpretation, documentation and secretarial support. During the year, the unit provided support to several meetings, including that of the Board of Trustees and its committees, the In-House Review, the Donors' Conference and the technical meetings of the research Working Groups and Task Forces.

Work began on an English-French rice terminology and a CGIAR terminology, the aim being to produce a harmonized technical vocabulary for use by interpreters and translators.

REGIONAL AND INTERNATIONAL COLLABORATION IN COMMUNICATIONS

Collaborative communications activities were strengthened with national groups and international organizations. The activities undertaken with national groups were as follows:

- *Côte d'Ivoire:* WARDA's Library and Documentation Center staff regularly visited relevant institutions and information services in the Bouaké and Abidjan area to establish and strengthen collaboration. Staff also took part in the activities and quarterly meetings of the Ivorian Agricultural Information Network (REDACI).
- *Congo:* At the request of IDRC-Dakar the WARDA Documentalist undertook a consultancy mission to Brazzaville from 16 to 24 August 1991. He helped the Congolese Agricultural Information Network (REDICA) at the Ministry of Agriculture solve problems related to the computerization and efficient management of the national agricultural bibliographical database.
- *Sierra Leone:* The WARDA Documentalist visited Rokupr from 26 to 31 May 1991 to help reorganize the Rice Research Station library. He worked with the Rokupr Librarian to develop more efficient processing procedures for library holdings and installed two computerized bibliographical databases to improve access to relevant literature available in the CGIAR centers. The WARDA Mangrove Swamp Rice Program library collection was merged with that of the Rice Research Station library. In addition, books and reference materials requested by Rokupr scientists were ordered by WARDA's library.

Activities undertaken with international organizations were as follows:

- *IRRI, South-East Asia and France:* From 13 to 28 July 1991 the WARDA Documentalist visited the libraries and information centers of IRRI and various other organizations in the Philippines and France. Useful contacts were made and agreements reached for the exchange of publications. Information and publications relevant to rice in West Arica were also collected. At IRRI, records pertinent to rice in West Africa were downloaded from the IRRI Rice Database and a copy of the Rice Entomology Database was obtained from the Entomology Department. The Centre International de Documentation en Agronomie des Régions Chaudes (CIDARC) agreed to run profiles for the WARIS SDI service and to send the outputs on diskettes regularly to WARDA.
- *Canadian Embassy, Abidjan, Côte d'Ivoire:* The WARDA Documentalist was invited to the Cooperation Department of the Canadian Embassy in Abidjan from 23 to 27 September 1991 to assist with the reorganization of the Department's Documentation Center. He reviewed and improved the definition and structure of the computerized bibliographical database. Various display and print formats for literature searches and methods of producing bibliographies were developed. He also trained the staff responsible for database management and assisted in the development of a users' guide.

FINANCIAL STATEMENT

PRINCIPAL PERSONNEL

SHORT-TERM CONSULTANTS

STAFF PUBLICATIONS

LIST OF ACRONYMS

West Africa Rice Development Association

Statement of Financial Position as at 31 December 1991

(expressed in US dollars)

	1991	1990
CURRENT ASSETS		
Inventory	154 881	82 505
Accounts Receivable — Donors	2 291 547	1 452 382
Accounts Receivable — Other	596 920	514 559
Cash and Bank Balances	401 707	2 779 159
	3 445 055	4 828 605
CURRENT LIABILITIES		
Bank Overdrafts	880 258	—
Accounts Payable	976 547	343 222
Provisions and Accruals	2 671 650	1 673 433
Contributions in Advance	283 777	864 915
Project Fund Balances	192 733	68 457
	5 004 965	2 950 027
Net Current (Liabilities) Assets	(1 559 910)	1 878 578
Property, Plant and Equipment	9 614 256	3 217 152
NET ASSETS	8 054 346	5 095 730
Represented by:		
Capital Invested in Fixed Assets	9 614 256	3 217 152
Restricted Funds		
Capital Fund	(2 549 200)	1 473 181
Unrestricted Funds		
Working Capital	500 000	500 000
Operating Fund	489 290	(94 603)
FUND BALANCES	8 054 346	5 095 730

The financial statements were approved by the Board of Trustees on 11 April 1992 and were signed on their behalf by:

Director General

Director of Administration and Finance

West Africa Rice Development Association

Grants and Contributions for the Year ended 31 December 1991

(expressed in US dollars)

	UNRESTRICTED CORE	RESTRICTED CORE	COMPL. PROJECTS	CAPITAL DEVELOPMENT	TOTAL 1991	TOTAL 1990
DONORS						
World Bank	1 785 000	—	—	—	1 785 000	1 600 000
Sweden	595 803	—	—	—	595 803	615 631
Canada	656 990	—	—	175 285	832 275	783 563
IDRC	—	41 933	—	—	41 933	3 099
AfDB	200 000	324 225	—	200 000	724 225	350 000
The Netherlands	97 874	—	—	536 688	634 562	633 792
Germany	303 298	—	—	1 290 803	1 594 101	1 141 269
France	295 305	13 750	—	1 181 481	1 490 536	1 138 292
Japan	792 769	—	17 630	500 000	1 310 399	1 448 374
Belgium	60 155	—	—	—	60 155	266 058
EEC	—	532 927	—	—	532 927	401 289
UNDP	—	70 570	—	—	70 570	487 213
USAID	—	527 976	—	—	527 976	289 524
Italy	120 299	—	—	—	120 299	128 375
UK	180 416	—	—	—	180 416	175 035
Rockefeller Foundation	—	5 000	—	—	5 000	3 770
Subtotal	5 087 909	1 516 381	17 630	3 884 257	10 506 177	9 465 284
MEMBER STATES						
Burkina Faso	13 142	—	—	—	13 142	18 604
Mali	—	—	—	—	—	18 604
Nigeria	50 000	—	—	—	50 000	—
Sierra Leone	6 011	—	—	—	6 011	18 604
Togo	18 500	—	—	—	18 500	—
Subtotal	87 653	—	—	—	87 653	55 812
SUNDRY INCOME	22 290	—	—	11 996	34 286	132 429

West Africa Rice Development Association

Statement of Activity by Funding Source for the Year ended 31 December 1991

(expressed in US dollars)

	UNRESTRICTED CORE	RESTRICTED CORE	COMPL. PROJECTS	TOTAL OPERATING	CAPITAL DEVELOPMENT	TOTAL 1991	TOTAL 1990
INCOME							
Grants and Contributions							
Donors	5 087 909	1 516 381	17 630	6 621 920	3 884 257	10 506 177	9 465 284
Member States	87 653	—	—	87 653	—	87 653	55 812
Other Income	22 290	—	—	22 290	11 996	34 286	132 429
	5 197 852	1 516 381	17 630	6 731 863	3 896 253	10 628 116	9 653 525
EXPENDITURE							
Research Programs	1 918 467	1 385 716	15 557	3 319 740	—	3 319 740	2 801 715
Training and Communications	682 889	107 760	—	790 649	—	790 649	1 600 008
General and Administration	1 766 097	—	—	1 766 097	—	1 766 097	1 925 415
Capital Development	—	—	—	—	563 211	563 211	243 088
	4 367 453	1 493 476	15 557	5 876 486	563 211	6 439 697	6 570 226
ADD							
Depreciation of Fixed Assets	238 532	22 905	2 073	263 510	144 513	408 023	342 276
	4 605 985	1 516 381	17 630	6 139 996	707 724	6 847 720	6 912 502
EXCESS OF (EXPENDITURE OVER INCOME) INCOME OVER EXPENDITURE	591 867	—	—	591 867	3 188 529	3 780 396	2 741 023
Extraordinary Items	80 804	—	—	80 804	—	80 804	(92 047)
Prior Year Adjustments	(30 804)	—	—	(30 804)	(25 078)	(55 882)	(25 761)
FUND BALANCES AT BEGINNING OF YEAR	(94 603)	—	—	(94 603)	—	(94 603)	171 996
Bad Debts Written Off	(57 974)	—	—	(57 974)	—	(57 974)	(9 921)
Transfer to Capital Fund	—	—	—	—	(3 163 451)	(3 163 451)	(2 879 893)
FUND BALANCES AT END OF YEAR	489 290	—	—	489 290	—	489 290	(94 603)

Principal Personnel

Office of the Director General

Eugene R. Terry, PhD [3]	Director General
Salif Camara, MS [1,4]	Internal Auditor
Djawadou Sanni, Eng. GR [1,3]	Special Assistant to the Director General for International Cooperation

Administration and Finance Division

Gordon MacNeil, MBA [3]	Director of Administration and Finance
Kwame Akuffo-Akoto, BSc, FCCA [3]	Financial Controller
Honore Bobo, MBA [4]	Chief Accountant
Bola Andrews, MA [4]	Administrative Officer
Ursule Konan, ML, CFB [4]	Personnel Officer

Research Division

Research Coordination

Peter Matlon, PhD [3]	Director of Research
Edgar W. Richardson, PhD [3]	Biometrician
Chitti Babu Buyyala, BSc [3]	Farm Manager
Michel Briat, IA [5]	Assistant Farm Manager

Upland/Inland Swamp Continuum Program

Bouaké, Côte d'Ivoire

Elvis A. Heinrichs, PhD [3]	Program Leader and Entomologist
Abdoul Aziz Sy, PhD [3]	Pathologist
Akinwumi Adesina, PhD [3]	Production Economist
Monty Jones, PhD [3]	Breeder
Kanwar L. Sahrawat, PhD [2,3]	Soil Scientist
Laurence Becker, PhD [7]	Geographer
Thomas Remington, PhD [3]	Cropping Systems Agronomist
Sitapha Diatta, DEA [4]	Research Associate
Roger Diallo, Ing. Agr. [4]	Research Associate
Michio Takeda, BSc [6]	Post-Harvest Specialist

Ibadan, Nigeria

Baij N. Singh, PhD [9]	Lowland Breeder

Sahel Irrigated Rice Program

St Louis, Senegal

Kouamé Miézan, PhD [3]	Program Leader and Breeder
Michael Dingkuhn, PhD [3]	Physiologist

Mangrove Swamp Rice Network

Rokupr, Sierra Leone

Martin Agyen-Sampong, PhD [3]	Network Coordinator and Entomologist
Robert Guei PhD [7]	Breeder

Training and Communications Division

Anthony Youdeowei, PhD, FAAS [3]	Director of Training and Communications

Training

Zainabou Cole, BSc [8]	Trainer Intern

Communications

Christiane Soufflet, MA [3]	Translator/Reviser
Alassane Diallo, MSc [3]	Documentalist
Solange Bembatoum, DESS [4]	Translator
Messan Dossekou, MSc [8]	Desk Top Publishing Assistant

Capital Development

Peter Mather, ARIBA [8]	Development Officer
Gregory Servant, BBA [1]	Capital Projects Officer

1 Left on or before 31 December 1991
2 Joined in 1991
3 International senior staff (core programs)
4 Professional general service staff
5 French co-operant
6 Japanese contract staff
7 Post-Doctoral Fellow
8 Long-term consultants
9 Visiting scientist

Short-Term Consultants

Administration

Dr Robert I. Ayling	Preparation of External Program Review Materials
Mr Richard Bilodeau	Computer Networking Services

Research

Dr Ernest W. Nunn	Development of Land Use Plan for M'bé Research Farm
Dr Andrew Polaszik	Integrated Pest Management Evaluation of Parasitoids of Stem Borers of Cereals, especially Rice
Dr Richard Plowright	Assessment of the Importance of Plant Parasitic Nematodes of Rice in the Continuum and Sahel

Training and Communications

Dr Roger Stern	Development of curriculum for training course on Computer Applications and Statistical Analysis in Agricultural Research
Dr Osebi Asiribo	Development of curriculum for training course on Computer Applications and Statistical Analysis in Agricultural Research
Dr Olufunke Egunjobi	Development of curriculum for training course on Crop Protection
Dr Yamar Mbodji	Development of curriculum for training course on Crop Protection
Mr Ludovic N'Cho	Development of curriculum for training course on Upland Rice Production
Dr Rita Agboh-Noameshie	Development of curriculum for training course on Upland Rice Production
Mr Barry Hall	Production of WARDA documentary film
Mr David Constable	Production of WARDA documentary film
Mr Simon Chater	Editing/writing
Mr Messan Dossekou	Establishment of Desk Top Publishing facility
Dr Edward D. Spiff	Preparation of Rice Production Training Manual materials
Mr Douglas Ede	Editing of Rice Production Training Manual

Publications by WARDA Staff 1991

Journal articles

Adesina, A.A. and Sanders, J.H. 1991. Peasant farmer behaviour and cereal technologies: Stochastic programming analysis in Niger. *Agricultural Economics* 5: 21-38

Cork, A., Agyen-Sampong, M., Fannah, S.J., Beevor, P.S. and Hall, D.R. 1991. Sex pheromone of female African white rice stem borer, *Maliarpha separatella* (Lepidoptera: Pyralidae) from Sierra Leone: Identification and field testing. *J. Chemical Ecology* 17(6): 1205-19

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Graf, B., Dingkuhn, M., Schnier, F., Coronel, V. and Akita, S. 1991. A simulation model for the dynamics of rice growth and development. III. Validation of the model with high yielding varieties. *Agricultural Systems* 36: 329-49

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Chevas, J-P., Kristjanson, P.M. and Matlon, P.J. 1991. On the role of information in decision making — the case of sorghum yield in Burkina Faso. *J. Development Economics* 35: 261-80

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Sy, A.A., Albertini, L., Moletti, M. and Hamant, C. 1991. Mécanismes potentiels régissant le contrôle biologique des agents phytopathogènes. *Cryptogamie Mycologie* 12 (2): 133-47

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Heinrichs, A.E. and Miller, T.A. (eds) 1991. *Rice Insects: Management Strategies*. New York, USA: Springer-Verlag

Book chapters

Dingkuhn, M., Penning de Vries, F.W.T., De Datta, S.K. and van Laar, H.H. 1991. Concepts for a new plant type for direct-seeded flooded tropical rice. In *Direct-Seeded Flooded Rice in the Tropics*. Manila, the Philippines: IRRI

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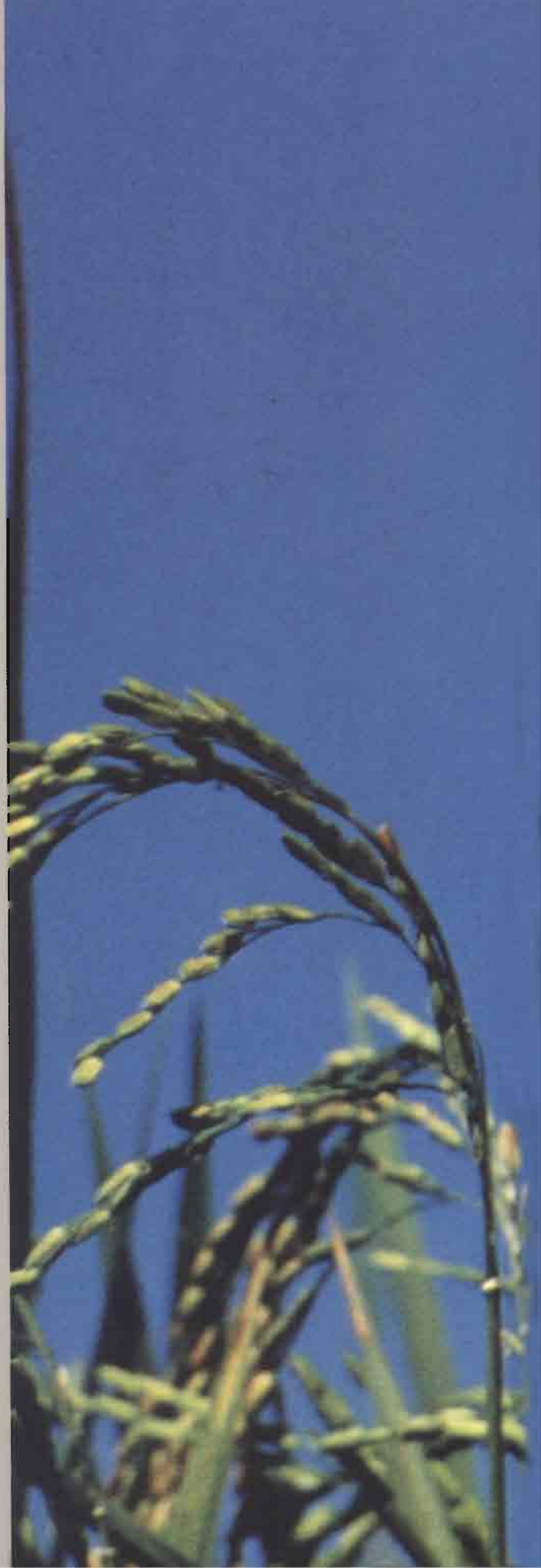
List of Acronyms

AASE	African Association of Science Editors
AfDB	African Development Bank
AGRICOLA	Agricultural On-Line Access (National Agricultural Library, USA)
AGRIS	Agricultural Information System (FAO)
BNDA	Banque Nationale de Développement Agricole (Mali)
CABO	Center for Agrobiological Research
CECI	Centre Canadien d'Etude et de Coopération Internationale
CGIAR	Consultative Group on International Agricultural Research
CIAT	Centro Internacional de Agricultura Tropical
CIDA	Canadian International Development Agency
CIDARC	Centre International de Documentation en Agronomie des Régions Chaudes
CIRAD	Centre de Coopération Internationale en Recherche Agronomique pour le Développement (France)
CIRES	Centre Ivorien de Recherches Economiques et Sociales
CLEMCI	Group CLEMSI of Côte d'Ivoire
CNPAF	Centro Nacional Pesquisa Arroz e Feijao (Brazil)
CNRST	Centre Nationale de Recherche en Scientifique et de Technologie (Burkina Faso)
CONGAT	Conseil Gestion Afrique, Togo-Initiatives des Communautes de Base
CORAF	Conférence des Responsables de la Recherche Agronomique Africains et Français
CTA	Technical Centre for Agricultural and Rural Cooperation (The Netherlands)
ECA	Economic Commission for Africa
ECSA	East, Central and Southern Africa
EEC	European Economic Community
FAO	Food and Agriculture Organization of the United Nations
FOPADESC	Fondation Pan Africaine pour le Développement Economique, Social et Culturel
GTZ	Deutsche Gesellschaft für Technische Zusammenarbeit
IARI	Indian Agricultural Research Institute
IBPGR	International Board for Plant Genetic Research
ICRAF	International Center for Research in Agroforestry
ICRISAT	International Crops Research Institute for the Semi-Arid Tropics
IDESSA	Institut des Savanes (Côte d'Ivoire)
IDRC	International Development Research Centre
IFAD	International Fund for Agricultural Development
IIMI	International Irrigation Management Institute
IITA	International Institute of Tropical Agriculture
ILCA	International Livestock Centre for Africa
INERA	Institut National pour l'Etude et la Recherche Agricole (Zaire)
INGER	International Network for Genetic Evaluation
INSAH	Institut du Sahel
IRAT	Institut de Recherches Agronomiques Tropicales et des Cultures Vivrières (France)
IRRI	International Rice Research Institute
ISNAR	International Service for National Agricultural Research
ISRA	Institut Sénégalais de Recherches Agricoles
KIT	Koninklijk Instituut van de Tropen (The Netherlands)
MRC & HQ	Main Research Center and Headquarters (WARDA)
NCRI	National Cereals Research Institute (Nigeria)
ODA	Overseas Development Administration (UK)
PERIO	Periodical Database (WARDA)

PNDC	Provisional National Defence Council (Ghana)
RESADOC	Reseau Sahéliѐn de Documentation Scientifique et Technique
RICA	Réfrigération Ivoirienne de Conditionnement d'Air
SAED	Société Nationale d'Aménagement et d'Exploitation des Terres du Delta du Fleuve Sénégal et des Vallées du Fleuve Sénégal et de la Falémé
SAFGRAD	Semi-Arid Food Grain Research and Development
SDI	Selective Dissemination of Information
SETAO	Société d'Etudes et de Travaux d'Afrique de l'Ouest
SPAAR	Special Program for African Agricultural Research
TAC	Technical Advisory Committee (CGIAR)
TOT	Training of Agricultural Trainers
UNDP	United Nations Development Programme
USAID	United States Agency for International Development
USDA	United States Department of Agriculture
WARBI	West African Rice Bibliographic Database
WARIS	West African Rice Information System
WHO	World Health Organization



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