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WARDA

ANNUAL REPORT

1992

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ANNUAL REPORT

1992

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FOREWORD

The three major events which dominated WARDA's calendar of activities in 1992 were the completion and occupation of the Association's Main Research Center and Headquarters at M'bé in Côte d'Ivoire, the external review of WARDA's programs and management by a panel of experts appointed by the Technical Advisory Committee (TAC) of the Consultative Group on International Agricultural Research (CGIAR), and the development of proposals for WARDA's second Medium-Term Plan (MTP) for the period 1994-98.

The construction of the first phase of the research facility was completed on schedule in February 1992, and occupied in May, contributing significantly to the efficient implementation of the 1992 program of work. The research complex consists of well-equipped laboratories, offices and basic infrastructural support facilities for our research farm. Good progress was also made in the execution of WARDA's long-term master land use plan.

The first two activities relating to WARDA's third External Program and Management Review (EPMR), namely the review of the Board of Trustees by the external review panel and the initial phase of the EPMR, were held in April and August 1992, respectively. The main and final phase was scheduled for January 1993. In line with the decision by the CGIAR to harmonize the implementation of the second MTPs for all its 18 centers, it was agreed that WARDA's first MTP (1990-94) would terminate in 1993. This new timetable meant that certain critical decisions had to be made by the Board and management on the content of the 1992 and 1993 programs and their effect on the program for 1994. WARDA's programs and management were therefore subjected to an in-depth internal review in April 1992 in preparation for the EPMR and for the formulation of proposals for the second MTP. These proposals were completed in December in time for consideration by the external review panel and the TAC Working Group assigned to WARDA for preliminary discussions on the proposals.

Severe budgetary constraints resulted in the modification of the scale and dimensions of the programs originally proposed for 1992. Management therefore effected appropriate adjustments to ensure continuity of the programs implemented in 1991 and to protect the integrity of programs proposed in the first MTP.

In 1992, WARDA consolidated its efforts to develop an innovative program of partnership with its national program colleagues. These initiatives culminated in the establishment of four new Regional Task Forces for collaboration in the development of technologies which would increase sustainable rice production in West Africa. Sixteen countries participated in these Task Force activities to implement collaborative projects in upland and lowland rice breeding for the continuum environment, irrigated rice improvement for the Sahel and integrated pest management. The activities were jointly planned, prioritized and executed as fully integrated regional research programs. The participation of national scientists in these activities was supported by small grants specifically provided by WARDA's donors.

WARDA continued its efforts in 1992 to integrate the key components of its research, training and communications activities in a manner that would ensure not only progress in technology generation but also the development of the human resources of its national program partners. Thus, there was an increase in the number of research scholars conducting research at WARDA's field locations.

The loss of WARDA's Training Center in Liberia, coupled with the budgetary constraints which limited recruitment of international-level training specialists, led to the suspension of training

activities in 1991. In 1992, WARDA continued with its itinerant training strategy initiated in 1990 in member countries, in partnership with national scientists. This approach allowed these scientists to participate fully in the design and implementation of training courses, ensuring that the orientation of these courses addressed their needs. National scientists also served as resource persons and their course notes were utilized extensively to develop training manuals.

In the area of communications, WARDA's selective dissemination of information (SDI) service was strengthened in 1992 to enable the Association to target literature to specific user needs throughout West Africa. The document delivery and literature search services to national programs were expanded considerably in an effort to satisfy the increased demand for information from rice scientists and other agricultural researchers in the region.

This Annual Report provides details and summaries of all the activities outlined above, including reports on on-going research activities in the continuum, Sahel and mangrove swamp rice production systems and on progress in our training and communications programs. It also contains a feature article which presents details of the main results and conclusions from WARDA's research on salt tolerance of rice varieties grown under irrigated conditions in the Sahel.

On behalf of the Board of Trustees, management and staff, it gives me great pleasure to present WARDA's 1992 Annual Report. I take this opportunity to express our sincere appreciation to our donors for their continued strong financial and moral support. I would also like to thank all WARDA's national, regional and international partners for their important contributions to the progress achieved in 1992. I expect and hope that the activities described in this report, and the technical and scientific knowledge generated through those activities, will significantly enhance our collective efforts to achieve sustainable food production in sub-Saharan Africa.

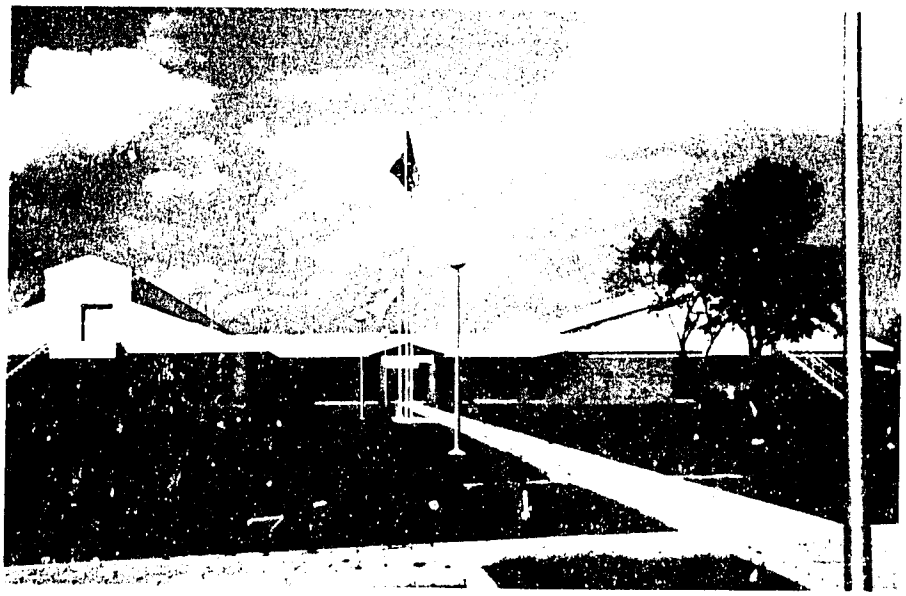
Eugene R. Terry, PhD (Illinois)
Director General

About WARDA

The West African Rice Development Association (WARDA) is an intergovernmental research association with a mandate to conduct rice research, training and communications activities for the benefit of the West African region. Formed in 1971 by 11 countries with the assistance of the UNDP, FAO and ECA, WARDA now consists of 17 member countries, including Cameroon which joined in 1991. WARDA is a member of the network of 18 international agricultural research centers supported by funds from donors of the 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 WARDA are 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.



WARDA's Main Research Center and Headquarters at M'bé, Côte d'Ivoire

Donors

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
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United Nations Development Programme (UNDP)
United States of America
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- Burkina Faso
- Cameroon
- Chad
- Côte d'Ivoire
- Ghana
- Guinea
- Guinea-Bissau
- Liberia
- Mali
- Mauritania
- Niger
- Nigeria
- Senegal
- Sierra Leone
- The Gambia
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Calendar of Events in 1992

January

6-31	Training course: Computer applications and statistical analysis in agricultural research, ICRISAT, Niamey, Niger
15-18	Director General attends CGIAR Strategy Formulation meeting in London, UK
20-21	Lowland Breeding Task Force meeting, Ibadan, Nigeria
22	Meeting of the Steering Committee of the Upland Rice Breeding Task Force, Ibadan, Nigeria
28	Nigerian Ambassador to Côte d'Ivoire, H.E. J. Coker, visits WARDA

February

12	Estates Committee meeting, M'bé and Bouaké
14	Tenders Committee meeting (No. 22), Bouaké
19-20	Integrated Pest ManagementTask Force meeting, Bouaké
26	Reception Provisoire of the Main Research Center and Headquarters, M'bé

March

2-30	Training course: Water and irrigation management for rice production, Ouagadougou, Burkina Faso
3	Program Management Committee meeting, Bouaké
12-22	Director General attends TAC meeting (No. 57), Aleppo, Syria

April

1	Director General attends UN/World Bank/FAO sponsored Special Briefing, New York, USA
1-5	EPMR Consultant, Dr Ralph Riley, undertakes country visits
6-8	Internal Program Review and In-House Review
9-10	Meetings of the Board of Trustees Program, Nominating and Executive Committees, Bouaké
23-24	Integrated Pest Management Steering Committee meeting, Bouaké

May

3-7	Inter-Center Rice Review Chairman, Dr Grant Scobie, visits WARDA
4-6	WARDA/NARS seminar: Human resources development for rice science in West Africa, M'bé
6	Training Working Group meeting, M'bé
8	Office of the Director General moves to M'bé
4-13	Development Officer moves to M'bé
11-12	Crop and Resource Development Working Group meeting, Banjul, The Gambia
12	Mayor of Bouaké visits M'bé
14	Ivorian Minister for Scientific Research and Professional and Higher Education visits WARDA, accompanied by representatives of Ministers of Agriculture, Environment, Construction and Urbanism, and Communications
16-22	Office of the Director of Administration and Finance moves to M'bé
21	Office of the Director of Research moves to M'bé

June

1-29	Training course: Training of agricultural trainers, Cotonou, Benin
5	Office of the Director of Training and Communications moves to M'bé
19	Continuum Program moves to M'bé
22-29	Director General attends TAC meeting (No. 58), Rome, Italy
24-27	Director of Training and Communications attends closing stages of Training of agricultural trainers course, Cotonou, Benin
29-11 July	Director of Training and Communications attends CGIAR Senior Management Development Course, USA

July

5-10	Director General visits AVRDC in Taiwan
13-7 August	Training course: Crop protection in rice, Bouaké
22-24	CGIAR Senior Finance Officer visits WARDA

August

6-11	EPMR: initial phase at WARDA
17-18	CGIAR Chairman and Executive Secretary visit WARDA
12-23	EPMR: field visits to WARDA member states

September

3-4	Japanese scientists visit WARDA
7-14	Training course: Upland rice production, Bouaké
7-14	Director of Agricultural Research, Cameroon, and the Coordinator of the Cameroon Rice Program visit WARDA
18	Director of Administration and Finance, Gordon MacNeil, leaves WARDA
20-25	Director General and Director of Research make official visit to Cameroon
24	British Ambassador to Côte d'Ivoire, H.E. M.I. Rothwell, visits WARDA
28-29	Varietal Improvement Working Group meeting, Ibadan, Nigeria

October

5	Experts from the AICAF, Japan, visit WARDA
12-15	Director General visits BMZ, GTZ and ATSAF, Germany
26-30	Director General and Director of Research attend International Centers Week, Washington DC, USA

November

15-20	Director General attends 13th SPAAR Plenary Session, The Hague, The Netherlands
16-28	Training course Scientific writing for agricultural research scientists Yamoussoukro, Côte d'Ivoire
24	Program Management Committee meeting, Bouaké

December

7	Deputy Director, Industrial Cooperation, Ministry of Agriculture, Japan, Mr K Sakata, visits WARDA
9-13	Director General visits Sierra Leone on behalf of the EEC

RESEARCH

OVERVIEW

Peter Matlon

As 1992 came to a close, WARDA's research scientists could take satisfaction in the manner with which they had worked together as team not only to expand and accelerate their research efforts but also to meet three particular challenges they had faced during the year. The first was to initiate collaborative research through the newly formed Task Forces; the second was to prepare for the External Progam and Management Review (EPMR); and the third was to develop the 1994-98 Medium-Term Plan (MTP). The MTP reflects the importance WARDA attaches to fostering regional and international collaboration in the development of technologies which will increase sustainable rice production in West Africa.

Task Force Initiatives

Task Forces are the key mechanism through which WARDA works with scientists in national programs to jointly plan and execute fully integrated regional research programs in areas of mutual interest. The priorities for collaborative activities are determined by national scientists.

Four Task Forces were formed in 1992, three in the Continuum Program (the Upland Rice Breeding Task Force, the Lowland Rice Breeding Task Force and the Integrated Pest Management Task Force) and one in the Sahel Program (the Sahel Irrigated Rice Improvement Task Force). At the planning workshops, the importance of production constraints and researchable problems were evaluated country by country and aggregated to the regional level. The ability of institutions participating in the Task Forces to address the major regional problems were critically evaluated and responsibilities were assigned based on comparative advantage. National scientists then developed project proposals within the context of these assignments. The proposals were reviewed by Task Force Steering Committees chaired by national scientists. For all approved projects, the Task Forces awarded small grants to help national programs conduct activities which had the potential to make a significant impact on the region.

Sixteen countries participated in Task Force activities in 1992. A total of 59 collaborative projects benefiting from Task Force support were conducted by national scientists. Table 1 summarizes the Task Forces activities in 1992.

Table 1 **NARS/WARDA Task Forces, 1992**

Task Force	First year active	No. of WARDA countries	Projects supported by small grants	Research priorities
Mangrove Swamp Rice	1991	6	20	Varietal tolerance to saline and acid soils High and stable yields Consumer acceptability
Upland Rice Breeding	1992	14	8	Varietal tolerance to drought, acid soils, rice blast and weeds High and stable yields Consumer acceptability
Lowland Rice Breeding	1992	13	9	High and stable yields Varietal tolerance to waterlogging, submergence, iron toxicity, rice blast, rice yellow mottle virus and African rice gall midge Consumer acceptability
Integrated Pest Management	1992	12	13	Rice blast Rice yellow mottle virus Stem borers African rice gall midge
Sahel Irrigated Rice Improvement	1992	7	9	High yield potential Varietal tolerance to extreme temperatures and salinity

External Program and Management Review and Medium-Term Plan

The EPMR began with an initial visit by the external review panel in August 1992 to WARDA research locations in Côte d'Ivoire, Nigeria, Senegal and Sierra Leone, as well as to national programs in those countries and in Burkina Faso. All scientists participated in preparing presentations and drafting documents requested by the panel.

The Research Division took advantage of the timing of the EPMR to conduct an internal review and to advance our on-going program planning. An planning document, 'Project, Sub-Project and Activity Summaries', was produced after a thorough review and restructuring of research projects in the Continuum and Sahel Programs. The aim of this restructuring exercise was to achieve greater interdisciplinarity in all our research activities and to emphasize priority resource and crop management issues. The document also gave more accountability to WARDA's research by specifying measurable outputs for all research activities year by year, through to 1995. The accent on accountability was strengthened by the production of a companion study which established research targets and quantified their potential impact on production, through to 1998. Both documents will be used extensively as reference points against which research progress will be measured.

In addition to meeting the needs of the review panel and catalyzing the on-going internal review process, the papers which were prepared for the EPMR were also designed to contribute directly to the development of WARDA's 1994-98 MTP. A first complete draft of the MTP was available for review by a Technical Advisory Committee (TAC) Working Party in December and by the EPMR panel in January 1993.

SALT TOLERANCE OF RICE VARIETIES UNDER IRRIGATED CONDITIONS IN THE SAHEL

M. Dingkuhn, F. Asch and K. Miézan

Soil and water salinity are important constraints to irrigated rice production in the Sahel. Although only a few Sahelian environments are inherently saline because of their proximity to the sea, most irrigation schemes in the region tend to accumulate critical concentrations of salt in the topsoil, particularly if drainage is poor.

Lysimetric studies at WARDA's research sites in the Sahel show that evapotranspiration from rice plots is 7-10 and 10-13 mm/day during the wet and the hot-dry seasons, respectively. Percolation is poor in the heavy soils of the region (< 1 mm/day) and rainfall is low (100-600 mm/year, usually with no rainfall in the dry season). If topsoil salinization is to be prevented, salt imported through irrigation water must be drained off. Salinization is also caused by the rise of a saline ground water table under irrigation. Salinity stress is sometimes compounded by alkalinity due to the accumulation of sodium bicarbonate or by acid sulfate.

Severe salinization can be prevented if appropriate irrigation systems are in place and farmers follow recommended practices. In many systems, however, topsoil and floodwater salinity tend to remain high, particularly in village-level systems where drainage is poor. Small- to medium-scale systems are becoming increasingly common in several Sahelian countries because of reduced state intervention and increased private sector involvement in rice production schemes; however, these systems tend to be characterized by sub-optimal water control and plot leveling, and instead of deep drainage at the end of the season, the floodwater is simply evacuated from the field. While this practice is usually appropriate for controlling progressive salinization, it is often associated with transient salinity levels which are harmful to salt-susceptible varieties. Under arid conditions, a floodwater electric conductivity (EC) of 1-3 mS/cm can significantly affect rice yields, unlike the situation in monsoonal climates where such EC levels are considered sub-critical.

Research on rice salt tolerance began at WARDA in 1990. It is based on physiological field experiments, varietal selection, and hybridization at the research farm at N'Diaye in the Senegal river delta. In-depth physiological studies are being conducted in collaboration with the Univeristy of Hamburg, Germany. WARDA is collaborating with NARS in the Sahel to develop improved plot-level technologies which will control salinization and soil degradation. Recent studies conducted by WARDA on small- and medium-scale irrigation systems have yielded new approaches in the effort to improve village-level rice production systems.

Research approach

The sustainable control of salinity in the Sahel should include at least two technology components:

- water management practices at both the irrigation scheme and plot levels which allow for the removal of salt imported with irrigation water
- high yielding varieties that tolerate moderate salinity without significant losses in grain yield and quality

Varieties should also show tolerance to extreme temperatures, appropriate duration under the thermal and photoperiodic conditions of the Sahel, and adaptation to the hot, dry winds (the Harmattan) which occur in the dry season. The two most salt-susceptible growth stages, seedling and heading, usually occur in different climatic periods. The dry-season crop is exposed initially to cold air and water, whereas the reproductive stage is affected by winds with temperatures of up to 50°C. Since climatic and salt stress interact physiologically, an integrated research approach is required to study their effects on the performance of rice varieties in Sahelian conditions.

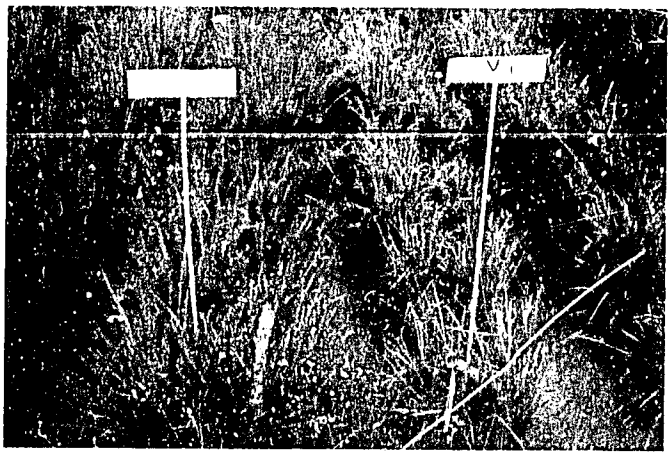
The combination of salt tolerance with climatic stress tolerance is a complex phenomenon. Our approach was to characterize the component morpho-physiological and genetic traits and to selectively combine them. Among the determinants of salt tolerance are plant uptake and transport of cations, particularly K^+ and Na^+. These processes are governed partly by physiological root properties but are modulated by the crop's transpiration rate. The latter depends on water status, stomatal regulation and climatic parameters. Salt tolerance also depends on the efficient removal of excess salt from plant organs, and ion and osmotic stress tolerance in young tissues. The focus of the study described here was on plant ion relationships, morphology, water status and the regulation of leaf gas exchange.

The materials characterized for salt tolerance were simultaneously but separately characterized for thermal dependency of crop duration, adverse temperature tolerance and yield potential. Based on this information, key traits were identified and are now being analyzed genetically, using

diallel crosses of selected materials. During this process, parents are being identified for a hybridization program aimed at developing germplasm well adapted to Sahel conditions. Introduced materials with good performance are also being identified, using the same evaluation process; they are then tested throughout the region for possible release by national programs.

The specific objectives of our study can be summarized thus:

- to identify and characterize physiological mechanisms and component traits contributing to salt tolerance under Sahelian climatic conditions
- to determine the salt tolerance of materials adapted to the Sahelian climate
- to identify new materials bearing component traits for salt tolerance for use in hybridization



WARDA's salt-susceptible check variety, IR 31785, planted alongside a new salt-tolerant entry in a salinity trial, N'Diaye, Senegal, 1992

Materials and methods

Starting in mid-1991, two crops were planted annually at the N'Diaye farm in a continuous salinity trial. All materials (27-34 rice genotypes per season) were introductions; half were advanced selections from WARDA's Sahel Irrigated Rice Program, and half were checks or selections from an initial evaluation of entries from external salt tolerance nurseries. The locally adapted varieties I Kong Pao (IKP) and IR 31785-58-2-2 served as local tolerant and susceptible checks, respectively; Pokkali and IR 28 served as the international tolerant and susceptible checks, respectively.

Seedbeds were established in mid-February (hot-dry season) and late July (wet season). Each treatment (irrigation with fresh water, and irrigation with saline water with an EC of 3.5 mS/cm) was replicated three times in a randomized strip plot design; 34 hills per variety and plot were transplanted at a 20 x 20 cm spacing. To achieve salinization, evaporative salt residues scraped from nearby soil were added to a clay water reservoir. Floodwater EC was kept constant during the season. The soil was a heavy, slightly acid Vertisol clay (percolation < 1 mm/day). Initial soil samples were taken for each experiment. Topsoil salinity depended on the treatment but the subsoil had natural salinity. Roots and shoots were sampled at 10-day intervals during vegetative growth to determine dry matter and morphology. Sampling for leaf positions, stem segments and roots took place in the late vegetative stage for analysis of K^+ and Na^+ content, using acid extraction and flame photometry. For selected varieties, pre-noon measurements were made of leaf net photosynthetic rate, stomatal resistance and intercellular CO_2 concentration (Ci), using a portable infra-red gas analysis system. Leaf water potential (LWP) was measured by pressure probe. Yield and yield components were determined from a 12-hill sample.

The yield response of IKP to various salinity levels was studied in a separate trial. The impact of salinity on paddy yields in farmers' trials was estimated from yield surveys and corresponding measurements of floodwater EC in irrigation schemes adjacent to the N'Diaye farm.

In a complementary study with the University of Hamburg, Pokkali, IR 28, IR 31785 and IR 50 were grown in growth chambers at 40% and 75% humidity and at different levels of substrate salinity. Stomatal resistance was measured porometrically and root water potential (RWP) by pressure probe, applying a pressure gradient between the root and the stem base. Xylem sap was analyzed for abscisic acid (ABA) content by radio-immuno assay.

Results and discussion

Extent and dynamics of salinity and impact on rice yield

Observations on farmers' fields. The irrigation water available to most schemes in the Senegal delta is low in salt (0.05-0.1 mS/cm EC). Evaporative residues and the capillary rise of salt between crops, however, can lead to salt accumulating in the topsoil even under conditions considered non-saline, making it necessary to flush fields at the onset of each season. The EC of evacuated water can reach 18 mS/cm. With the saline crust removed, water salinity remains moderate (typically, 0.2-1.5 mS/cm EC) in the following season but fluctuates considerably and can rapidly become critical under low water conditions. In the delta, sea-borne salts in the subsoil contribute to topsoil and water salinity. In the hot-dry season stagnant water accumulates salt, sometimes raising the irrigation water EC to over 1 mS/cm/s. The major cations are Na^+ (64-72%), Mg^{++} (19-28%) and Ca^{++} (8-9%); the major anions are Cl^- (>80%) and SO_4^{--} (16-19%).

A survey on 29 farmers' fields in an irrigation scheme near the N'diaye farm during the 1992 hot-dry season indicated significant yield reductions due to water salinity at the heading stage. The variety grown was Jaya, high yielding but salt susceptible. Although the EC was 0.78-2.73 mS/cm (only up to half the level critical for rice in monsoonal Asia), yields were reduced by about 1.4 t/ha per unit of EC ($P < 0.01$). Yields ranged from 0.7 to 7.2 t/ha (mean 4.7 t/ha, typical of the delta). Other factors responsible for yield reductions were N fertilizer rate x split ($P < 0.05$) and sedge-type weeds ($P < 0.01$) (R of multiple linear regression 0.76, with $P < 0.001$).

Observations on experimental fields. In a yield trial conducted in the 1991 hot-dry season to determine the impact of salinity, IKP was planted in 15 moderately saline plots (mean topsoil EC 2.1 mS/cm and pH 4.8) and subjected to different irrigation/drainage frequencies. Nutrient removal through drainage was compensated by a high N dosage (150 kg N/ha, triple split). The floodwater EC varied between 1.6 and 2.8 mS/cm in the vegetative stage, depending on water regime, and gradually fell to 1.2-1.8 mS/cm at flowering. Due to day-to-day fluctuations in floodwater depth (5-12 cm), however, daily EC levels oscillated by about 50% around the mean value.

Grain yields (4.6-9.7 t/ha) were negatively correlated with EC at the reproductive stage ($P < 0.01$). An increase in EC by 1 mS/cm was associated with a 1.5 t/ha decline in yield; an EC of about 3 mS/cm reduced yields by 50%. The effect of salinity on yield was much greater in this study and in nearby farmers' fields than that reported from more humid Asian environments, suggesting that climate may modulate the physiological effects of salinity. Indeed, researchers at IRRI reported greater varietal salt tolerance in the wet than in the dry season.

The relationship between yield and salinity observed in farmers' fields and the experimental fields indicated that the margin of tolerable salt concentrations in soil and water is narrow in the Sahel. Under poor water management, salinity can rapidly become critical, even in a soil classified as non-saline.

Varietal performance in the wet and hot-dry seasons

We studied the response of 29, 34 and 34 cultivars to salinity in the 1991 wet season, 1992 hot-dry season and 1992 wet season, respectively. Floodwater EC was kept at 3.5 mS/cm to induce severe but non-lethal stress. Mean yields in the control treatments were 723 g/m^2 in the 1991 wet season and 744 g/m^2 in the 1992 hot-dry season. Salinity reduced yields by 48% and 54%, respectively, reflecting independent observations in farmers' fields and other experimental fields.

Twenty varieties tested in 1991 showed significant ($P < 0.05$) reductions in yield compared with the control. This was caused by spikelet sterility and incomplete grain filling. Tiller number was generally unaffected. Only four cultivars had significantly reduced dry matter. The number of spikelets per panicle was reduced in four cultivars.

Aborted and degraded spikelets, typical of salt injury in rice under Sahelian conditions, in a salinity trial at N'Diaye, Senegal, 1992

In the 1992 hot-dry season, salinity had a similar effect on spiklelet fertility (-38% for all cultivars) and grain filling (-27%); total dry matter was also significantly reduced (-37%). In only two cultivars were tiller and panicle number reduced. Chlorophyll content of young, fully expanded leaves at the vegetative stage was generally unaffected, and visible injury such as necrotic discoloration appeared on older leaves. Upon flag leaf emergence and booting of the panicle, however, the salt-treated plants degenerated rapidly and many were completely discolored at anthesis.

Varieties showed significant and generally consistent differences in salt tolerance across seasons. However,

comparison with data from other (e.g. Asian) environments was difficult due to the anomalous performance of the international checks IR 28 (susceptible) and Pokkali and Nona Bokra (tolerant). Both the tolerant checks showed salt-induced yield reductions of over 50% in 1991, compared to only 38% for IR 28. They also showed visible salt injury such as early leaf discoloration and rolling (Pokkali) or curling (Nona Bokra). Their usefulness was further reduced by the long duration of the hot-dry season due to photoperiodism (Pokkali and Nona Bokra) and by high spikelet sterility under hot-dry conditions (IR 28), even in the absence of salinity.

The local check IKP showed consistently good performance under saline conditions, as did some materials which had recently been selected for the Sahel, including IR 4630-22-2, 32-Xuan 5C, ITA 222 and BW 293. However, a promising short-duration, high yielding line (IR 31785-58-22-1) with superior adaptation to arid conditions was extremely susceptible at all growth stages and for both growth and reproductive processes (spikelet fertility and grain filling). The morphological similarity of IR 31785 with more tolerant entries such as IR 29725-40-3-2-3 suggests that salt tolerance under arid conditions probably depends on physiological traits rather than morphological plant type. This observation suggests that there may be substantial diversity in salt tolerance among the high yielding, short-duration materials.

Physiological responses to salinity

The physiological components of salt tolerance were investigated for five cultivars in the 1991 wet season and the 1992 hot-dry season: IKP (locally grown, salt-tolerant *japonica* cultivar); Pokkali (moderately tall, traditional cultivar with superior salt-tolerance in monsoonal Asia); IR 50 (improved, moderately salt-tolerant *indica* cultivar, well adpated to the Sahelian climate); IR 28 (improved *indica* cultivar, salt-susceptible in monsoonal Asia); and IR 31785-58-2-2 (improved *indica* cultivar, well adapted to the Sahelian climate but extremely salt-susceptible). Due to its consistent yield reductions by at least 75% under saline conditions over three seasons, IR 31785 is now used as WARDA's susceptible check; IKP is the tolerant check. Yield data are presented in Table 2.

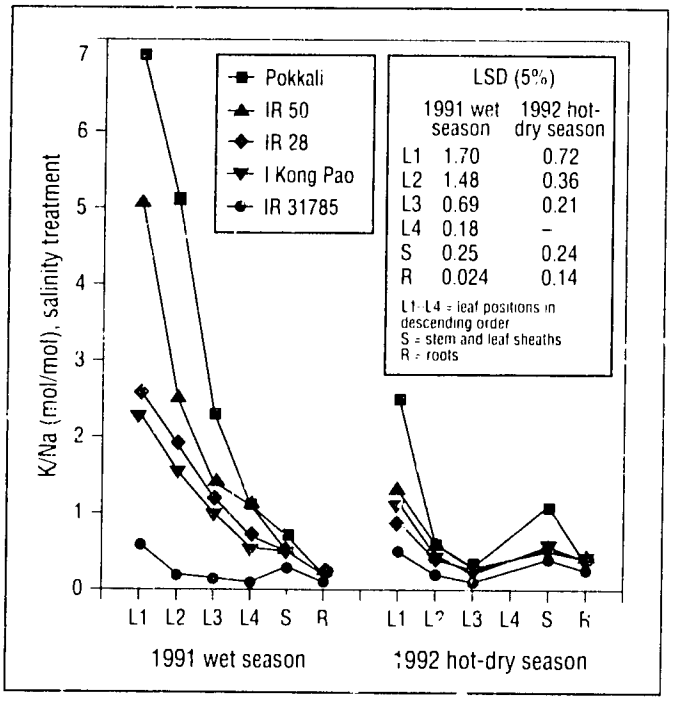
Cation uptake and distribution in the plant. Salt stress is partly a nutritional stress because of the physiological displacement of an essential element (K) by a chemically similar but physiologically functionless element (Na). Selective uptake of K by the roots, or removal of Na from metabolically active tissues, are therefore important components of salt tolerance, enabling a favorable K/Na ratio. The highest K/Na ratios were found in young leaves (*see* Figure 1). No differences were found between upper and lower segments of the same leaf. The lower K/Na ratios in 1992 were probably due to greater transpiration and thus

Table 2 **Effects of salinity on grain yield (GY), harvest index (HI), spikelet sterility (SS) and dry weight of 100 filled grains (100GW) in five rice cultivars in the 1991 wet and 1992 hot-dry seasons, N'Diaye, Senegal**

Entry	GY (g/m^2)	Treatment effect (%)[a]	HI (g/gl)	Treatment effect (%)	SS (%)	Treatment effect (%)	100GW (% of control)
Wet season 1991							
IR 31785	126	-80*	0.28	-36*	70	+57*	-36
IR 28	394	-31*	0.53	-11	27	+9	-11
IR 50	336	-38*	0.52	-18	32	+15	-18
I Kong Pao	486	-27*	0.47	-27*	40	+29	-25*
Pokkali	142	-49*	0.28	-67*	41	+12	-14
Mean (excluding Pokkali)	336	-44	0.45	-23	42	+28	-23
LSD (5%)	145		0.06		13		
Hot-dry season 1992							
IR 31785	74	-86*	0.17	-68*	79	+55*	-44*
IR 28	200	-59*	0.22	-40*	48	0	-24*
IR 50	287	-62*	0.36	-38	47	+25	-31*
I Kong Pao	471	-43*	0.42	-33	31	+16	-33*
Pokkali[b]	—	—	—	—	—	—	—
Mean	258	-52	0.29	-45	51	+24	-33
LSD (5%)	137		0.09		16		

Note: a Relative to control
b Pokkali did not flower in the hot-dry season, 1992, due to photoperiodism
* $P < 0.05$

Figure 1 **Molar K/Na ratios in five rice cultivars at the vegetative stage under irrigation with saline water**



greater passive uptake of Na. The cultivar IR 31785 had low K/Na ratios, while Pokkali had the highest, followed by IR 50. Under test conditions, a high K/Na ratio was probably essential (IR 31785) but not sufficient (Pokkali, IR 50) for a cultivar to be salt tolerant.

With fresh water, all cultivars maintained high K and low Na contents in the leaves (*see* Figure 2 *overleaf*). Great quantities of both ions were accumulated in the stems, particularly in 1992. Salinity dramatically reduced tissue K content in IR 31785, the reduction in K uptake equalling the additional uptake in Na. In Pokkali, Na content also increased but did not significantly affect K content. All cultivars accumulated K in young leaves and Na in old leaves, and high amounts of both in the stem base. Within a treatment and season, the cultivars had almost identical molar concentrations of Na and K combined. Differences, therefore, were due to ion selectivity in uptake and transport in the plant. In IR 31785, salt-susceptibilty was associated with poor selectivity of cation uptake, leading to a low overall K/Na ratio, and an inability to maintain high K concentrations in the first and second leaves which produce most of its photosynthates.

The physiological function of Na and K accumulation in the stem, particularly its base, requires further research. It is likely that the stem base contains much K^+ at the center where the apex is located, and much Na^+ in the periphery consisting of sheath bases. Ion relationships in the apex may be important for panicle differentiation, and perhaps explain the frequent appearance of malformed, feathery panicles under saline conditions.

Leaf gas exchange and water status. Leaf water potential (LWP) and gas exchange were measured for five cultivars at a late vegetative stage. LWP was lower (not significantly) in salt-treated plants by about 0.2 MPa compared to the controls (*see* Table 3). The check IKP had significantly lower LWP under both saline and control conditions compared with IR 31785. Low LWP therefore did not necessarily reflect a high level of stress suffered by the plant; instead, it might have resulted from osmotic adjustment.

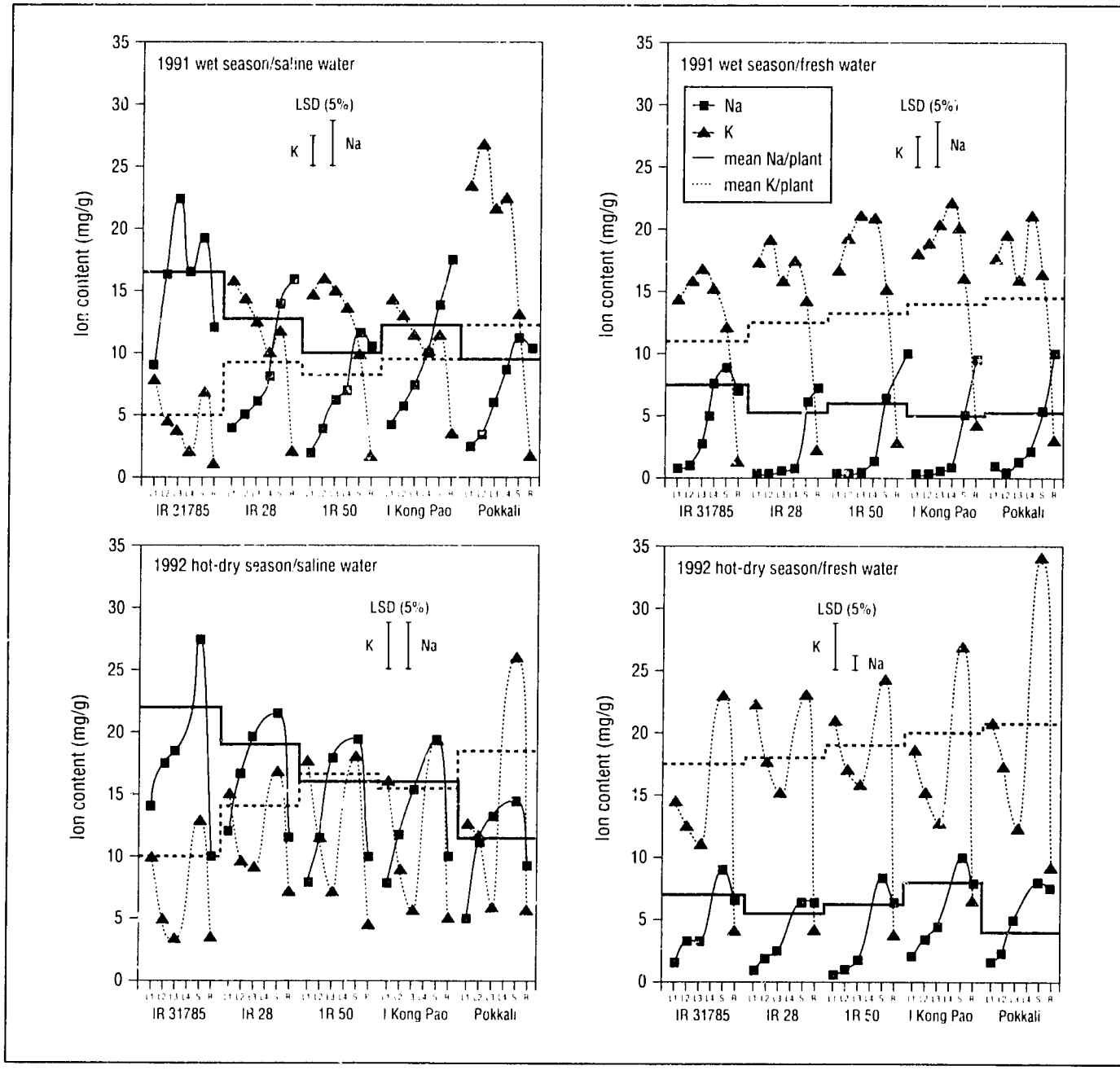
All cultivars except IR 50 had greater stomatal resistance in the stress treatment. This was associated with a mild reduction in net CO_2 exchange rate (CER) and Ci. Midday correlations between stomatal resistance and LWP indicated that stomatal sensitivity to LWP was almost identical and unaffected by salt treatment for all cultivars except Pokkali. The stomata of Pokkali were more sensitive to LWP, closure occurring abruptly at about -1.0 MPa (salt-treated) or -12.5 MPa (controls). Salinity therefore increased Pokkali's stomatal sensitivity.

Comparing gas exchange (*see* Table 3) with cation uptake (*see* Figures 1 and 2), it seems that varieties with high K/Na ratios also had high stomatal resistance but lower Ci. It is

Table 3 **Difference in leaf water potential (LWP), stomatal resistance (rs), CO_2 exchange rate (CER) and intercellular CO_2 concentration (Ci) for five rice cultivars grown in the field and irrigated with fresh water (FW) or salt water (SW, 3.5 mS/cm EC), measured 51 days after transplanting, N'Diaye, Senegal, 1992 hot-dry season**

	LWP (MPa)		rs (s/m)		CER (µmol/m²/s)		Ci	
Entry	FW	SW	FW	SW	FW	SW	FW	SW
IR 31785	0.54	0.78	30.3	58.5	28.2	23.0	289	268
IR 28	0.66	0.97	30.0	54.4	27.7	25.0	281	269
IR 50	0.68	0.87	30.0	47.7	26.7	26.1	272	257
I Kong Pao	1.10	1.36	40.3	62.8	27.1	26.0	267	243
Pokkali	0.95	1.12	52.9	74.2	19.3	17.6	258	255
Mean	0.79	1.02	36.7	59.5	25.8	23.5	273	258
LSD (5%)	0.38		20.1		4.6		23	

Figure 2 Concentrations of K^+ and Na^+ at the vegetative stage in various plant organs and the means for the whole plant in five rice cultivars irrigated with saline or fresh water, N'Diaye, Senegal, 1991 wet and 1992 hot-dry seasons



possible that greater cation selectivity in IKP and Pokkali was due partly to greater water-use efficiency (WUE). Generally, WUE is negtively correlated with Ci and permits lower water consumption per unit of growth. Lower water uptake, in turn, is likely to reduce the proportion of cations passively absorbed by the roots, which may explain the high K/Na ratios of Pokkali and IKP in the past.

More research is needed on root ion selectivity, osmotic adjustment and WUE, particularly for improving salt tolerance under conditions of high evaporative demand.

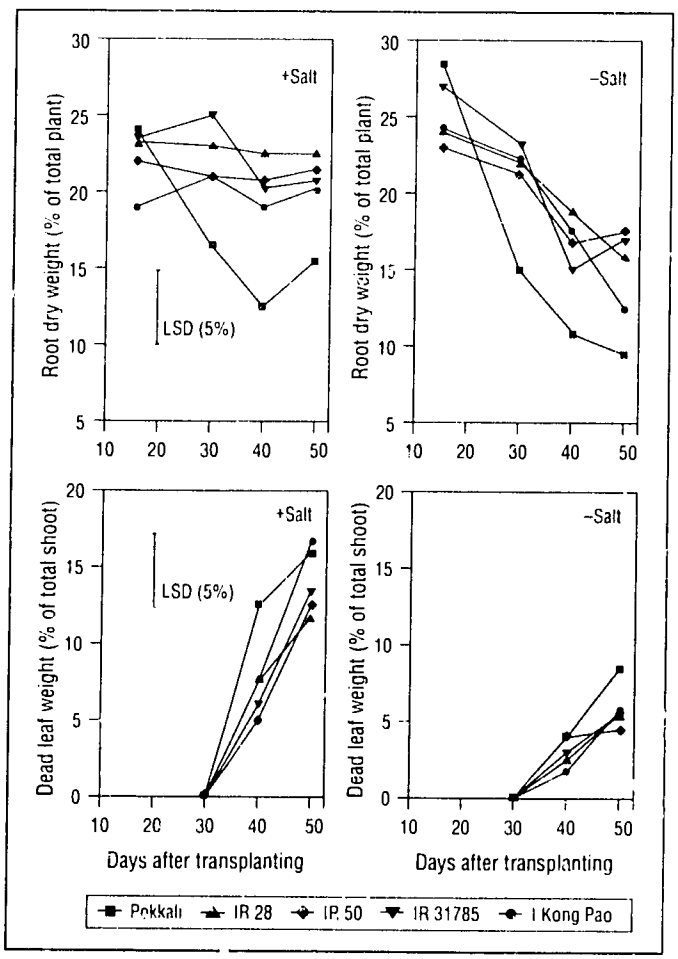
Interactive effects of dry air and salinity. There were significant varietal differences for ion uptake and selectivity, but they did not entirely explain the variation in performance under saline conditions. We tested the hypothesis that the dry air conditions of the Sahel require additional traits for salt tolerance.

Arid conditions are associated with a great evaporative demand and, thus, high transpiration. The tendency of Pokkali to develop greater water deficits (in terms of LWP) and close its stomata more readily (in terms ofstomatal resistance) than

other cultivars suggests an involvement of water stress. Two morphological traits were probably responsible for this: Pokkali's height, which exposes it to hot-dry winds; and its comparatively small root system under experimental conditions. In control plants, the root/plant weight ratio decreased over time (*see* Figure 3). In the semi-dwarf cultivars, however, relative root dry matter remained constant throughout the vegetative stage; the roots probably used more energy for osmo-regulation and replacement of dead roots, leaving less assimilate for shoot growth. Pokkali's low LWP, smaller root system and more rapid senescence suggest that it is particularly sensitive to water stress induced by dry air.

Root-specific weight (an indicator of root porosity and, indirectly, the radial resistance to water flow) was generally uniform (0.75-0.8 g/g). Mean root diameter, however, was 12-14% smaller ($P < 0.05$) in the saline than in the control treatment, regardless of variety. Root diameters of controls ranged from 0.98 mm (IR 31785) to 1.4 mm (Pokkali and IR 28), showing no link with salt tolerance.

Figure 3 **Relative root dry weight and dead leaf weight during the vegetative stage of five rice cultivars irrigated with saline or fresh water in the field, N'Diaye, Senegal, 1991 wet season**



To obtain further evidence of Pokkali's dry air sensitivity, a phytotron study was conducted with the University of Hamburg in Germany. Pokkali, IR 28, IR 50 and IR 31785 were subjected to dry (40% RH) and humid (75%) air, and to saline and non-saline substrates. Pokkali's stomatal resistance increased threefold in the dry air (*see* Table 4).

Table 4 **Effect of a constant level of air humidity (RH) on the stomatal resistance (rs) of four rice cultivars grown under non-saline, controlled conditions, University of Hamburg, Germany 1992**

Entry	rs (75% RH) (s/m)	rs (40% RH) (s/m)	Relative effect (%)
IR 31785	76	183	241
IR 28	113	245	217
IR 50	135	213	158
Pokkali	97	312	322
Mean	105	238	235
LSD (5%)	51		

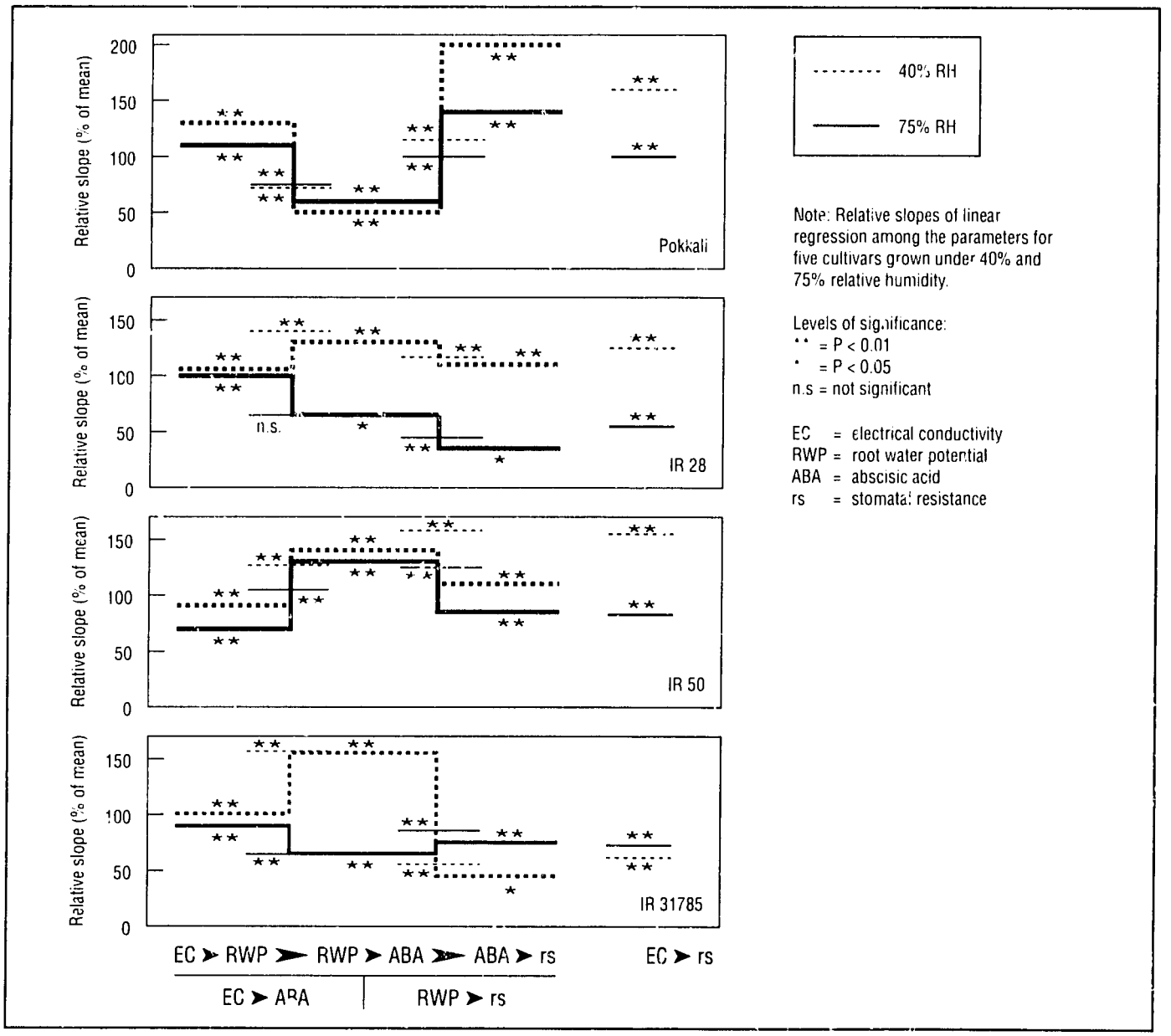
For the same four cultivars, a hypothetical cascade of physiological parameters affecting stomatal resistance was analyzed:

1 soil solution EC
2 RWP
3 ABA concentration in the xylem sap
4 stomatal resistance in the leaves

It was assumed that EC affects RWP (steps 1 to 2), RWP induces the production of ABA in the roots and its release to the transpiration stream (steps 2 to 3), and ABA is transported to the leaves where it induces partial stomatal closure (steps 3 to 4). The theory was that a root signal (ABA) induces stomatal closure. For every step for a given cultivar and level of air humidity, the physiologically dependent variable was linearly regressed against the hypothetical effector variable (*see* Figure 4 *overleaf*). For easier comprehension, the slopes of the relationships (correlation coefficients B) were expressed as the percentage of the varietal mean; a higher value for B indicates greater sensitivity.

Most correlations tested were highly significant ($P < 0.01$). The response of RWP to EC was similar for the four cultivars, dry air slightly enhancing it. ABA release from the root to the xylem was little affected by RWP in Pokkali. The apparent stomatal response to ABA, however, was strong, especially in dry air. The overall response of stomatal resistanceto EC in Pokkali was greater in dry than in humid air. Assuming that ABA mediated this reponse, Pokkali's roots produced little ABA in response to salinity but its stomata were highly responsive. In several ways, the salt-susceptible, dry air-tolerant IR 31785 was the physiological opposite of the

Figure 4 **Relationships between physiological variables forming a hypothetical cascade of events from substrate salinity (EC) over root water potential and abscisic acid hormone concentration in the xylem sap to stomatal resistance, WARDA/University of Hamburg/Institute for General Botany, Germany, 1992**



salt-tolerant, dry air-susceptible Pokkali. In IR 31785, the effects of EC on stomatal resistance were small and unaffected by air humidity. High ABA release rates in response to salinity were not reflected by stomatal resistance, probably indicating that the stomata of IR 31785 are insensitive to the root signal. IR 28 and IR 50 were intermediate in terms of apparent stomatal resistance to root-borne ABA. IR 31785 differed profoundly from the other cultivars regarding its comparative stomatal insensitivity to salinity in both dry and humid air.

The University of Hamburg results help explain the extreme salt-sensitivity of IR 31785 and the unexpectedly poor performance of Pokkali under saline-arid conditions:

- IR 31785 appears to be a high-transpiring cultivar with poor ability to regulate its stomatal conductance under salt stress; high transpiration combined with poor WUE may be responsible for high salt uptake and a poor K/Na ratio
- Pokkali had superior K^+ uptake and, probably, WUE; its height and small root system, however, probably caused water deficit and poor photosynthesis, followed by early senescence and poor yield under dry air and salt stresses.

Component traits for salt tolerance under arid conditions

The following morphophysiological traits appear to play an important role in salt tolerance in rice grown under arid conditions:

- high K/Na in the whole plant
- accumulation of K^+ in young leaves and Na^+ in old leaves
- high root/plant weight ratio and probably short stature
- high WUE and efficient regulation of transpiration in response to salt stress
- high tolerance of reproductive organs to hot, dry winds and water deficit

Some additional factors which may be related to combined salt and dry air tolerance require further study:

- the accumulation of K^+ and Na^+ in the stem base and leaf sheaths
- ion relationships in the shoot apex
- osmotic adjustment, particularly in the roots
- the importance of hormonal root signals in regulating salt and water uptake
- plant leafiness and continued leaf expansion after full emergence of the terminal (flag) leaf

Leaf growth patterns may be particularly important for salt tolerance. After a period of good tolerance in mid-season, plants rapidly developed salt injury once the last leaf generation (flag leaves) had emerged. Having no salt excretion mechanisms, cultivated rice has limited scope to shift salt within the plant once vegetative growth ceases. The continued presence of tissues where salt can be dumped after emergence of the last leaf generation, and a late-senescing flag leaf, may be essential features of high yielding, salt-tolerant rice varieties.

Future research

Morpho-physiological mechanisms exist that could improve rice tolerance to combined salt and dry air stresses. Genotypes differ strongly in the expression of these mechanisms. It will therefore be possible to identify a number of key component traits for breeding. WARDA's physiological research on salt tolerance in 1993 will have the following objectives:

- a detailed characterization of component traits, particularly those identified in 1992 but not yet characterized
- the development of screening tools
- the intensification of collaborative research on regulatory mechanisms

The salinity trials described here require little modification to accommodate a larger number of genetic materials. Traits related to K^+ and Na^+ uptake and transport can be screened rapidly and cheaply. Gas exchange measurements, however, are expensive and tedious, and will be replaced by two methods better suited to mass screening: remote, infra-red sensing of leaf/air temperature differentials to estimate transpiration; and, in collaboration with external partners, measurement of ^{13}C discrimination to evaluate WUE. Diallel crosses among selected parents will be performed in 1993 to determine genetic parameters of component traits. Based on the genetic information, a breeding strategy will be formulated.

WARDA will continue to develop its integrated approach to salinity — breeding for high yielding varieties tolerant to moderate salinity in an arid climate and developing plot-level cultural practices that economically and sustainably control soil degradation and salinization. WARDA is currently addressing the latter mainly agronomic and socio-economic issues in collaboration with NARS. An in-house agronomic research capacity for the Sahel will be developed and collaborative research on cropping systems will be strengthened.

SUMMARIES OF RESEARCH ACTIVITIES

Upland/Inland Swamp Continuum Program

The continuum rice growing environment covers about 82% of total rice area in West Africa and accounts for 75% of regional production. It consists of several contiguous ecosystems where rice is grown in warm sub-humid and humid tropical conditions: the upland rainfed ecosystem (57%) where rice depends entirely on rainfall for soil moisture; the hydromorphic ecosystem (18%) where the water table is within the crop's root zone at key growth periods; the rainfed ecosystem or inland valleys (20%) where rice is periodically flooded; and the irrigated lowland ecosystem (5%) where there is a high level of water control. Because these ecosystems vary in space and time as a function of local rainfall, precise estimates of cultivated areas and production are not available.

In 1992 WARDA completed a comprehensive review of research literature on rice in West Africa, undertaken partly to identify and prioritize the main physical and biological constraints to the sustainable intensification of rice production. The review showed that the main constraints in the upland/hydromorphic ecosystem are drought stress, low soil fertility, acidity and erosion. In the hydromorphic/lowland 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, blast, leaf scald, brown spot and insect pests (mainly stem borers and the stalk-eyed fly). Potential major threats to rice production under hydromorphic/swamp conditions are rice yellow mottle virus, unique to Africa, and the African rice gall midge. Although local rice varieties are generally well adapted to low-input systems, most of them have modest yield potential and poor response to improved inputs such as fertilizers and insecticides.

The goal of the Continuum Program is to develop technology options suitable for resource-poor farmers making the transition from extensive to intensive cropping systems. These technologies should be socially profitable, maximize the use of farm resources and of purchased external inputs, be technically sustainable, minimize environmental degradation, be amenable to the incremental adoption of new technology components, and minimize the need for major changes in social behavior and institutions. Technologies will be designed which enable farmers to shift from fragile uplands towards intensive cultivation of more robust land types across the continuum, particularly the inland valley ecosystems, where rice has a strong comparative advantage.

PROJECT 1: CHARACTERIZATION OF RICE GROWING ECOSYSTEMS

The goal of the characterization project is to identify and quantitatively assess the major factors affecting rice production on the continuum. The approach is twofold: first, to determine the major production systems (macro-level characterization); and second, to select representative key sites where more intensive diagnostic research can be conducted on the soils, hydrology, cropping sytems and socio-economic factors determining overall system productivity (micro-level characterization).

Macro- and micro-level characterization of rice ecosystems

A. Adesina

In 1992 a macro-level characterization of the major rice production systems in Côte d'Ivoire was completed. The study, which began in mid-1990, used rapid rural appraisal techniques and socio-economic criteria to classify rice systems.

The area under rice was estimated to be about 330 000 ha. A map (1 : 1 000 000) of the area was developed and the distribution of 10 rice production systems was defined on the basis of agro-ecological zones, local hydrology, ethnicity, land tenure, rice production objectives, use of modern varieties, gender of rice grower, planting and tillage methods, and intercropping patterns. The 10 production systems can be grouped into six major rice ecosystems. The improved uplands (17.2% of the rice area), found only in the savanna, can be further divided into those which are fully mechanized and those where animal traction or small 25-30 hp Bouyer tractors are used (*see* Table 5).

Following this macro-level characterization study, an intermediate characterization study was conducted. Representative

Farmer planting rice under the low-input management conditions typical of much of West Africa

Table 5 **Area under rice in the six major rice ecosystems in Côte d'Ivoire, 1992**

Ecosystem	Area ('000 ha)	% total area
Upland (traditional)	187.3	57.0
Upland (improved: animal traction or small tractors)	49.3	15.0
Upland (improved: fully mechanized)	7.4	2.2
Lowland (traditional)	49.5	15.1
Flood plains	10.9	3.3
Irrigated	24.4	7.4
Total	328.8	100.0

sites were selected for more intensive vertical characterization, using satellite pictures and SPOT images complemented by on-the-ground verification. A range of physical parameters (including geology, hydrology, morphology and climate) were then used to select three key sites, Gagnoa and Duékoué (humid-forest zone) and Boundiali (Guinea savanna zone). Detailed micro-level characterization studies, bio-physical and socio-economic at the watershed and field levels, are being conducted at these sites.

PROJECT 2: CROPPING SYSTEMS

In developing new rice production technologies, it is necessary to consider the crop within the context of the range of agricultural activities performed by rice farming households in West Africa, including cultivating other crops and raising livestock. The design of appropriate technologies must also take account of the resources and objectives of rice farmers.

With increasing demographic pressures in the region, farming systems are undergoing intensification. The greatest pressure is in the uplands where there is least potential to maintain sustainable intensive rice cultivation; fallow periods, vital in maintaining the productivity of most upland systems, are being reduced. In contrast, the inland valleys, which can sustain continuous cultivation at higher levels of productivity in most of the region, are under-utilized. The main constraints to sustainable intensification need to be clearly identified in order to guide cropping systems research towards intensifying rice-based cropping in the lowlands and developing low-cost technical options to stabilize production systems in the uplands. An initial objective of the cropping systems project is to identify and classify rice farming systems in the transition from extensive to intensive production.

Production costs and profitability of rice-based cropping systems

A. Adesina

Information on farm-level production costs and the relative profitability of rice cultivation in local farming systems provides useful guidelines for developing appropriate rice technologies. As much of the available data in West African countries are no longer reliable because of the substantial policy and technological changes of the past decade, a study is being conducted to generate indices of farm-level and social profitability for alternative rice systems in Côte d'Ivoire.

The first step was to characterize the major rice ecosystems across agro-ecological zones and determine representative production systems for detailed micro-economic analysis, building on the characterization study in Côte d'Ivoire completed in 1992. Household surveys are being conducted at sites representative of the three agro-ecological zones of Côte d'Ivoire (Gagnoa — humid-forest; Touba — forest-savanna; and Boundiali — savanna) to determine the proportion of farmers growing rice under different production systems. In addition, production systems are being characterized according to: position of rice field on the toposequence; level of water control; use of modern inputs; and tillage technology (hand, oxen, small tractors or full mechanization).

The survey, conducted over 3 months in 1992, covered 1912 farmers in 39 villages. A total of 20 production system combinations were identified (*see* Table 6). A random sample of 180 farmers,

Table 6 **Number of farmers growing rice in various ecosystems in three agro-ecological zones in Côte d'Ivoire, 1992**

Ecosystem	Agro-ecological zones: Humid-forest (Gagnoa)	Savanna (Boundiali)	Forest-savanna (Touba)
Rice ecosystem			
Upland (traditional)	459	12	256
Upland (improved)	9	282	75
Inland valleys (IVS) (traditional)	84	96	4
IVS (semi-traditional)	2	—	—
IVS (improved)	110	8	—
Irrigated (partial water control)	—	—	43
Irrigated (complete water control)	—	41	1
Cross-ecosystem			
Upland (traditional) + IVS (traditional)	118	1	28
Upland (traditional) + IVS (improved)	10	—	—
Upland (traditionall) + upland (improved)	—	2	12
Upland (improved) + IVS (traditional)	—	14	1
IVS (traditional) + IVS (modern)	—	6	—
Upland (improved) + IVS (traditional) + IVS (improved)	—	3	—
Upland (improved) + IVS (improved)	—	1	—
Upland (traditional) + irrigated (complete water control)	—	11	—
Upland (improved) + irrigated (partial water control)	—	7	—
Upland (traditional) + IVS (traditional) + IVS (modern)	—	2	—
Upland (traditional) + IVS (traditional) + irrigated (complete water control)	—	—	1
IVS (traditional) + irrigated (partial water control)	—	—	4
Upland (traditional) + irrigated (partial water control)	—	—	209

representing the major production systems, was then selected for more intensive monitoring of field operations and production data for rice and non-rice enterprises; complementary data on off-season activities and the rice milling industry were also collected. Preliminary analysis of these data will begin in 1993.

Identification and distribution of key weeds

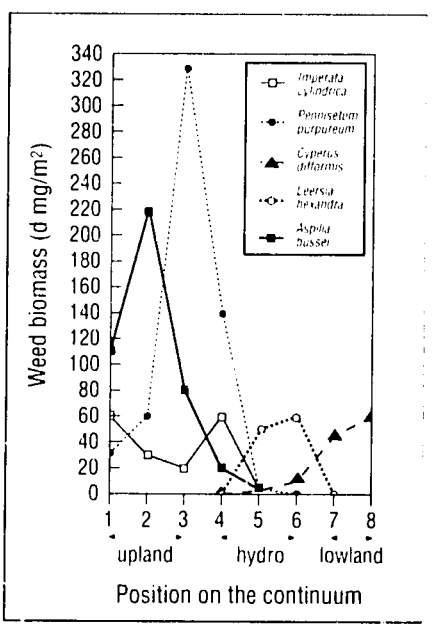
D. Johnson

A clear understanding of the diversity and problems of important weed species in the rice ecosystems of the continuum is essential in determining appropriate management strategies. The characterization of weed species in M'bé valley was initiated in 1989 with a survey of farmers' fields in selected sites on the continuum. In 1992, as part of a multidisciplinary experiment in which eight rice varieties were grown at M'bé, weeds were sampled at harvest from unweeded strips located at fixed intervals across the slope. Surveys of weeds on farmers' fields and of *Striga* species growing on rice in the Guinea savanna of northern Côte d'Ivoire were conducted in collaboration the NRI.

Weed sampling in rice crops across the continuum at M'bé revealed 63 species,

Weed infestation, a major constraint to rice production in West Africa

Figure 5 **Distribution of five weed species in rice across the continuum at M'bé, Côte d'Ivoire, 1992**



with floral composition strongly influenced by position on the toposequence. The distribution of five species, which together formed a large proportion of the weed biomass, is shown in Figure 5. Total weed biomass was greatest on the upland portion of the continuum; the diversity of weed species was also greatest in this ecology. There were no significant differences in weed growth among the eight rice varieties grown in the experiment. The studies on farmers' fields in the humid-forest zone were interrupted by drought. In the forest-savanna transition zone, weed growth (including *Paspalum* and *Imperata* species) was closely correlated ($P < 0.001$) with reduced grain yield. In northern Côte d'Ivoire, four species of *Striga* were observed growing on rice; two of them (*S. hermonthica* and *S. aspera*) caused significant damage to the rice plants.

Similar studies will be conducted at M'bé and at key sites in Côte d'Ivoire during 1993.

Competitiveness of rice with weeds

D. Johnson and M. Jones

Rice varieties differ in their ability to tolerate or compete with weeds. The ability to compete successfully would significantly enhance rice yield stability under the extensive, low-input conditions common in West Africa. Because of shortage of labor and capital on many farms, weeds are not controlled sufficiently to prevent significant yield losses. In 1992, research was initiated at M'bé, Côte d'Ivoire to measure varietal differences in weed competitiveness and to determine the varietal traits contributing to these differences.

Studies were conducted on two screening trials (elite early selection of 15 varieties and advanced yield selection of 20 varieties) grown on land recently cleared from bush fallow and reflecting widely used practices (low levels of fertilizer, zero tillage and one handweeding). Weed growth in these experiments was studied to determine how rice plant growth influenced weed growth. At harvest, weeds from each plot were cut, separated by species, and weighed. In the elite trial there were significant differences ($P \leq 0.001$) in weed weight; weight tended to be lowest in varieties taller than 90 cm and producing a straw weight exceeding 400 g/m^2. There were significant ($P \leq 0.05$) negative correlations between plant height, straw weight and grain yield against weed weight at harvest. In the advanced trial there were no significant differences in weed weight. In both experiments plants suffered from drought stress, which prevented good establishment in the advanced yield trials.

In 1993, rice varieties of differing and distinct plant type will be selected utilizing information from the varietal

characterization studies. The growth of these varieties will then be compared under different levels of weed control to determine plant traits related to tolerance or competitiveness with weed growth.

PROJECT 3: DEVELOPMENT OF INTEGRATED PEST MANAGEMENT PRACTICES

Weeds, diseases, insects, nematodes, rodents and birds are among the most important environmental constraints to rice production in West Africa. The severity of pest problems generally increases with an intensification of production systems and a growth in fertilizer and pesticide use. It is estimated that 4 million t of rice are lost annually to weeds, insects and diseases in Africa; additional losses are caused by nematodes, rodents and birds. There is thus an urgent need to develop effective but low-cost pest management technologies. Socially acceptable, ecologically safe and economically profitable strategies are being developed using an integrated pest management (IPM) approach.

The major contribution of IPM to rice production in West Africa will be to reduce yield losses through the improvement of current traditional pest control practices, the integration of natural control agents and the development of pest-resistant cultivars. To determine the target pests against which genetically resistant rice cultivars can be developed, basic information on the yield losses caused by various species and an understanding of their biology and ecology are needed. The goal of WARDA's IPM project is to develop technologies that maintain pest populations at levels below the economic injury level. In 1992, the project focused on: a survey of farmers' pest perceptions and pest management practices; distribution and abundance of pests; integrated blast control; rice yellow mottle virus detection, distribution and resistance sources; biology and ecology of key insect pests; and identification of insect-resistant cultivars.

Rice pests, farmers' perceptions and management methods

A. Adesina, E. Heinrichs and D. Johnson

To generate information on farmers' perceptions of pests and the control methods used, an interdisciplinary survey was initiated in 1992 in Côte d'Ivoire, covering 178 farmers in three key site villages in three agro-ecological zones. The use of formal survey instruments was supplemented by informal discussions with farmers (individually and in groups). Although information was gathered on vertebrate pests during the informal survey, the focus of the formal survey was on weeds and insect pests.

Table 7 **Percentage of farmers citing various pests as problems in rice production in three agro-ecological zones in Côte d'Ivoire, 1992[a]**

Pest	Agro-ecological zones: Humid-forest (Gagnoa)	Forest-savanna (Touba)	Savanna (Boundiali)	All zones
Weeds	100	100	100	100
Birds	98	98	53	84
Bush rats	88	87	2	60
Insect pests	48	60	12	40

Note: a Number of farmers = 60 in Gagnoa, 60 in Touba, and 58 in Boundiali

Farmers were asked to indicate what they considered to be the most important pest problems affecting rice production (*see* Table 7). Weeds were cited by all respondents as a major problem, and 53 species were identified as common in rice fields. In the humid-forest zone the most important species were *Panicum laxum* (cited by 100% of the farmers), *Chromolaena odorata* (68%), *Centrosema* species (42%) and *Scleria* species (32%). None of these species was mentioned by farmers in the other two zones. The most commonly cited weeds in the savanna zone were *Echinochloa colona* (50%), *Rottboellia cochinchinensis* (45%), *Ageratum conyzoides* (26%) and *Euphorbia heterophylla* (22%). In the forest-savanna transition zone the major species cited was *Imperata cylindrica* (72%); less important species were *A. conyzoides* (62%), *Paspalum scrobiculatum* (37%), *Digitaria horizontalis* (33%) and *R. cochinchinensis*. On weed control methods, 69% of the farmers reported using long-duration fallow, 48% used practices linked with soil tillage and 15% used date of planting; only five farmers (all in the savanna zone) used crop associations as a method of weed control. Data were also collected on whether farmers relied on hand pulling, hoes, herbicides or a combination of these; nearly half relied on hand pulling and hoes; only 2% relied exclusively on herbicides.

Although most farmers were aware of the effect of insects on rice production, only 45% were able to recognize the major insect pests. Across all zones, 41% identified leaf feeders (*Trichispa* spp.) as the most important insect pests; other pests cited as important were stem borers (*Diopsis* spp.) (31%) and termites (23%). In the uplands, 51% of the respondents cited leaf feeders as the most important insect pests, while 46% cited termites. In the inland valley swamp ecosystems, 28% cited stem borers as the most important insect pests. In general, farmers showed considerable understanding of the factors (such as soil type and fertility, drought occurrence, standing water and presence of certain weeds) causing insect problems in their rice fields. Among the control methods used were random disposal of lemons on fields, pouring hot water on or destroying termite hills, laying palm leaves on fields and using traditional herbalists. The percentages of respondents in each rice ecosystem using insecticides were 6% in the uplands, 13% in the traditional lowlands, 60% in the semi-traditional lowlands, 68% in the improved lowlands, 10% in the irrigated systems and 13% in the flooded rice systems.

The survey data will contribute to the design of IPM technologies that are compatible with farmers' resources, build on indigenous control methods and minimize reliance on chemical inputs. In 1994, a major study will be conducted in Nigeria to determine farmers' perceptions, control methods and the economic impact of losses due to the African rice gall midge.

Inventory of rice insect pests and their natural enemies

E. Heinrichs (WARDA), A. Russell-Smith (NRI), A. Barrion (IRRI) and D. Rider (NDSU)

Rice pests and their natural enemies vary in species composition and population levels, as well as in time and space across the

Table 8 Insect pests collected in rice fields, Burkina Faso and Côte d'Ivoire, 1992

Ecosystem	Insect pest species	
Upland	Anthicidae	*Formicomus* sp. 1
	Buprestidae	*Argilus* sp.; *Aulacophora* sp.; *Agonita* sp.; *Archicollivnis* sp.; *Chaetocnema pulla*; *Chaetocnema pusilla*. *Chaetocnema* sp.; *Cryptocephalus* sp. A; *Cryptocephalus* sp. B; *Dactylispera spinigera*; *Dicladispa viridicyanca*; *Hispa* sp.; *Monolepta* ? *bifasciata*; *Nisotra* nr. *maculiceps*
	Cicindelidae	*Cicindela* sp.
	Scarabeidae	*Pachnoda* sp.
	Alydidae	*Riptortus dentipes*
	Cercopidae	*Locris* sp. B
	Cicadellidae	*Nephotettix afer*; *Nephotettix modulatus*; *Paramesus* sp.
	Lygacidae	*Amblypelta cocophaga*: *Cletus fuscescens*; *Parabrachius* sp. A; *Paramius piratoides*
	Nabidae	*Arbela confusa*
	Pentatomidae	*Aeliomorpha griseoflava*; *Aethemenes chloris*: *Aspartia acuminata*; *Aspauia albidomaculata*; *Aspauia armigera*; *Aspauia brunnea*; *Carbula citheris*; *Carbula difficitis*; *Carbula* sp.; *Diploxys arkheana*; *Diploxys bipunctata*: *Diploxys senegalensis*; *Dorycoris pavoninus*; *Durmia tomentiventris*; *Eysercoris ventralis*; *Menida* sp.; *Mormidea* sp.; *Nezara viridula*; *Scotinophara* sp. A; *Zincrona caerules*
	Pyrrhocoridae	*Dysdercus superstitiosus*
	Acrididae	*Catantops melanostictus*
	Tettigoniidae	*Conocephalus* sp.
Total number of species collected — 51 (60%)		
Irrigated	Anthicidae	*Formicomus* sp. 2
	Carabidae	*Drypta* sp. A; *Drypta* sp. B
	Chrysomelidae	*Aspidomorpha aerata*; *Trichispa sericea*
	Curculionidae	*Cylas puncticollis*
	Meloidae	*Cylimdrothorax* sp. A; *Cylindrothorax spurcuticollis*; *Mylabris* sp.
	Diopsidae	*Diasemopsis meigeri*; *Diopsis apicalis*; *Diopsis lindneri*
	Alydidae	*Stenocoris annulicornis*
	Cerlopidae	*Locris* sp. A
	Cicadellidae	*Hecalus* sp.; *Hortensia similis*
	Cixiidae	*Oliarus* sp.
	Lyaeldae	*Blissus leucopterus*; *Clavigralla* ? *gibbosa*; *Parabrachius* sp. B
	Pentatomidae	*Agonoscelis* sp. nr. *pubescens*; *Diploxys fallax*; *Scotinophara* sp. B
	Pyrrhocoridae	*Dysdercus volkeri*
	Reduviidae	*Rhinocoris* sp.
	Acrididae	*Atractomorpha acutipennis gerstaekeri*
Total number of species collected — 26 (31%)		
Irrigated/upland	Coccinellidae	*Microspis striata*
	Forficulidae	*Diaperasticus erythrocephalus*
	Diopsidae	*Diopsis macrophthalma*
	Alydidae	*Mirperus jaculus*
	Cicadellidae	*Cofana spectra*; *Cofana unimaculata*
	Nabidae	*Stenonabis conspurcatus*
	Tettigoniidae	*Paratettis* sp.
Total number of species collected — 8 (9%)		

continuum, across agro-ecosystems and across climatic zones. Because of this variation, it is necessary to understand the factors affecting the distribution and abundance of rice pests and their natural enemies in order to develop economic pest management technologies. A survey was initiated in 1992 in Burkina Faso and Côte d'Ivoire to determine the insect pest/natural enemy complex in irrigated and upland rice. Arthropods were collected mainly with sweep nets, but some spiders were collected by hand. The arthropods were identified by taxonomists at IRRI, NRI and North Dakota State University, USA.

Among the insect pests collected were leaf-feeding beetles (including reported rice yellow mottle virus vectors) and grain-sucking insects (*see* Table 8). Spider composition was extremely diverse (*see* Table 9); many species in the family Lycosidae have been reported previously as predators of stem borers. Additional surveys will be conducted in other West African countries in 1993 to fully characterize the phenological growth stages of rice before assessing the relative importance of the various insect pests and their natural enemies.

Effect of toposequence position on distribution and abundance of rice insect pests and their natural enemies

E. Heinrichs

Preliminary studies show that the abundance of certain rice insect species varies along the continuum. To develop IPM technologies adapted to this variation, more information is needed on the effect of toposequence position and rice varietal type (upland vs lowland) on the abundance and species composition and on insect pest-related rice plant damage.

In 1992 an experiment was conducted at M'bé to characterize the soils, vegetation and insects along the continuum. Five upland rice cultivars (IDSA 6, ITA 257, WAB 56-104, WAB 56-125 and WAB 56-50) and three lowland cultivars (BG 90-2, ITA 212 and Bouaké 189) were planted in three replications in a randomized complete block design. Toposequence sites were divided into the upper and lower portions of the upland (Upland 1 and 2), the upper and lower portions of the hydromorphic zone (Hydromorphic 1 and 2) and the valley bottom (Lowland). The upland and

Table 9 **Spiders collected in rice fields, Burkina Faso and Côte d'Ivoire, 1992**

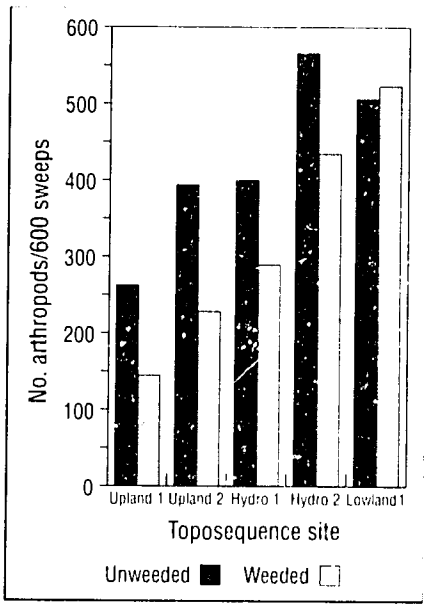
Ecosystem	Spider species	
Upland	Araneidae	*Araneus mirificus*; *Cyclosa* sp.; *Gasterocantha mammosa*; *Gasterocantha* sp.; *Hypositiga* sp.; *Neoscona* sp.
	Argiopidae	*Argiope* sp.
	Clubionida	*Aphantaulax* nr. *cinila*; *Clubiona* sp., *Cheiracunthium* sp.
	Dolomedidae	*Dolomedes* sp.
	Gnaphosidae	'*Camillina*' *luteus*
	Lycosidae	*Hippasa* sp.; *Hippasa* sp. A; *Hippasa* sp. B; *Lycosa* sp.; *Pardosa* sp.A; *Wadicosa oncka*
	Linyphiidae	*Deelemania* sp.
	Oxyopidae	*Oxyopes* sp.; *Peucetia* sp. nr. *diversipes*
	Theridiidae	*Theridula gonygaster*; *Theridula* sp.
	Thomisidae	*Runcinia* sp.; *Thomisus* sp.
Number of species collected — 25 (37%)		
Irrigated	Araneidae	*Araneus* sp. B; *Neoscona* sp.
	Lycosidae	*Pardosa* sp.; *Pirata* sp.
	Linyphiidae	*Eburnella* sp.; *Labullula annulipes*; *Lephthyphantes* sp.; *Meineta* sp.; *Metalepthyphantes machadoi*; *Metalepthyphantes* sp.; *Oedothorax macrophthalmus*
	Metidae	*Leucauge* sp.
	Philodromidae	*Thamatus* sp.
	Disauridae	*Dolomedes* sp.; *Thalassius* sp.
	Salticidae	*Heliophanus* cf *paulus*; *Myrmarachne* sp. B; *Myrmarachne* sp. C
	Tetragnathidae	*Tetragnatha boydi*; *Tetragnatha javana*; *Tetragnatha mandibulata*; *Tetragnatha nitens*; *Tetragnatha subsquamata*
	Theridiidae	*Coscinidia tibialis*; *Theridion* sp.
	Thomisidae	*Runcinia aethiops*; *Runcinia depressa*; *Synaema* sp.
Number of species collected — 28 (42%)		
Irrigated/upland	Araneidae	*Araneus* sp. A; *Araneus* sp. B.; *Neoscona theisi*
	Lycosidae	*Arctosa* sp.; *Pardosa injucunda*; *Trochosa* sp.
	Linyphiidae	*Simplicistilus tanuekes*
	Risauridae	*Pisaurina* sp.
	Salticidae	*Cyllobellus rufopictus*; *Myrmarachne* sp. A
	Tetragnathidae	*Tetragnatha jaculator*
	Theridiidae	*Dipoena* sp.; *Enoplognatha* sp.
	Thomisidae	*Imarus* sp.
Number of species collected — 14 (21%)		

hydromorphic plots were seeded with a drill and the lowland plots were transplanted on 17 June. The plots (4 x 20 m) consisted of 16 rows per cultivar and were divided into unweeded and weeded (herbicide) sections. Sweep net counts were made, tillers were dissected to determine stem borer infestations and plant damage was recorded in each plot.

The number of arthropods collected increased from Upland 1 to Lowland (*see* Figure 6). However, the abundance of individual species at different positions on the toposequence varied: some were equally abundant at all positions, others were more abundant at either the upper or lower positions. Plant damage was scored on a 1-9 scale, where 1 = 0-1% of leaf area damaged (mainly by leaf-feeding beetles, *Trichispa sericea*) and 9 = more than 50% of leaf area damaged. Rice plants scored about 1 in Upland 1 but averaged 7 in Lowland. Dissections to determine the percentage of tillers infested by stem borers showed an increase from less than 1% in Upland 1 to 6% in Lowland. Populations of most arthropod species were higher in the unweeded than in the weeded plots. The eight cultivars responded similarly.

These results underline the need to accumulate the relevant information on pest and natural enemy relationships required to develop distinct insect management strategies for the various continuum ecosystems. The experiment will be repeated in the 1993 wet season to verify the 1992 results.

Figure 6 **Numbers of arthropods collected at points along the continuum, Côte d'Ivoire**

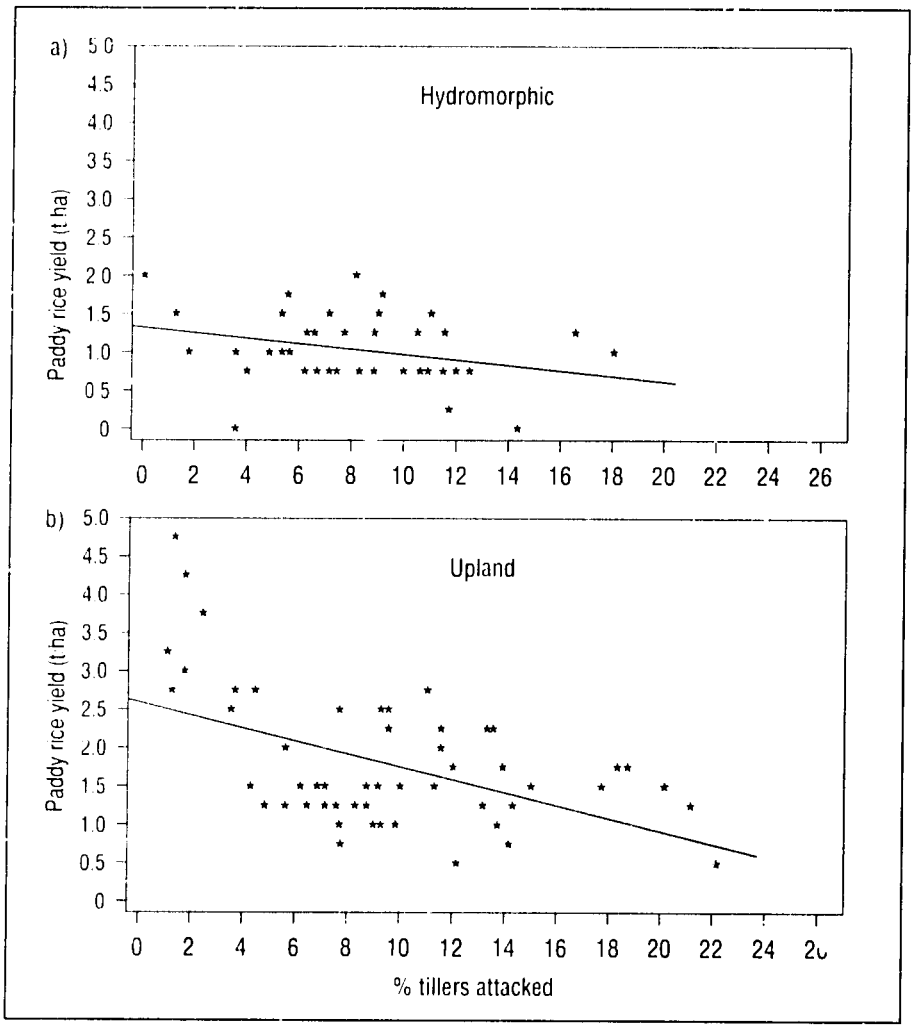


Grain yield losses caused by stem borers and the African rice gall midge

E. Heinrichs

Rice stem borers are pests throughout the continuum; the African rice gall midge is a pest mainly under lowland irrigated conditions but it has recently been observed infesting fields in the hydromorphic zone. A study was conducted at M'bé, Côte d'Ivoire to measure yield losses caused by combined stem borer and gall midge attack. The rice variety IDSA 10 (118-day duration) was sown on 13 June; the upper

Figure 7 **Effect of percentage of tillers attacked by stem borers and the African rice gall midge on grain yield of IDSA 10 in (a) the hydromorphic zone and (b) the upland area**



section of the experiment area was in the upland zone (60 plots) and the lower section in the hydromorphic zone (60 plots). Fertilizer was applied basally at 200 kg/ha (10-18-18 NPK), with a topdressing of 40 kg N/ha. The percentage of stems which were attacked by the two pest species was recorded on 5 August. At maturity, the plots were individually harvested and grain yields recorded.

The linear regressions of yield against the percentage of tillers attacked are shown in Figure 7. The predictive equation indicated a 32.6 kg/ha yield loss for each percent tiller attack in the hydromorphic zone and a 89.1 kg/ha yield loss in the upland area. The predictive equations were used to the estimate economic injury levels (EILs). First, a gain threshold (Gth) of 303 kg/ha of rough rice was established as follows:

$$\text{Gth} = \frac{\text{Cost of control (US\$72.62/ha)}}{\text{Price of rough rice (US\$0.24/kg)}}$$

One application of carbofuran granules at 1.0 kg ai/ha costing US$72.62 is considered adequate to control the gall midge and stem borers when applied with the seed at planting. The price of rough rice in February 1993 in the M'bé area was US$0.24/kg. The estimated EILs (percentage tillers attacked where the gain threshold is reached, calculated as Gth/kg per ha yield loss for each percent tillers attacked) are 9.3% (303/32.6) for rice in the hydromorphic zone and 3.4% (303/89.1) for rice in the upland area. The economic impact of stem-feeding insects is evident from these results, underlining the need to develop effective and economic strategies to manage these pests. Additional studies will be conducted in 1993 in which the effect on yield of various stem borer species and the gall midge will be isolated.

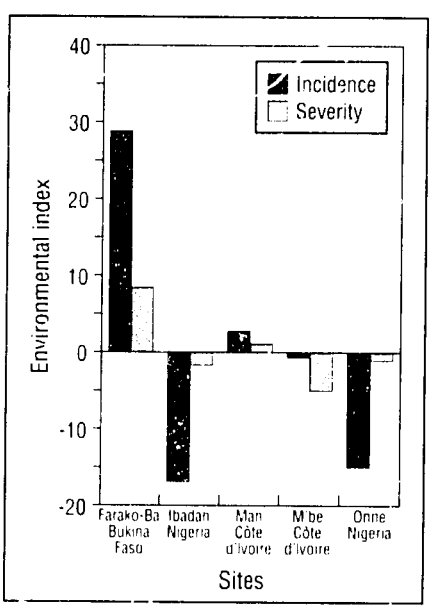
Identification of representative sites for selecting blast-resistant rice cultivars

A. Sy (WARDA), K. Alluri (INGER-Africa), E. Imolehin (NCRI), M. Jones (WARDA) and Y. Séré (INERA)

The release of rice cultivars with disease resistance levels acceptable to farmers can be achieved only after careful screening at representative sites. One of the aims of a multilocational trial established in 1992 was to collect data that could help measure the extent to which study sites in West Africa reflected actual conditions. Environments were ranked according to the degree of blast pressure. The trial involved 50 entries and the sites were at Farako-Bâ in Burkino Faso, Santchou in Cameroon, Man and M'bé in Côte d'Ivoire, Nyankpala in Ghana, Ibadan and Onne in Nigeria, and Rokupr in Sierra Leone. Only the data for sites in Burkino Faso, Côte d'Ivoire and Nigeria, representing five environments, are reported here.

Plot sizes were 1 x 2 m (10 x 20 cm spacing, 10 rows, 1; alternate rows were

Figure 8 **Incidence and severity of blast at sites representing five environments in West Africa, 1992**



Susceptible (left), highly susceptible (centre) and resistant (right) rice varieties in a blast nursery

used for disease assessment. To score disease incidence (proportion of affected plants) and severity (expression of level of severity), a modified Castano and Zaini scoring scale was used (1 = absence of visible symptoms, 3 = 1 to < 5% leaf lesions, 7 = > 50% leaf lesions). For a given environment, the environmental index (Ij) was estimated by deducting the average performance of the host-plant population in that environment from the average performance of the host-plant population in all five environments studied.

Blast incidence and severity were highest at Farako-Bâ, as shown in Figure 8. Two-way analysis of variance with two classification criteria (mixed model and cross classification) revealed highly significant differences in the five environments studied, the intrinsic host-plant potential and the reactions of entries to the gradient of the environment. At Farako-Bâ, FARO 29 had average rates of 42.7 (incidence) and 8.8 (severity). At Ibadan and Onne, IDSA 13 and WAB 99-14, respectively, showed complete resistance. At the Côte d'Ivoire sites, the best variety was WAB 56-60. From the analysis of entries at all sites, the performance of WAB 56-125 was superior to all other entries. The best entries will undergo further trials in 1993.

Screening for the genetic basis of blast resistance: African Rice Blast Nursery

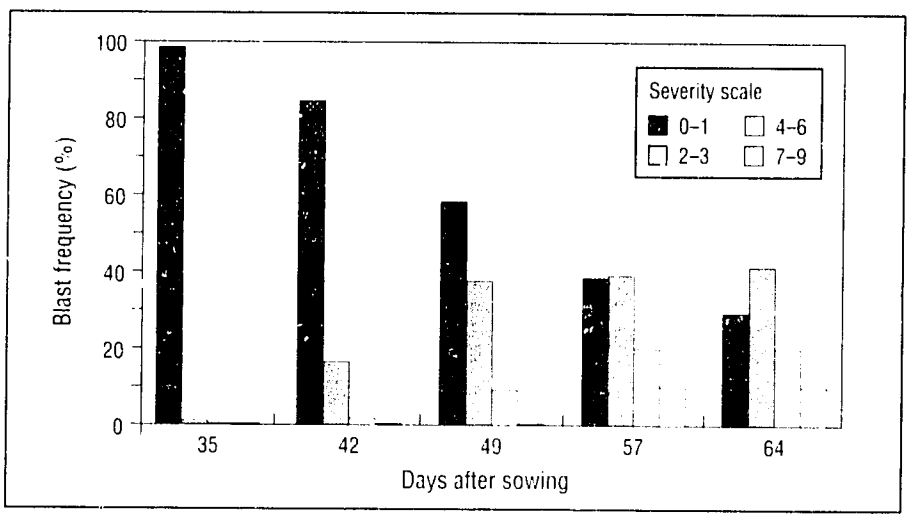
A. Sy (WARDA), K. Alluri (INGER-Africa), F. Abamu (INGER-Africa) and K. Akator (WARDA)

Identifying durable resistance in rice against the diversity of blast fungus populations is essential for increased rice production. WARDA participated in a multilocational trial conducted by INGER-Africa in the African Rice Blast Nursery in 1992. The main aims of the trial were to: identify varieties/lines with stable spatial resistance; analyze the virulence spectrum of *Pyricularia oryzae* populations at sites throughout Africa; and obtain information on the different rice growing areas. The assessment of the 160 entries in the trial was undertaken over a 5 week period, starting from the date the first symptoms appeared; entries were sown in single rows, bordered by the susceptible check, Usen.

The results, summarized in Figure 9, indicate that multilocational screening of this kind is useful for characterizing sites and genetic materials. Among the entries which showed good resistance (maximum severity score of 1) were: Kataktarada 2, BG 367-4, IRAT 156, IRAT 161, ITA 143, Salumpikit, TOX 1011-4-A2, IR 1346, IR 31429-14-2-3, IR 48812-SRN-41-B-1-1, OR 79-21, Suweon 341, TOX 3112-41-1-3-6-3, TOX 3118-6E2-1-4, TOX 3118-73-2-1-1-1, IR 31805-20-1-3-3, IR 35546-17-3-1-3, IR 37873-16-2-3-3-1, IR 3880-10, IR 39323-110-5-2-2, IR 39357-45-3-2-3, IR 39379-90-2-2-2-2, IR 39379-99-2-3-3-2, IR 46375-CPA-19-3-1, IR 48751-B-B-39-2, IR 49500-54-1-2-3, P 2025 FA-93-2-2-1B, Tainug Sen Glutinos 2, TOX 3114-10-1-2-3-3, TOX 3118-6-E2-3 and TOX 3142-1-1-1-3-1. The resistant check, IDSA 6, had a resistance profile slightly lower (severity 0-3) than those of the entries studied.

After INGER-Africa has analyzed the data collected in 1992, a list of promising materials will be sent to WARDA for possible inclusion in the plant breeding progam.

Figure 9 Blast frequency based on severity in a multilocational trial, 1992



Characterization of germplasm for resistance to leaf blast: Rapid screening nursery

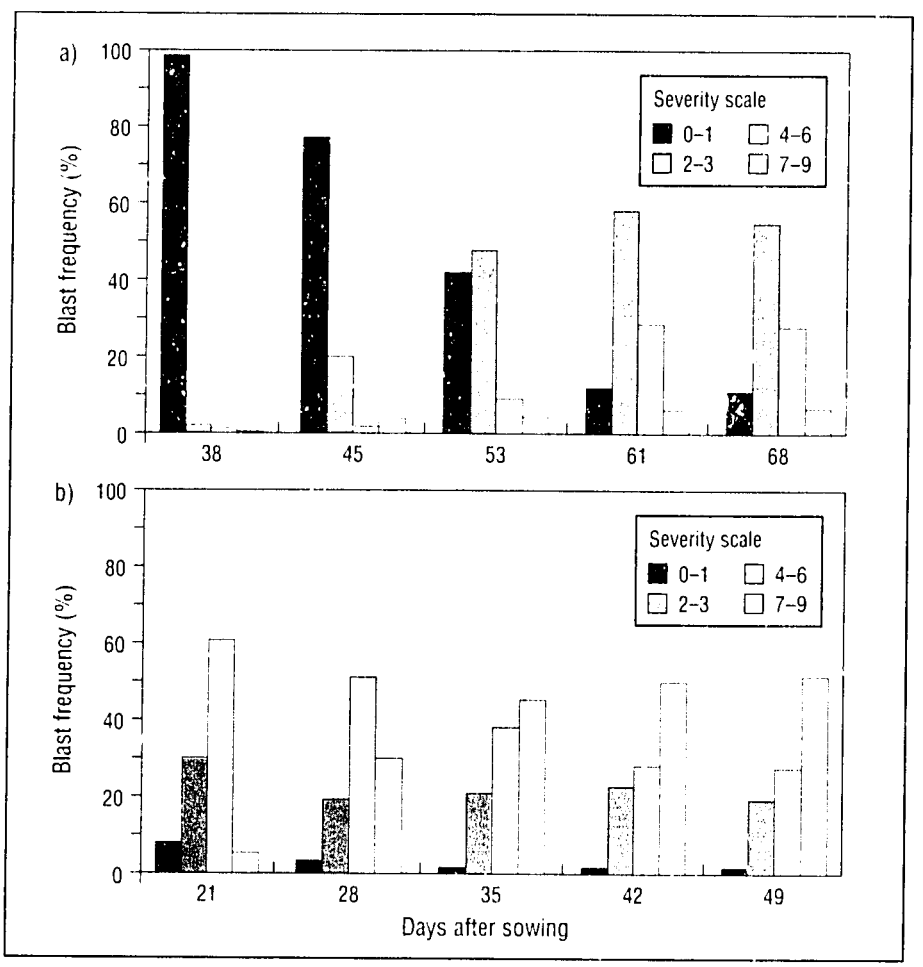
A. Sy, M. Jones and K. Akator

During 1992, two sets of entries underwent rapid screening in upland conditions at M'bé, Côte d'Ivoire to define the blast profile of fixed or segregating materials (based on the IRRI standard evaluation system), identify susceptible and resistant checks, provide data for the development of a rice blast resistance improvement strategy and identify entries to be used in an in-depth screening program. The trial design followed that used by the African Rice Blast Nursery, with each entry replicated four times (4 rows, 50 cm long).

For the susceptible check, in the first trial (242 entries) the average severity for Maratelli ranged from 4 to 9 and for Fanny and CO 39 from 5 to 9; the corresponding scores in the second trial (236 entries) were 8 to 9 and 7 to 9. For the resistance check, in the first trial the average severity for Moroberekan, OU 244 and CG 20 ranged from 1 to 3; in the second trial, Moroberekan and OU 244 scored 3 to 5 and CG 20 scored 2 to 3. There were 27 highly resistant entries in the first trial and three in the second; the number of highly susceptible entries was 12 in the first trial and 125 in the second (*see* Figure 10).

The best performing entries in the first trial were IR 46, CICA 8, Dular, Oryzica 3, CTA 6775-5-17-4-2-70, CT 6775-5-17-4-2-5P, IR 35366-40-3-3-2-2, IR 42, ITA 139, ITA 402, WAB 56-104, CG 14, Kinandang Patong, TOX 3081-36-1-4-1-1, FKR 27, CT 6240-12-2-2-3-6P, ITA 135, CNA 66"5, IR 25587-133-3-2-2-2, IR 22082-41-2, IR 21118-138-2-3, IR 32429-138-1-3-3, IR 35546-17-3-1-3, IR 29725-76-3-3-2, IR 28228-12-3-1-1-2, FAROX 306-3-2 and FAROX 317-3-5-2. In the second trial, the only entries matching the performance of those listed above for the first trial were TOS 13031, TOX 3118-73-2-1-1-1 and 15891.

Figure 10 Blast resistance profile for (a) 242 entries and (b) 236 entries screened at M'bé, Côte d'Ivoire



Screening for resistance to rice yellow mottle virus: RYMV evaluation screening test

A. Sy (WARDA), K. Alluri (INGER-Africa), F. Abamu (INGER-Africa) and K. Akator (WARDA)

Rice yellow mottle virus occurs mainly in the lowland ecosystems, but has also been observed in the irrigated uplands. In spite of advances in knowledge of the biology of this pathogen, it is difficult to estimate its contribution to yield loss. In 1992, a trial was conducted in M'bé and Gagnoa, Côte d'Ivoire in collaboration with INGER-Africa to assess the genetic diversity of the virus, identify rice genotypes with durable spatial resistance and contribute to a pan-African strategy to combat the disease.

The trial involved 100 entries, with Moroberekan and BG 690-2 as the resistance and susceptible checks, respectively, and Bouaké 189 (susceptible) as the local check. Artificial inoculation (inoculum produced by Bouaké 189, which was naturally infested on adjacent plots) was carried out 39 days after transplanting; disease rating was based on the IRRI standard evaluation system. The most promising entries on the 40th day after inoculation were TOG 5681, Moroberekan, FARO 39 (IRAT 44), FARO 43 (ITA 128), IRAT 112, IRAT 208, WABIS 18, WABIS 675, TOX 3629-1-4NR-6, Yu Keng 136, Yu Keng 219 and Xinan 175. Entries which were severely affected included IR 4632-2-3, TOX 3069-66-2-3-6, IR 5, BG 90-2, TOX 3055-10-1-1-1 and TOX 3211-14-1-2-1-2A. However, the most suitable susceptible checks, showing spectacular symptoms of foliar attack, were Bouaké 189, TOX 3211-49-1-2-2 and TOX 3058-50-1-2-3-1.

Plans are under way to implement an in-depth study on rice yellow mottle virus in 1993, based on assessing the impact of the disease on tillering, yield and grain weight.

Varietal resistance profiles for rice yellow mottle virus

A. Sy and K. Akator

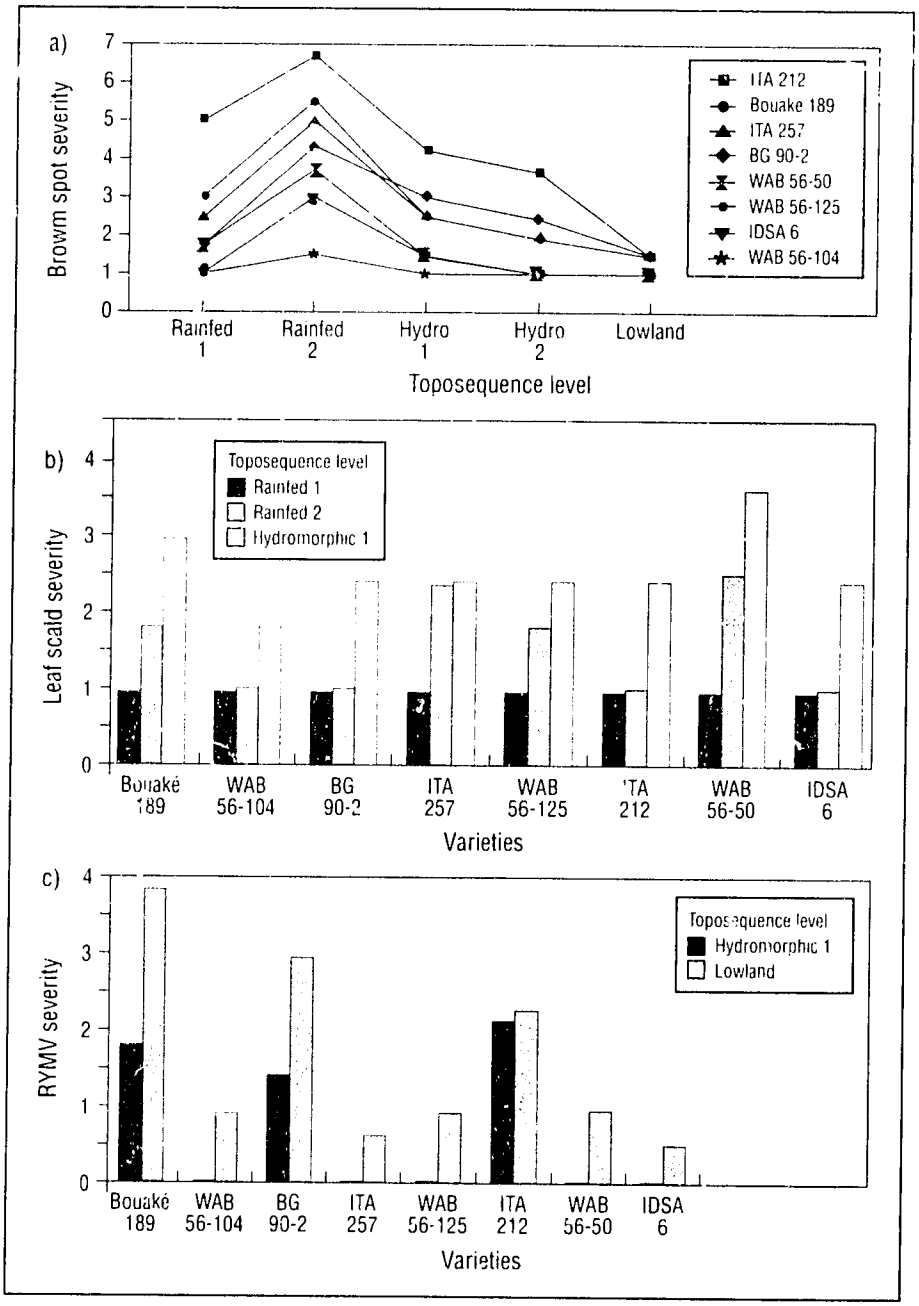
Within the context of research on rice yellow mottle virus, a trial was established

in 1992 to compile the resistance profiles of 36 rice varieties and characterize the M'bé and Gagnoa sites in Côte d'Ivoire. Entries were taken from WARDA and INGER-Africa collections, multiplied, and grown in a randomized complete block design, with three replications. The resistant check was Moroberekan and the susceptible checks Jaya and IM 16. Where necessary, artificial inoculation was carried out on the 12th day after transplanting. Disease assessment, using the IRRI standard evaluation system, was conducted over a 65-day period, starting 2 weeks after inoculation.

No varieties showed levels of resistance equal to that of the check, Moroberekan. TOX 3068-28-1-1 and TOX 3233-31-6-2-1-2A were superior to all other entries, irrespective of the site. Varieties showing high susceptibility at both sites were TOX 3219-5-1-1-1, TOX 3441-96-1-1-3, TOX 3559-6-2-2-2, TOX 3399-158-1-3-2, TOX 3552-84-1-2-1, ITA 306, BG 90-2, ITA 400, ITA 402, FAROX 315-1-2-2, ITA 304 and ITA 308. Under artificial inoculation, there was a significant effect on the formation of floral organs and delayed exsertion, leading to a sharp increase in the percentage of deficient panicles: at M'bé, this ranged from 17% (uninoculated) to 63% (inoculated) for Bouaké 189; at Gagnoa, the corresponding figures were 19 and 71%. The impact of artificial inoculation on plant height was also recorded. The maximum reduction in height was 33% for TOX 3552-84-1-2-1 at Gagnoa and 26% for ITA 400 at M'bé. There was no significant reduction in the heights of the resistant varieties TOX 3058-28-1-1 (average height 86 cm at M'bé and 75 cm at Gagnoa), TOX 3211-14-1-2-1-2 (94 cm and 85 cm) and Moroberekan (110 cm and 95 cm).

In 1993, work will be undertaken to broaden the scope of this trial in collaboration with NARS, study the impact of rice yellow mottle virus on tillering and assess yield losses caused by the virus.

Figure 11 **Reaction of rice varieties grown in different ecosystems along the continuum to (a) brown spot, (b) leaf scald and (c) rice yellow mottle virus (RYMV)**



Characterization of the continuum toposequence for disease prevalence

A. Sy, A. Adesina, F. Heinrichs, M. Jones, D. Johnson and K. Sahrawat

The continuum offers an ideal environment for the assessment of the population dynamics of pathogenic agents and the adaptibility of their host populations. A trial was conducted at various points on the toposequence, using a randomized complete block design, with three replications; in each replication, entries were sown parallel to the gradient on a 4 x 100 m plot. The plot was divided into five sections, representing: upper and lower rainfed uplands (Rainfed 1 and 2); upper and lower hydromorphic zone (Hydromorphic 1 and 2); and lowland (Lowland).

The upland varieties tested were WAB 56-104, WAB 56-125, ITA 257 and IDSA 6 (check); the lowland varieties were ITA 212, BG 90-2, WAB 56-50 and Bouaké 189 (check). The prevailing disease patterns for each section of the toposequence were diagnosed and the levels of severity assessed, using the IRRI standard evaluation system. The predominant diseases were brown spot (*Drechslera oryzae*), leaf scald (*Gerlachia oryzae*) and rice yellow mottle virus (*see* Figure 11).

The results confirmed a relationship between soil-climate characteristics and

disease incidence. Rice yellow mottle virus predominated in the lower part of the toposequence, whereas brown spot was prevalent in the upper parts. The absence of blast and the relatively low severity for the other three diseases were due mainly to the nature of the experimental site and the varieties tested. The response of ITA 212, a lowland variety with good resistance to brown spot, illustrated the effect of transferring a variety to an ecosystem too far from its preferred environment.

PROJECT 4: SOIL FERTILITY MANAGEMENT

Nitrogen and phosphorus deficiency are the most important nutrient constraints to rice production in the continuum. N deficiency occurs throughout West Africa, but is most severe in the savanna zone; P deficiency is a serious problem in the forest zone and in acidic uplands. In the lowland and irrigated ecologies, iron toxicity is the most important nutrient disorder, and the development of improved varietal tolerance is considered the most practical solution to this problem for resource-poor farmers. WARDA's research on soil fertility management is focusing on the diagnosis and management of these soil disorders. Complementary studies have been undertaken to determine the mineral reserves in the upland and irrigated lowland ecosystems.

Table 10 Yield and yield attributes of IDSA 6 under different fertilizer treatments in the fourth year of a continuous cropping trial in upland soil conditions

Treatment[a]	Grain yield (t/ha)	Straw yield (t/ha)	Tillers (no./m²)	Panicles (no./m²)
Check (no fertilizer)	1.61	1.84	220	155
CF	2.90	3.66	265	223
CF-N	1.54	1.67	227	171
CF-P	2.63	2.88	226	186
CF-K	3.49	3.57	292	225
CF-Ca	2.45	3.49	285	238
CF-Mg	3.06	3.43	286	238
CF-Zn	2.15	3.20	274	186
LSD (5%)	0.895	0.579	73.0	52.1
CV	24.53	13.27	19.1	17.5

Note: a See text for details of treatments

Table 11 Yield and yield attributes of Bouaké 189 under different fertilizer treatments in the first year of a continuous cropping trial in lowland irrigated conditions

Treatment[a]	Grain yield (t/ha)	Straw yield (t/ha)	Tillers (no./m²)	Panicles (no./m²)
Check (no fertilizer)	1.44	2.53	235	135
CF	2.77	4.23	303	177
CF-N	1.66	3.31	232	133
CF-P	3.11	5.58	347	186
CF-K	2.68	4.43	315	163
CF-Ca	2.62	5.64	282	163
CF-Mg	2.75	5.10	334	178
CF-Zn	2.62	4.81	319	178
LSD (5%)	0.549	0.968	47.5	126.9
CV	15.20	14.77	10.9	9.0

Note: a See text for details of treatments

Soil nutrient deficiency studies

K. Sahrawat and S. Diatta

A multi-year experiment to determine the status of mineral reserves in an upland soil was initiated at M'bé, Côte d'Ivoire in 1989. A parallel experiment in a lowland soil under irrigated conditions, using a similar design, began at M'bé in 1992. A complete fertilizer (CF) treatment (100 kg N/ha as urea, 100 kg P_2O_5/ha, 100 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 were individually omitted. A randomized complete block design was used, with four replications. P, K, Ca, Mg and Zn were applied basally at planting; N was applied in three equal splits at planting/transplanting, tillering and flowering. The cultivar IDSA 6, a widely grown upland variety, was used for the upland trial; Bouaké 189, common in the lowlands, was used for the irrigated lowland study.

Since 1989, trials have been conducted at M'bé to determine the natural nutrient reserves in soils at different locations (plateau, upper slope and mid-slope) in the upland ecosystem. The trial fields were under fallow for 5-7 years; the soils are slightly acidic (pH 6.5) in the top 20 cm layer and low in organic matter. The soil profile is gravelly throughout, with a sandy clay texture in deeper horizons (30-50 cm); N was the only deficient nutrient.

Tables 10 and 11 summarize the 1992 data on yield and yield attributes for the upland and lowland ecologies. In the upland trial, grain and straw yields and numbers of tillers and panicles in the CF-N treatment were significantly lower than in CF. In the CF-P treatment, numbers of tillers and panicles were significantly lower than in CF; straw yield was also lower in the CF-P treatment. In the lowland trial, grain and straw yields and numbers of tillers and panicles were significantly lower in the CF-N treatment than in CF. For all other treatments there were no significant differences in grain and straw yields. The results suggest that inadequate N is the most important nutrient deficiency in these ecologies. This trial will continue for a further 3-4 years.

Response of upland rice varieties to phosphorus deficiency in a forest zone Ultisol

K. Sahrawat, M. Jones and S. Diatta

Phosphorus is the most limiting nutrient in the acidic soils of West Africa's humid-forest zone. Availability of P in these soils is reduced by the interaction of soluble P with iron and aluminum oxides. An

experiment was initiated in 1992 at Man in Côte d'Ivoire to measure the P responsiveness of five upland varieties and determine their P requirements and efficiencies in an Ultisol low in available P. Exchangeable Al content is high and P is unavailable because it is combined with Al. The soil is loamy sand and has adequate organic matter content. The aim of this study is to develop better P management practices for acidic uplands by integrating soil management with improved varietal efficiency.

Four rates of P were applied (0, 30, 60 and 90 kg P/ha as triple superphosphate) in an Ultisol (pH 4.8; organic C 1.5%) low in available P (2.9 ppm Bray-1 extractable P). A randomized complete block design was used, with four replications. Each plot (5 x 3 m) received N (100 kg N/ha) in three splits at planting, tillering and flowering. Plots were handweeded at 3 and 6 weeks after seeding. Without applied P, WAB 56-125 gave the highest yield (*see* Table 12). Because of severe disease incidence (brown spot and other diseases) ITA 257 did not give a significant response to applied P. The response equations for the remaining varieties were:

WAB 56-125:

$Y = 1.64 + 0.0483P - 0.00037P^2$

$R^2 = 0.684$

WAB 56-104:

$Y = 1.44 + 0.03638P - 0.00021P^2$

$R^2 = 0.811$

WAB 56-50:

$Y = 1.22 + 0.0555P - 0.00034P^2$

$R^2 = 0.800$

IDSA 6:

$Y = 1.40 + 0.0124P^2$

$R^2 = 0.530$

where:

Y = grain yield in t/ha

P = rate of applied P in kg/ha

Rice crop response to applications of 0 kg P/ha (foreground) and 30 kg P/ha (background)

The P efficiency of the cultivars will be determined after analyzing grain and straw for P content. In 1993 the residual value of the P applied in 1992 will be determined without additional applied P. The experiment will be repeated in 1993 to cover a higher and wider P response range.

Table 12 **Response of five upland rice cultivars to phosphorus deficiency in an Ultisol in the forest zone, Côte d'Ivoire, 1992**

P rate (kg/ha)	Grain yield (t/ha)				
	WAB 56-125	WAB 56-104	WAB 56-50	IDSA 6	ITA 257
0	1.64	1.43	1.15	1.32	0.90
30	2.75	2.39	2.78	1.87	2.24
60	3.19	2.82	3.09	2.20	1.21
90	2.96	3.03	3.49	2.44	1.44
LSD (5%)	0.757	0.477	0.836	0.469	n.s[a]
CV	17.97	12.43	19.88	14.98	—

Note: a Not significant

Evaluating promising rice cultivars for iron toxicity tolerance in lowland soils

K. Sahrawat, B. Singh, S. Diatta and M. Jones

Iron toxicity is a major nutrient disorder of lowland and irrigated rice in West Africa. Varietal tolerance is a practical and low-cost means of increasing rice productivity in iron-toxic conditions. An experiment was conducted in 1992 to evaluate the iron toxicity tolerance of promising lowland rice varieties and to provide additional information for selecting breeding materials. The varieties tested included five upland cultivars which had shown good performance in acidic upland soils.

Twenty cultivars were grown at M'bé and Korhogo, Côte d'Ivoire. These two sites represented markedly different iron toxicity pressures in the 1992 growing season. The iron toxicity score (based on the IRRI standard evaluation system) for the standard tolerant check, Suakoko 8, was high (3) and sustained at Korhogo and very low (1) at M'bé. A randomized complete block design was used, with four replications. All the plots (12 m²) received a basal application of 200 kg NPK/ha (10-18-18).

Table 13 (*overleaf*) summarizes the yield data. The upland varieties (the last five varieties in the table) showed little tolerance at Korhogo; their performance at M'bé was relatively poor, reflecting poor adaptation to flooded conditions. Suakoko 8 gave a lower grain yield at Korhogo than at M'bé. The performance of the local check, Bouaké 189, reflected its ability to take advantage of the low iron-toxic conditions prevailing at M'bé during 1992. The check variety ITA 247 appeared to be relatively tolerant to iron toxicity.

These results show that some TOX lines may have promising iron toxicity tolerance. In contrast, the iron toxicity-tolerant variety Suakoko 8 may have low yield potential and thus be uniquely suited for conditions of high iron toxicity pressure. The study will continue at M'bé and Korhogo in 1993, accompanied by collaborative studies

Table 13 **Performance of 20 rice cultivars at a site with high iron toxicity (Korhogo, Côte d'Ivoire) and a site with low iron toxicity (M'bé, Côte d'Ivoire), 1992**

Entry	Grain yield (t/ha) Korhogo	M'bé	Iron toxicity score at Korhogo
TOX 3100-32-2-1-3	5.04	6.35	2
TOX 3107-39-1-2-1	5.00	5.65	2
Suakoko 8 (standard tolerant check)	4.85	4.44	3
ITA 408	4.42	6.49	3
ITA 247 (check)	4.37	4.68	3
TOX 3113-6-E2-3-2	4.33	5.72	3
TOX 3081-36-2-3-1	4.33	5.54	3
TOX 3027-43-1-E3	4.26	5.79	3
TOX 3118-42-1-1	4.09	6.36	3
ITA 326	3.95	4.50	3
TOX 3050-46-E3-3	3.31	6.52	3
TOX 85C-C1-10-WAS	3.29	4.70	5
TOX 85C-C1-17-WAS	3.24	4.70	7
Bouaké 189 (local check)	2.87	5.64	7
TOX 3052-46-3-3-1	2.76	5.96	5
IDSA 10	<0.10	3.80	9
IDSA 16	<0.10	4.12	9
IRAT 144	<0.10	3.60	9
ITA 120	<0.10	5.90	9
ITA 257	<0.10	3.64	9
LSD (5%)	1.078	0.959	
CV	27.50	18.40	

with Louisiana State University, USA on iron toxicity processes in the lowlands.

PROJECT 5: DEVELOPMENT OF IMPROVED RICE VARIETIES

The goal of this project is to develop higher and more stable yielding rice varieties for the upland/hydromorphic and hydromorphic/lowland ecosystems of West Africa. Although most rice farmers in these ecosystems are likely to continue with traditional low-input cultivation systems in the medium-term, some are making the transition to high-input intensive systems. WARDA's goal is to develop varieties for low-, medium- and high-input production systems in order to cater for all levels of management.

The improved materials should perform as well or better than local varieties under low management, should respond well to better management and the addition of nitrogen, and should be at least as tolerant as most traditional varieties to drought, flooding, adverse soils, insect pests and diseases. They should also have appropriate plant architecture to minimize lodging and suppress weeds, as well as grain quality properties which suit the diverse preferences of the region's consumers.

In 1992, upland yield and stress trials were conducted in Côte d'Ivoire at WARDA's experimental farm at M'bé (forest-savanna transition zone; bimodal rainfall; 1992 total rainfall 1030 mm), at Man and Gagnoa (humid-forest zone; monomodal; 1563 mm and 1610 mm, respectively) and at Korhogo (savanna zone; monomodal; 1302 mm). Lowland breeding activities concentrated on breeding for yield and yield stability and selecting for resistance or tolerance to the major stresses, including blast, glume discoloration, leaf scald, rice yellow mottle virus, stem borers, gall midge, drought, flooding, submergence and iron toxicity. The trials were conducted in Nigeria at Ibadan, Edozhigi, Kano, Ikenne, Onne and Itoikin; these sites represent a wide range of lowland rice growing conditions in West Africa.

Farmers' knowledge and preferences for rice varietial characteristics

A. Adesina and M. Jones

The adoption rate of new rice varieties is often low because they lack the traits preferred by farmers. To address this problem, surveys were initiated in 1992 in Côte d'Ivoire to characterize the diversity of existing germplasm, determine farmer knowledge of germplasm conservation and assess farmers' preferences for specific varietal traits. The study covered 174 farms in 12 villages in the humid-forest, forest-savanna and savanna agro-ecological zones.

The results, summarized in Table 14, show that farmers considered that local varieties

Table 14 **Farmers' comparison of the best local rice varieties with the best improved varieties, Côte d'Ivoire, 1992**

Trait	Comparison of local and improved varieties (% of respondents)[a] Local better	Improved better	No difference	Not applicable
Agronomic traits:				
Plant height	86	4	10	—
Resistance to shattering	81	12	7	—
Weed competitveness	79	7	14	—
Panicle length	76	17	7	—
Panicle exsertion	74	12	14	—
Tillering capacity	73	17	10	—
No. grains per panicle	52	45	2	—
Yield	50	40	10	—
Drought tolerance	31	45	17	7
Insect pest and disease tolerance	7	81	10	2
Early maturity	2	91	7	—
Post-harvest traits:				
Good aroma	64	17	19	—
Ease of cooking	29	33	38	—
Taste	29	29	23	19
Ease of milling	9	74	17	—
Ease of threshing	5	76	3	16

Note: a N = 42 farmers

Table 15 **Farmers' assessment of the relative importance of agronomic and post-harvest traits in adoption decisions on rice varieties, Côte d'Ivoire, 1992**

Trait	Assessment of importance of traits (% of respondents)[a]			
	Very important	Important	Minor importance	Not applicable
Agronomic traits				
Yield	99	1	—	—
Tillering capacity	99	—	1	—
Drought tolerance	93	1	6	—
Panicle exsertion	88	11	1	—
Resistance to shattering	50	32	18	—
Plant height				
tall	72	9	1	18
medium	55	13	1	31
short	1	3	1	95
Crop duration				
long	11	11	9	69
medium	55	21	8	16
short	39	13	7	41
Weed competitiveness	34	24	42	—
Insect pest tolerance	24	9	67	—
Disease tolerance	24	7	69	—
Post-harvest traits:				
Good taste	97	2	1	—
Ease of cooking	82	17	1	—
Ease of milling	77	17	6	—
Good aroma	57	21	22	—

Note: a N = 140 farmers

had several advantages over improved varieties, particularly in terms of plant height, resistance to shattering, panicle length and exsertion, competitiveness with weeds, and tillering capacity. Interestingly, they did not perceive a distinct yield advantage for improved varieties over local ones. Table 15 summarizes farmers' responses on which varietal traits they considered 'very important', 'important' or of 'minor importance'.

From these surveys, a comprehensive database was developed on the major local varieties cultivated by farmners in the surveyed villages, and farmers' preference profiles for different agronomic and post-harvest traits were compiled. Because of the considerable interest in this type of study shown by rice breeders in the region, this work will be expanded over the next 5 years to involve national researchers in the development of a database on the varietal preferences of rice farmers in West Africa.

Germplasm characterization

M. Jones, D. Johnson, K. Sahrawat, A. Sy, E. Heinrichs and S. Mandé

The ability of improved rice varieties developed by WARDA, IITA and IRAT to tolerate ecosystem-specific stresses along the continuum is inhibited by the lack certain morpho-agronomic traits. In 1992 a multi-year, multidisciplinary study was initiated at M'bé, Côte d'Ivoire to measure the yield response of improved varieties and identify the traits which enhance adaptability to specific ecosystems.

Five elite upland cultivars (WAB 56-50, WAB 56-125, WAB 56-104, ITA 257 and IDSA 6) and three elite lowland cultivars (ITA 212, BG 90-2 and Bouaké 189) were grown along the continuum at five positions on the toposequence representing the major ecosystems (Upland 1 and 2, Hydromorphic 1 and 2, and Lowland). The average slope was 1-3%, with Upland 1 at the uppermost position. A split plot design with three replications was used, with weeded and unweeded plots of each variety in each ecosystem; 200 kg NPK/ha was applied at planting, and 40 kg N/ha was applied as urea in equal doses at flowering and maximum tillering.

The grain yields are given in Figure 12 *(overleaf)*. In Upland 1, where the water table was always below 1.5 m, yields ranged from 0 to 0.41 t/ha from 0 to 1.37 t/ha under unweeded and weeded conditions, respectively. The five highest yielding cultivars in weeded and unweeded plots showed better resistance to the drought conditions experienced during the early vegetative and late reproductive stages and had good tillering capacity with well-exserted panicles. Under unweeded conditions, significant correlations were obtained between grain yield and growth duration ($r = 0.385$, $P < 0.05$), panicle number ($r = 0.409$, $P < 0.005$) and plant height ($r = 0.402$, $P < 0.005$), indicating that medium-statured varieties (100-120 cm) with early maturity (100-110 days) and moderate tillering (250 panicles/m^2) are best suited to this ecosystem. In Upland 2, where the water table was always below 1 m, yield was again correlated with duration, plant height and panicle number, as well as with neck blast ($r = 0.376$, $P < 0.005$) under weeded conditions, and with leaf blast ($r = 0.397$, $P < 0.005$) and neck blast ($r = 0.651$, $P < 0.001$) under unweeded conditions. The results indicate that the most suitable varieties for this ecosystem are early maturing types with medium stature, moderate tillering and blast resistance.

The highest average grain yields were obtained in Hydromorphic 1, where the water table was within 60 cm of the soil surface. Yield was significantly correlated with duration ($r = 0.746$, $P < 0.001$) and plant height ($r = 0.628$, $P < 0.001$) under weeded and unweeded conditions. The best adapted cultivars had medium stature and medium duration (120-135 days). In Hydromorphic 2 the water table was at the soil surface throughout the season. Yield was significantly correlated with plant height ($r = 0.439$, $P < 0.005$), panicle number ($r = 0.508$, $P = 0.001$) and growth duration ($r = 0.494$, $P < 0.005$) under weeded conditions, and with emergence ($r = 0.715$, $P = 0.001$) under unweeded conditions. In this ecosystem, lowland cultivars with medium duration (120-130 days) and short to medium stature performed best.

High yields were produced by lowland varieties in flooded conditions. Yield was significantly correlated with duration ($r = 0.821/0.718$, $P < 0.001$), panicle number ($r = 0.888/0.922$, $P < 0.001$) and plant height ($r = 0.455/0.412$, $P < 0.005$) under weeded and unweeded conditions, respectively, indicating that medium-duration varieties with high tillering capacity (over 300 panicles/m2) and short

stature are best suited to the lowland ecosystem. This trial will be repeated in 1993 at M'bé and two additional lcoations, using the same entries.

Initial screening for adaption to upland and hydromorphic conditions

M. Jones

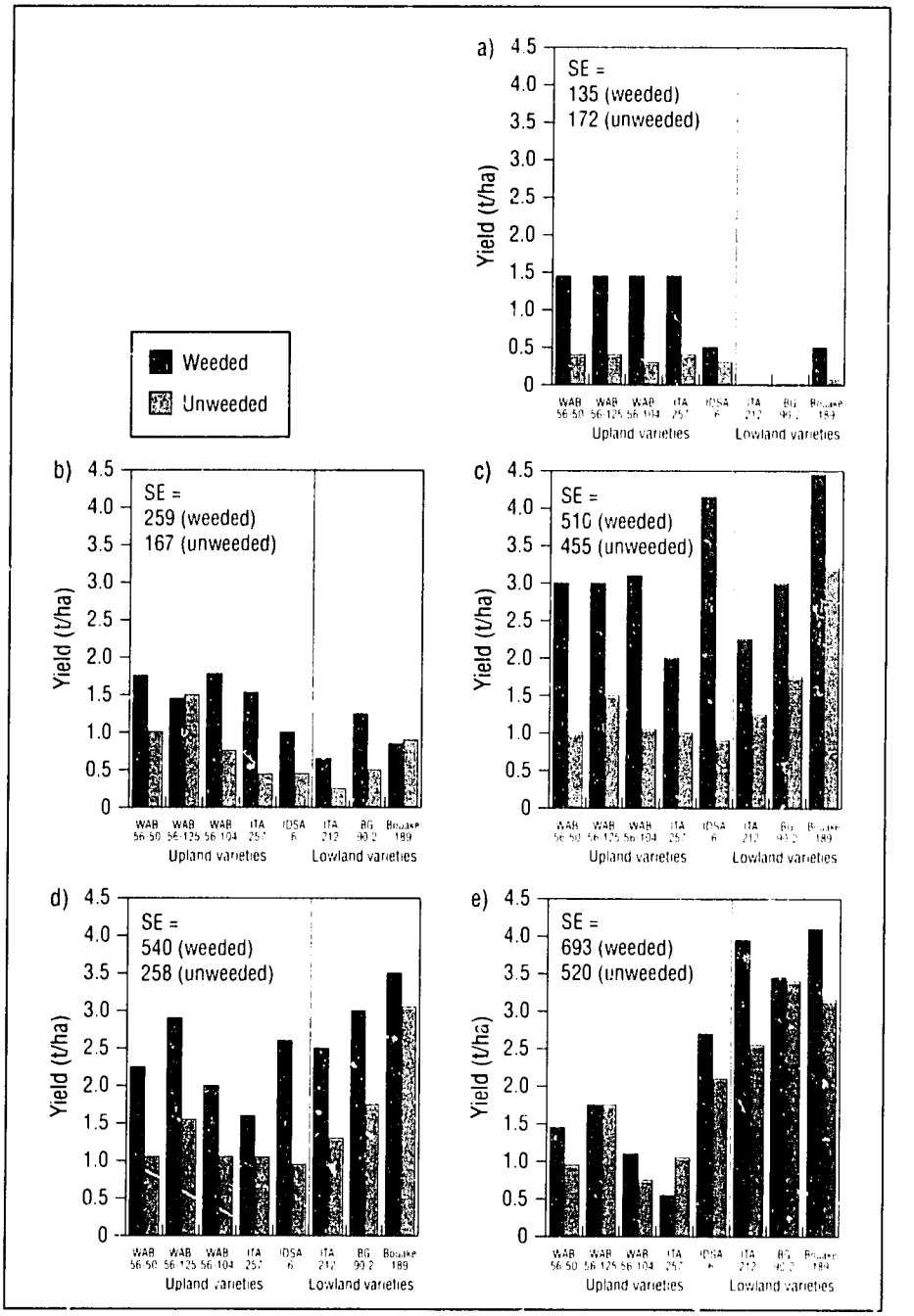
Since 1985, WARDA has evaluated about 5000 varieties/lines introduced from Asia, Latin America and Africa. Introduced varieties with high yield potential, fertilizer responsiveness, resistance or tolerance to major environmental stresses and suitable plant type have been identified for use in breeding programs. During 1992, 490 introductions were evaluated in observational nurseries at M'bé, Man and Korhogo, Côte d'Ivoire. The entries were grown in single plots (4 rows, 5 m long): the check varieties, WABC 165 (short duration) and IDSA 6 (medium duration) were repeated after every 20 test entries.

At Korhogo, severe leaf, neck and panicle blast, sheath rot, leaf scald and drought allowed easy identification of susceptible entries. At Man, only those entries with resistance to blast, sheath rot and glume discoloration, and tolerance to soil acidity and low P were selected for further evaluation. At M'bé, crop stand was good throughout the growth cycle; with the low incidence of disease, insect and soil problems, it was possible to assess the phenotypic adaptation of the entries under low stress.

Entries with consistently good performance at all three locations were CT 7242-16-4-3-2-3P, IRAT 302, B 2997C-TB-60-3-3, CABACU, WAB 33-19, CNA 762069, IRAT 300, WAB 181-18, WAB 32-133, Oitava, Mafumira and Jibudr. Entries showing good resistance to acidity and low P (pH < 4.0) at Man were WAB 32-80, WAB 32-59, WAB 36-54, WAB 30-24 and WAB 32-133. Entries showing good drought tolerance at Korhogo were CT 6949-7-1-4-2-M, IRAT 301, WABIS 737, WAB 181-18, WAB 32-55 and IRAT 300.

A total of 129 entries with acceptable grain properties and better phenotypic acceptability scores than the check were selected for inclusion in observational yield and stress trials in 1993.

Figure 12 Grain yields of upland and lowland rice varieties grown in weeded and unweeded conditions in the major ecosystems on the continuum at M'bé, Côte d'Ivoire, 1992: (a) Upland 1; (b) Upland 2; (c) Hydromorphic 1; (d) Hydromorphic 2; (e) Lowland



Screening promising upland rice selections

M. Jones

Several improved rice varieties with moderate resistance to drought and blast (ITA 120, ITA 150, ITA 257, IRAT 13, IRAT 116, IDSA 6 and WAB 56-104) are being adopted by farmers in the region because of their earliness and high yields under improved management conditions. To identify varieties with higher and more stable yields under high-input management for the upland and hydromorphic ecosystems, WARDA is conducting observational and replicated yield trials of promising varieties and advanced lines.

Two observational yield trials (short and medium duration) were conducted at M'bé, Man and Korhogo in Côte d'Ivoire to evaluate 190 entries under various environmental conditions; a trial (medium duration) was also conducted at M'bé on hydromorphic soils. Entries were grown in single plots (2 x 5 m), with the check varieties WABC 165 (short duration) and IDSA 6 (medium duration) replicated after every 20 entries. At M'bé, grain yields ranged from 0.57 to 3.59 t/ha; the check yielded 2.0-2.22 t/ha. On the basis of high yields, good phenotypic acceptability and stress resistance, 38 varieties were selected for further testing. Varieties yielding over 3.0 t/ha and exceeding the checks by 10-38% were WAB 99-81, WAB 181-30, WAB 181-32, WAB 181-37 and WAB 181-18 (short duration), and TOX 3449-34-3-3-1, TOX 3443-28-2-2-1 and TOX 3380-8-2-2-3 (medium duration). Under hydromorphic conditions, 17 varieties outyielded the best checks by 14-85%; the top five with yields exceeding 3 t/ha, were WAB 96-B-12-HB, WAB 99-H-14-HB, WAB 126-18-11-HB, WAB 224-16-H-HB and WAB 99-H-16-HB. At Man and Korhogo, leaf and neck blast, leaf scald and brown spot were recorded; drought was also severe at Korhogo. Sixteen entries rated as resistant or moderately resistant to these factors were selected. The checks yielded 1.0-1.8 t/ha. Entries with yields exceeding 1.5 and 2 t/ha at Korhogo and Man, respectively, were WAB 95-B-B-40-HB, WAB 56-125, WAB 181-37, WAB 181-18, WAB 95-B-B-B-8-HB and WAB 99-1-1.

As a follow-up to trials of varieties/advanced lines selected in previous seasons, 120 entries were screened in two preliminary yield trials, two advanced yield trials and two elite variety trials. Blast, sheath rot and glume discoloration were recorded at Man and Korhogo. Mild acidity and low P were also noted at Man, while drought was severe during the vegetative and reproductive stages at Korhogo. In all trials, yields were higher at M'bé than at Man and Korhogo (*see* Table 16 and Table 17 *overleaf*), and a large proportion of the entries outyielded the check varieties. Many entries also had long, slender and translucent grain type, which is preferred by most West African consumers. The best entries will be evaluated in Task Force regional trials in 1993.

Breeding for plant type, grain yield and yield stability under low-input management
M. Jones

In the past 40 years, rice research in West Africa has emphasized evaluating germplasm under intensive systems in favorable environments, and thus many improved cultivars do not match the performance of traditional varieties in the low-input conditions under which 80% of upland and hydromorphic rice is grown in the region. In 1992, observational and replicated yield trials of materials developed under improved conditions were conducted at M'bé, Côte d'Ivoire under

Table 16 **Performance of three highest yielding, short-duration varieties in preliminary yield trials in upland conditions at M'bé, Man and Korhogo, Côte d'Ivoire, 1992**

Entry	Grain yield (t/ha)	Plant height (cm)	Days-to-maturity	Stress resistance rating[a] Leaf blast	Neck blast	Glume discoloration	Drought stress	Acidity
M'be (transition zone, bimodal rainfall):								
WAB 96-36	3.76	116	98	3	2	2	1	—
WAB 56-104	3.70	103	93	3	1	1	1	—
WAB 99-5	3.56	114	91	3	3	3	1	—
WABC 165 (check)	2.96	100	100	4	3	3	1	—
Mean of 20 entries	3.20	112	104	4	3	3	1	—
CV (5%)	18							
SE ±	300							
Man (forest zone, monomodal rainfall):								
WAB 99-5	2.63	98	104	1	3	1	—	2
WAB 56-104	2.53	97	103	1	3	2	—	2
WAB 96-9-1	2.30	110	107	3	7	4	—	2
WABC 165 (check)	1.01	95	115	1	4	4	—	3
Mean of 20 entries	1.68	100	107	2	6	4	—	4
CV (5%)	18							
SE ±	150							
Korhogo (savanna zone, monomodal rainfall):								
CNA	1.20	97	96	1	2	2	3	—
WAB 99-7	1.08	99	96	1	2	1	2	—
WAB 56-104	1.02	102	97	1	2	2	4	—
WABC 165 (check)	0.85	102	98	1	2	2	3	—
Mean of 20 entries	0.59	108	98	1	2	2	5	—
CV (5%)	31							
SE ±	153							

Note: a Scored according to the IRRI standard evaluation system (0 = no damage, 9 = dead plant)

Table 17 Performance of three highest yielding, short-duration varieties in advanced yield trials in upland conditions at M'bé, Man and Korhogo, Côte d'Ivoire, 1992

Entry	Grain yield (t/ha)	Plant height (cm)	Days-to-maturity	Stress resistance rating[a] Leaf blast	Neck blast	Glume discoloration	Drought stress	Acidity
M'bé (transition zone, bimodal rainfall):								
WAB 181-18	4.26	104	101	2	1	1	1	—
WAB 56-104	3.65	103	97	2	1	1	1	—
WAB 99-1-1	3.64	101	102	1	1	2	1	—
WABC 165 (check)	2.96	116	91	2	2	2	1	—
Mean of 20 entries	3.26	108	107	2	2	2	1	—
CV (5%)	17							
SE ±	275							
Man (forest zone, monomodal rainfall)								
WAB 181-18	3.49	98	111	3	2	2	1	2
WAB 56-39	3.42	110	124	4	1	1	1	2
WAB 56-125	3.14	107	115	3	1	1	1	2
WABC 165 (check)	2.67	114	115	1	2	1	1	2
Mean of 20 entries	2.61	109	115	4	2	2	1	3
CV (5%)	23							
SE ±	294							
Korhogo (savanna zone, monomodal rainfall)								
TOX 1011-4-A2	1.50	85	97	1	1	3	3	—
WAB 99-1-1	1.49	93	98	1	1	3	2	—
WAB 56-104	1.31	87	98	1	0	6	4	—
WABC 165 (check)	1.10	101	106	1	1	4	5	—
Mean of 20 entries	0.61	98	99	1	1	5	5	—
CV (5%)	37							
SE ±	117							

Note: a Scored according to the IRRI standard evaluation system (0 = no damage, 9 = dead plant)

low-input conditions (minimal land disturbance, with tree stumps retained; land not levelled but a hoe used to scarify the top 5cm; 40 kg N/ha applied as urea in equal doses, 15 and 45 days after sowing; plots handweeded at 28 days after sowing).

In the observational trial (single plots, 4 rows, 5 m long), 148 traditional and improved entries were tested against four improved varieties (WAB 56-104, WABC 165, IDSA 6 and IRAT 144). Only six improved varieties produced grain (WAB 96-1-1, 1.07 t/ha; WAB 56-10, 1.06 t/ha) WABC 165, 0.85 t/ha; IDSA 6, 0.55 t/ha; IRAT 144, 0.54 t/ha and ITA 257, 0.24 t/ha). Most other improved varieties were smothered by weeds and were stunted and highly chlorotic, with marked N deficiency symptoms. Most traditional varieties had higher yields and better phenotypic acceptability and seedling vigor scores than the improved varieties. The 26 varieties selected for inclusion in the 1993 observational trials included the following highest yielders: SP4, YS 236, Jeka Djare, ES 17A, D 10, SP 8, YS 231, WAB 56-104, Digba-Youho, M 2, IDSA 6, WAB 96-1-1 and WAB 181-18.

In the three replicated trials (randomized complete block design, with six replications; plots 3 x 5 m), yields of the 60 preliminary, advanced and elite varieties tested were very low (0.72-1.0 t/ha). Varieties yielding over 0.9 t/ha were IRAT 144, WAB 33-25, WABC 165, WAB 96-1-1, WAB 32-46, IDSA 46, WAB 33-17, WAB 181-18, CNA 4136 and WAB 99-17. Fifteen entries were selected for further tests for grain yield, phenotypic acceptability, seedling vigor and weed suppression.

The sustained yields in excess of 1.2 t/ha of a few promising improved and traditional varieties after 2 years of screening under low-input conditions is encouraging. Efforts will be intensified in 1993 to indentify the factors determining inter-varietal differences in grain yield, weed suppression and performance in poor soils.

Breeding drought-resistant upland rice varieties

M. Jones and K. Sahrawat

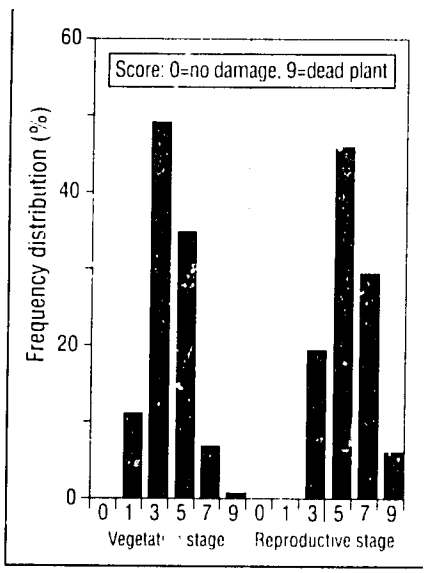
The lack of efficient screening methods has hampered progress in breeding for drought resistance. In December 1991 studies were initiated on varietal differences in resistance, recovery and yield under drought conditions in the upland and hydromorphic ecosytems. The method involved subjecting two sets of test and check varieties to 35 days of moisture stress during the vegetative stage (from 15 days after sowing) or the reproductive stage (from 45 days after sowing). This allowed for a comparison of drought resistance at the two stages and took into account drought adaption, escape, avoidance and recovery.

During 1992, 2500 entries (traditional and improved materials, and advanced breeding populations) were sown in 1 m rows, with resistant (OS 6) and susceptible (IR 20) check varieties repeated after every

20 entries. Four screenings were conducted (two field and two screenhouse), reducing the number of entries to 200 with the last evaluation. Figure 13 shows the distribution of drought resistance scores in the vegetative and reproductive stages. A positive correlation between resistance scores at these two stages ($r = 0.189$, $P < 0.001$) was obtained. There was a highly significant correlation between resistance scores, after 4 weeks of moisture stress at the reproductive stage, and seedling vigor ($r = 0.22$, $P < 0.001$), and a negative correlation ($r = 0.391$, $P < 0.001$) between resistance in the reproductive stage and leaf-rolling ability.

The results indicate that varieties with good resistance at the reproductive stage had good seedling vigor and high leaf rolling ability under stress conditions in the vegetative stage. Lines consistently showing good resistance at both stages were: WAB 340-B-B-B-1-H3, IR 47 310-94-4-3-1, FAROX 302, WAB 272-B-B-7-H2, WAB 92-B-B-B-B-1-H1, WAB 326-B-B-12-H2, WAB 326-B-B-8-H1, IR 47686-6-6-1-1, CT6 775-5-17-4-2-11P, IRAT II, WAB 56-125, WAB 326-B-B-2-H3, WAB 326-B-B-22-H1, WAB 56-50, IR 57893-60 and OS 6.

Figure 13 **Frequency distribution of scores for drought resistance in 200 selections after 4 weeks of exposure to drought during the vegetative and reproductive stages, 1992**



Screening upland rice varieties for drought resistance, M'bé, Côte d'Ivoire

In the 1992 wet season 112 entries, as well as 43 entries from the International Rice Drought Tolerance Nursery (IRDTN), were screened in an observational yield trial conducted at M'bé and Korhogo, Côte d'Ivoire. Drought was severe during both growth stages at Korhogo but mild in the vegetative stage at M'bé. The top five yielders (in excess of 3.0 and 1.0 t/ha at M'bé and Korhogo, respectively) were WAB 326-B-B-22-H1, WAB 56-50, WAB 326-B-B-12-H2, WAB 97 B B 21 H1 and WAB 226-B-9 H4. Of the 112 entries, 15 were selected for evaluation in Task Force regional trials scheduled for 1993. In the IRDTN, 15 promising lines with a score of 1, and 22 with a score of 3, will be advanced to observational yield trials in 1993.

Breeding for disease resistance

M. Jones, A. Sy and S. Mandé

Sources of durable resistance to blast, the most important rice disease in West Africa, have been found in some African landraces, including Moroberekan, OS 6, 63-104 and LAC 23. These varieties have been used extensively in hybridization and mutation research in the region. Other varieties showing moderate to high levels of vertical resistance to blast include ITA 118, ITA 257, ITA 25, WAB 99-1-1, IRAT 144 and WAB 56-57

In 1992 WARDA conducted research to upgrade levels of blast and drought resistance in improved lines, using the male-sterile (ms) facilitated recurrent selection scheme. IR 36 (ms) as the female parent was crossed with the following donor parents identified as being at least moderately resistant to drought and blast: WAB 100-B-B-21-H1, WAB 95-B-B-14-H2, WAB 95-B-B-27-H1, WAB 95-B-B-8-H1, WAB 95-B-B-29-H1, WAB 95-B-B-23-H1, WAB 100-B-B-22-H1, WAB 100-B-B-24-H1, Moroberekan, OS 6 and IDSA 78. F_1 progenies were interplanted with IR 36 (ms) to produce F_2 and back-cross seeds simultaneously. The interbreeding populations were grown at M'bé and several promising plant selections were made.

Observational yield trials of 112 entries selected in 1991 for field resistance to blast were grown at M'bé and Man, Côte d'Ivoire. The entries that yielded as well or better than the checks were CNA 6795, IRAT 209, WAB 56-57, WAB 33-17, IDSA 6, WABC 165, IR 47686-9-2-B, CT 6775-5-17-4-2-8-P, WAB 181-50 and ITA 118. At M'bé, where blast pressure was low in 1992, 11 entries yielded over 2.5 t/ha, compared to 2.2 t/ha for the check, Morobereken. The selected entries will be further evaluated in yield and stress trials in 1993.

Breeding for insect pest resistance
M. Jones and E. Heinrichs

About 20 of the more than 80 insect species harboured by rice in West Africa cause economic losses. Insect pests are generally more important in lowland rice; in upland rice, the prolonged drought pressure between harvesting one crop and planting the next reduces pest population build-up. However, stem borers, termites and grain-sucking bugs can be important in upland fields.

Breeding for varietal resistance to stem borers began at WARDA in 1986. Research focused on the African white borer (*Maliarpha separatella*), the African pink borer (*Sesamia zacconius*) and the stalk-eyed fly (*Diopsis longicornis*). Field screening of advanced lines and traditional varieties at M'bé, Man and Odienne in Côte d'Ivoire has identified several lines with resistance or moderate resistance to stem borers; some of these lines (including Moroberekan, Madeka D, OS 6, LAC 23, ITA 121 and TOX 936-153-5-3-3) were used as donors in 14 successful crosses made during 1992. Segregating populations will be evaluated in 1993.

Breeding for resistance to soil mineral stress
M. Jones, K. Sahrawat and S. Mandé

The acidic soils on which much of the upland rice in West Africa is grown are commonly found in the humid-forest zone, where rainfall can exceed 2000 mm per annum. P deficiency and Al and Mn toxicity are also common in the soils in the region's humid tropics. Breeding for greater tolerance to these stresses offers considerable promise for increasing production on marginal and less fertile lands, but the development of efficient laboratory screening techniques has been inhibited by difficulties in controlling the soil system, describing and reproducing the stresses, and isolating a particular stress response from that of other stresses. WARDA is therefore conducting analytical field screening at a 'hot spot' location in Man, Côte d'Ivoire.

In the 1992 wet season, 140 elite varieties and advanced lines were screened in soils with a pH of 4.5 and low P availability (2.9 ppm Bray-1 extractable P). An augmented design was used, with the check varieties LAC 23 (tolerant) and ITA 301 (susceptible) repeated after every 20 entries. Entries showing tolerance to acidity and associated soil problems were IAC 165, IDSA 75, WAB 96-24, WAB 96-5-1, WAB 181-44, WAB 30-24, WAB 96-1-1, CNA 762069, CT 6258-5-2-3-3P, IREM 192, WAB 32-80, WAB 32-59, WAB 33-17, IR 26957-86-2, KU 82, WAB 35-2-F1, WAB 56-50, ITA 335, CT 6240-12-2-2-3-6P and WAB 56-125. These and other lines will be further tested in observational yield and stress trials in 1993.

Hybridization and selection from segregating populations of upland rice
M. Jones

Work continued in 1992 on searching for new donors of *Oryza sativa* (*japonica* and *indica*) and *O. glaberrima* origin with desirable traits to diversify and broaden the genetic base of new breeding materials. The upland breeding program used a limited number of parents, emphasizing selection of parent combinations of the traits required to achieve desired objectives. To improve their resistance and yield potential, elite varieties and breeding lines were used extensively in crosses with new donors.

A crossing block of 58 entries was grown in the 1992 dry season under irrigation. Seventy successful crosses were made, aimed at incorporating genes for high yield (12), appropriate plant type to compete with or suppress weeds (20), blast resistance (8), drought tolerance (15), acidity tolerance (5) and good grain quality properties, including good aroma and taste and grain elongation ability (10). Of the 400 crosses made in 1986-90 to incorporate genes for high yield, earliness and short- to medium-stature into improved varieties, 70 F_1 populations were grown in 1992 for advancing to F_2 and possible use in top-, back- and double-crosses. Fifteen hybrid combinations were targeted to hydromorohic conditions; the others were for rainfed uplands, mainly to combine improved plant type and adaptability with good aroma and taste and resistance to blast, drought and acidicty. Currently, 70 F_2 populations are being evaluated and 3600 selections with a range of traits have been made. Selections will be evaluated in pedigree nurseries in 1993. Of the 1400 F_4-F_7 populations screened under high- and low-input levels of management in 1992, over 1200 individuals were selected; some of the selected lines combine a range of traits (*see* Table 18). A total of 240 fixed lines were bulk harvested for promotion to observational yield trials in 1993.

In research on the potential of *O. glaberrima*, five successful crosses (WAB 56-14/CG 20, CG 20/WAB 56-125, CG 20/WAB 56-104, CG 14/WAB 56-14 and CG 17/WAB 56-14) were obtained from *O. sativa* and *O. glaberrima* parents. The *O. glaberrima* varieties (CG 20, CG 14 and CG 17) possess useful traits for drought, blast and acidity tolerance, weed suppression, and good aroma and taste. The F_1 and F_2 populations had vigorous vegetative growth, with secondary branches on the panicles; ligules, however, were of the short *glaberrima* type. The high percentage sterility in F_1 and F_2 (> 90%) was improved slightly (by 20%) through

Table 18 **F_2 crosses yielding desirable lines under low- and high-input management in the upland pedigree nursery at M'bé, Côte d'Ivoire, 1992**

Cross	Parents	No. of plants selected	Desirable traits
High input:			
WAB 492	WAB 56-104/DR 2	400	Appropriate plant type, high yield, large panicle, good taste and aroma, resistance to diseases and lodging
WAB 49	WAB 56-125/Suakoko 8	100	Apropriate plant type, resistance to diseases and insect pests, tolerance to acidity and phosphorus deficiency
Low input:			
WAB 463	WAB 56-14/45 205-1	99	Rapid vegetative growth, appropriate plant type, high yield, good performance in low-nutrient soils, drought resistance
WAB 470	CG/DR 2	150	Rapid vegetative growth, drought resistance, intermediate stature, good performance in low-nutrient soils, good taste and aroma

back-crossing; anther culture is now being used to address this problem.

Crosses were made between upland (*japonica*) and lowland (*indica*) varieties to introgress desirable *indica* traits into upland types and vice versa. The lowland types generally have better resistance to lodging, high tillering ability and higher yield; the upland types have better resistance to blast, drought, acidity and rice yellow mottle virus. The *japonica/indica* crosses also showed good seed set and 30-60% sterility in the F_1 hybrids; again, anther culture is being applied to overcome this sterility problem.

Upland Rice Breeding Task Force regional trials

M. Jones

Environmental and socio-economic constraints to rice production in West Africa reduce average grain yields to less than 0.8 t/ha. The Upland Rice Breeding Task Force (URBTF) was established in 1991 to involve all rice scientists in WARDA and the region's NARS in a collaborative research effort to overcome these constraints, taking into account the varying strengths and weaknesses of the NARS and assigning research responsibilities accordingly.

In 1992, 54 URBTF trials were conducted in WARDA member countries. Over 2000 fixed and segregating populations were tested in observational nurseries (for yield and/or stress) and replicated yield trials (grouped by duration, stature and grain traits, with separate yield trials of materials selected for stress resistance). The composition of individual trials was based on requests from individual NARS for specific combinations of traits. In general, the observational nurseries were planted in single plots (4 rows, 5 m long), with local check varieties repeated after every 20 entries; in the replicated yield trials, the plots (10 rows, 5 m long) were replicated four times. Seeds of segregating populations were dibbled at 2-3 seeds/hill (25 x 25 cm spacing). Fertilizer application and other cultural practices reflected the conditions commonly found in each country.

In the short-, medium- and long-duration replicated yield trials (10, 7 and 2, respectively) conducted in 14 countries the best yielders (all yielding as much or more than the local checks) were WAB 32-80, WAB 33-25, WAB 56-104, WABC 165, WAB 65-50, IDSA 10, ITA 257 and WAB 99-1-1. The first four performed very well at humid-forest sites in Guinea, Guinea-Bissau and Sierra Leone; the last three performed well in savanna areas. At sites in nine countries, 342 entries were screened for resistance to blast and other diseases. In western Cameroon, northern Guinea and north-western Sierra Leone, blast and glume discoloration were severe. Mild blast pressure was recorded at sites in Benin, Burkina Faso, Guinea-Bissau, Nigeria and Senegal. The best entries with resistance to blast at more than one site were IDSA 62, NDR 97, WAB 181-36, WAB 181-11, WAB 181-49, CNA 6675, CNA 6719, IDSA 6, WAB 381-B-12-L1, WAB 381-B-17-L4, IRAT 144 and FARO 41. Over 300 entries were screened for drought resistance at 10 sites in Benin, Burkina Faso, Chad, Côte d'Ivoire, Guinea-Bissau, Nigeria, Senegal and The Gambia. Among the 48 varieties/lines which were as resistant or more resistant than the local checks, the best were WAB 99-1-1, CNA 6698, WAB 32-60, WAB 181-46, WAB 181-51, IRAT 144, WAB 326-B-B-9-L1 and WAB 326-B-B-4-13. In five acidity and low P tolerance trials at 'hot spot' sites in Côte d'Ivoire, Guinea-Bissau, Sierra Leone, The Gambia and Togo, 34 of the 284 varieties/lines screened were selected for further study. Among the entries which performed well across sites were WAB 32-80, WAB 32-46, WAB 96-18, WAB 99-24, IAC 164 and ITA 150.

NARS recommended over 154 varieties and 50 segregating lines for inclusion in regional yield and stress trials to be conducted by the URBTF in 1993.

Breeding for irrigated lowlands

B.N. Singh

In the 1992 regional irrigated lowland yield trial, work continued on selecting high yielding lines with semi-dwarf plant type, iron toxicity tolerance, and multiple resistance to leaf and panicle blast, rice yellow mottle virus and African rice gall midge. Twenty lines selected in 1991 were grown in an advanced trial at 11 sites in WARDA member countries. Blast was observed in Cameroon, gall midge and iron toxicity in Nigeria (Wuya), rice yellow mottle virus in Côte d'Ivoire (M'bé), and leaf scald and brown spot in Côte d'Ivoire (Bouaké) and Sierra Leone. The performance of the best entries at eight sites is summarized in Table 19.

In an on-station replicated yield trial at Ibadan, Nigeria, of the 358 lines tested for yield potential, six were significantly better than the best check (IR 36): TOX 3057-7-4-1-1, TOX 3118-56-1-2-5, TOX 3249-49-2-3-1, TOX 3109-73-4-1-3, TOX 3054-12-1-3-2-1 and TOX 3440-164-2-3-1. The trial

Table 19 Top-ranking entries in the regional irrigated lowland yield trial, 1992

Location	Entry (yield)
Niaouli, Benin	ITA 306 (5.4 t/ha), TOX 3081-36-2-3-1 (5.4 t/ha), TOX 3050-6-E2-3-4 (5.4 t/ha), ITA 230 (4.5 t/ha), ITA 312 (4.5 t/ha)
Lagdo, Cameroon	TOX 3050-6-E2-3-4 (7.0 t/ha), TOX 3081-36-2-3-1 (6.9 t/ha), TOX 3107-39-1-2-1-1 (6.9 t/ha), ITA 306 (6.7 t/ha)
Bouaké (IDESSA) Côte d'Ivoire	ITA 338 (7.0 t/ha), TOX 3050-6-E2-3-4 (6.2 t/ha), Bouaké ITA 230 (6.1 t/ha), TOX 3058-52-2-2-3 (6.0 t/ha), TOX 3092-35-2-3-3 (5.8 t/ha)
M'bé (WARDA) Côte d'Ivoire	ITA 338 (4.8 t/ha), ITA 334 (4.1 t/ha), TOX 3217-69-3-1 (3.9 t/ha), TOX 3052-46-3-3-1 (3.7 t/ha), Bouaké 189 (3.6 t/ha)[a]
Badeggi, Nigeria	TOX 3050-6-E2-3-4 (2.9 t/ha), ITA 410 (2.7 t/ha), TOX 3052-46-3-3-1 (2.6 t/ha), FARO 29 (2.6 t/ha)[a], TOX 3081-36-2-3-1 (2.6 t/ha)
Wuya, Nigeria (on-farm trial)	TOX 3107-39-1-2-1-1 (5.1 t/ha), TOX 3233-46-3-3-4-2-2 (5.2 t/ha), ITA 306 (5.1 t/ha), TOX 3081-36-2-3-1 (5.1 t/ha), ITA 230 (4.9 t/ha)
Rokupr, Sierra Leone	TOX 3255-82-1-3-2 (4.1 t/ha), TOX 3058-52-2-2-3-2 (3.9 t/ha), ITA 306 (3.8 t/ha), TOX 3109-73-4-5-1 (3.6 t/ha), ITA 410 (3.3 t/ha)
Bakendik, The Gambia	TOX 3233-46-3-3-4-2-2 (4.6 t/ha), ITA 324 (4.6 t/ha), TOX 3109-73-4-5-2 (4.5 t/ha), TOX 3217-69-3-1 (4.2 t/ha), IET 3137 (4.2 t/ha)[a]

Note: a Local check

was repeated at Wuya, where the check (ITA 306) gave the highest yield (5.0 t/ha). ITA 402, ITA 414, TOX 3107-39-1-2-1-1 and TOX 3402-6-3-2-2 also gave high yields and will be tested in the 1993 regional irrigated lowland yield trial. There was mild gall midge infestation (1-5%) at Wuya; three entries (TOX 3399-121-1-3-2, TOX 3058-41-1-1-2-4-2 and TOX 3231-31-6-2-6-1) were severely infested (14-20%) by bakanae.

In an observational yield trial, 130 entries selected from pedigree lines were evaluated for yield potential in an augumented design. The best yielders were TOX 3440-47-4-2-3-2 and RF 85C-C1-37-1-1-1-3-1-2; 48 entries showed good resistance to blast and the remainder showed moderate resistance. Gall midge attack was observed but 14 entries had no infestation; their resistance will be evaluated in a gall midge screening trial in 1993. Based on plant height, 20 and 33 entries were selected for rainfed and irrigated lowland trials, respectively, to be conducted in 1993.

Table 20 Top-ranking entries in the regional rainfed lowland yield trial, 1992

Location	Entry (yield)
Niaouli, Benin	TOX 3133-75-1-2 (6.1 t/ha), ITA 342 (5.9 t/ha), Cisadane (5.6 t/ha), TOX 3052-39-1-2-1 (5.6 t/ha), TOX 3154-17-1-3-2-2 (5.4 t/ha)
Banfora, Burkina Faso	TOX 3069-66-2-1-6 (6.7 t/ha), TOX 3118-2-E2-2-1-1 (6.6 t/ha), TOX 3133-74-1-2-2-2 (6.1 t/ha), TOX 3552-84-1-2-3 (6.1 t/ha), TOX 3052-56-3-1-3-2 (5.9 t/ha)
Bokle, Cameroon	IR 46 (6.9 t/ha), TOX 3100-32-2-1-3-5 (6.2 t/ha), TOX 3084-131-1-3-1-2 (5.6 t/ha), ITA 342 (5.4 t/ha), TOX 3133-74-1-2-2-2 (5.4 t/ha)
Bouaké (IDESSA), Côte d'Ivoire	TOX 3084-136-1-3-1-2 (9.0 t/ha), ITA 342 (8.1 t/ha), TOX 3052-41-E1-2-1-2 (8.0 t/ha), TOX 3118-2-E2-2-1-1 (6.9 t/ha), TOX 3100-32-2-1-3-5 (6.8 t/ha)
M'bé (WARDA), Côte d'Ivoire	IR 46 (4.8 t/ha), TOX 3052-39-1-2-1 (4.4 t/ha), Cisadane (4.2 t/ha), TOX 3052-56-3-1-3-2 (3.9 t/ha), TOX 3095-52-3-2-3 (3.9 t/ha)
Cantuboel, Guinea-Bissau	TOX 3100-44-1-2-3-3, TOX 3100-32-2-1-3-5, TOX 3226-7-1-3-2-1, TOX 3118-2-E2-2-1-1, Senquere[a]
Badeggi, Nigeria	TOX 3100-44-1-2-3-3 (4.8 t/ha), TOX 3084-136-1-3-1-2 (4.7 t/ha), TOX 3052-41-E1-2-1-2 (4.3 t/ha), TOX 3410-151-1-3-2 (4.1 t/ha), TOX 3069-66-2-1-6 (3.9 t/ha)
Wuya, Nigeria (on-farm trial)	TOX 3100-44-1-2-3-3, (4.8 t/ha), TOX 3084-136-1-3-1-2 (4.7 t/ha), TOX 3052-41-E1-2-1-2 (4.3 t/ha), TOX 3440-151-1-3-2 (4.2 t/ha), TOX 3069-66-2-1-6 (3.9 t/ha)
Rokupr (WARDA), Sierra Leone	TOX 3100-44-1-2-3-3 (3.8 t/ha), IR 46 (3.3 t/ha), Kuatic Kundir (3.2 t/ha)[a], TOX 3095-52-3-2-3 (3.2 t/ha), TOX 3133-74-1-2-2-2 (3.1 t/ha)
Djibelor, Senegal	TOX 3118-2-E2-2-1-1 (4.5 t/ha), TOX 3100-44-1-2-3-3 (3.3 t/ha), TOX 3100-32-2-1-3-5 (3.0 t/ha), TOX 3052-39-1-2-1 (2.8 t/ha), TOX 3052-56-3-1-3-2 (2.7 t/ha)

Note: a Local check

Breeding for rainfed lowlands in favorable areas
B.N. Singh

A regional rainfed lowland yield trial of 20 elite lines was conducted at 13 sites in West Africa in 1992. Severe African rice gall midge infestation was observed in Guinea-Bissau; mild infestation was observed in Nigeria (Wuya) and Senegal. Blast was recorded in Senegal and Cameroon, rice yellow mottle virus in Côte d'Ivoire (M'bé), and brown spot and leaf scald in Sierra Leone and Cote d'Ivoire (Bouaké). The best entries at 10 sites, together with some yield data, are listed in Table 20.

In an on-station trial at Ibadan, Nigeria, 406 entries were evaluated for yield potential. At Wuya, 28 entries were evaluated. The best entries at Wuya, with yields significantly higher than the check (IR 46), were TOX 3963-8-1-3 (4.2 t/ha), TOX 3162-11-1-2-1-1 (3.5 t/ha) and TOX 3399-108-3-2-2 (3.4 t/ha). In some entries, bakanae infestation was as high as 28%. Medium-duration lines (TOX 3399-157-1-3-2, TOX 3580-12-2-2-1-1, TOX 3580-41-2-2-2-2, TOX 3552-84-1-2-2, TOX 3552-80-3-3-3 and TOX 3580-41-3-1-3) were susceptible to bakanae.

An observational yield trial with 282 entries was planted at Ibadan in an augumented design, with five checks repeated after every 10 entries. Gall midge infestation was mild. Seventy-nine lines yielding more than 4 t/ha and showing blast resistance were selected. Based on plant height, entries were promoted to the irrigated or rainfed lowland replicated yield trial. In 1992, 115 new crosses were made using blast-resistant donors and elite rainfed lowland lines. About 3572 pedigree lines from F_3-F_8 generations were evaluated and individual plant selections were made. Uniform advanced lines were bulked for yield testing.

Breeding for rainfed lowlands in drought-prone areas
B.N. Singh

Three trials to select for drought tolerance in rainfed lowlands were conducted in 1992. The first, comprising upland and lowland rice varieties, was conducted at Moussourou, Benin. The ground water table was below 50 cm for the major part of the crop growth and thus most upland materials yielded better than lowland materials. However, four lowland varieties (TOX 3100-44-1-2-3-3, FARO 34, TOX 3217-69-3-1 and ITA 315) had low panicle sterility and their yields were comparable to the best upland lines.

An advanced yield trial of 28 entries in three replications was transplanted to a hydromorphic plot at Ibadan, Nigeria. The trial was transplanted late, due to the delayed onset of rain. The water table fluctuated from surface to 70 cm depth. Table 21 summarizes the performance of the best entries. Late maturing entries generally yielded better than early maturing entries. The correlation between grain yield and flowering was 0.42, and between grain yield and plant height 0.59. These are important selection criteria for breeding drought-tolerant rainfed lines under transplanted conditions in a sub-humid ecology with a bimodal rainfall pattern, such as that found at Ibadan.

In an observational yield trial, 100 entries were evaluated under transplanted

Table 21 Grain yield and other traits of entries tested in the rainfed lowland drought-tolerance advanced yield trial, Ibadan, Nigeria, 1992

Entry	Grain yield (t/ha)	50% flowering (days)	Plant height (cm)	Panicles/ hill	% bakanae infestation
TOX 3084-136-1-3-1-2	3.6	125	98	8	0.4
TOX 3154-17-1-3-2-2	3.5	122	99	7	0.0
TOX 3963-8-1-3	3.5	126	105	9	1.5
TOX 3552-80-3-2-3	3.3	123	93	8	11.5
ITA 328	3.2	129	94	9	0.4
TOX 3118-47-1-1-2-3-2	3.0	124	100	7	0.2
TOX 3580-45-2-2-3	3.0	128	91	8	1.4
TOX 3118-3-E1-1-4	2.9	129	90	7	0.0
TOX 3967-17-1-1	2.8	127	98	9	0.4
TOX 3580-12-2-2-1	2.8	126	94	9	7.6
IR 46 (check)	1.8	114	88	9	0.6
Mean	2.6	120	92.3	7.5	—
LSD (5%)	0.8	4.0	5.6	1.4	—
CV	18.1	2.0	3.7	11.5	—

conditions in a flat hydromorphic plot at Ibadan. The water table fluctuated from 50 to 90 cm depth for 3 weeks in September, 2 weeks after transplanting. The yields of the check varieties, ITA 235, OS 6 and IR 20, were 2.4 t/ha, 1.9 t/ha and 1.6 t/ha, respectively; 16 lowland lines yielded more than ITA 235. The highest yields were produced by TOX 3552-39-1-2 (4.5 t/ha), TOX 3580-47-1-1-2 (3.7 t/ha) and TOX 3580-11-1-3-2 (3.3 t/ha). Promising lines were tested for drought tolerance in the vegetative stage at Kano, northern Nigeria and at Ibadan in upland conditions. Total rainfall at Kano was 508 mm, with the rain stopping in mid-September. Drought scores (based on the IRRI standard evaluation system) were taken at Kano during the first week of October. IR 20 scored 7; 28 entries scored 3 and were comparable to OS 6, the upland tolerant check. Drought scores were taken at Ibadan 25 days into the rainless period. IR 20 scored 9 (permanent wilting); 11 lines scored 1, while 15 scored 3. During the 1992 wet season, 39 F_3 bulks and 1712 F_4 lines were screened for drought tolerance and individual plant selections were made; 149 new crosses were made involving upland drought-tolerant donors and elite lowland lines.

Breeding for medium-deep waterlogged conditions in the rainfed lowlands

B.N. Singh

A regional trial for medium-deep (20-50 cm) waterlogged conditions in rainfed lowlands, consisting of 20 elite lines selected from the 1991 yield trial, was grown at nine sites in West Africa. With the exception of the site at Ibadan, Nigeria, the water depth at all sites was less than 25 cm but moisture was adequate until maturity. Late maturing, non-lodging plant types with a height of about 140 cm are needed for these conditions. Several lines performed well across the region (*see* Table 22).

In the observational yield trial for waterlogged conditions, 212 entries were tested in an augmented design, with three checks after every 10 entries. The entries included 54 lines from WARDA's mangrove swamp research program at Rokpur, Sierra Leone. The water level was maintained at 20-30 cm for 45 days. Twenty-one lines had an acceptability score of 1; 56 lines scored 3. These lines will be evaluated in a replicated yield trial in 1993. Most mangrove lines were early maturing and tall, with a lodging plant type; some, however, were promising (including WAR 52-384-3-2, WAR 100-6-2-1 and WAR 102-1-3-1). During the 1992 wet season, 2940 pedigree lines were tested for tolerance to waterlogged conditions at Ibadan and individual selections were made.

Breeding lowland rice varieties for disease resistance

B.N. Singh

Research continued in 1992 on the development of improved lowland lines with resistance to leaf and panicle blast (the major disease risk in drought-prone rainfed lowland ecologies), rice yellow mottle virus and leaf scald.

A regional leaf and panicle blast screening nursery of 66 elite lowland lines, previously screened at Ibadan, Nigeria for

Table 22 Top-ranking entries in the regional yield trial for tolerance to medium-deep waterlogged conditions in rainfed lowlands, 1992

Location	Entry (yield)
Banfora, Burkina Faso	TOX 3440-164-3-3-2 (7.5 t/ha), TOX 3081-36-1-4-3 (7.0 t/ha), TOX 3055-10-1-1-3-3-2A (6.7 t/ha), TOX 3162-11-1-3-1-1-1 (6.5 t/ha), TOX 3809-53-3 (5.9 t/ha)
Nyankpala, Ghana	TOX 3052-41-E1-2-1-2 (8.3 t/ha), GR 21 (6.6 t/ha)[a], TOX 3440-164-3-3-2 (5.8 t/ha), TOX 3399-64-2-2-1 (5.6 t/ha), TOX 3716-5-3-1-2 (5.5 t/ha)
Badeggi, Nigeria	TOX 3118-47-1-1-2-3-2 (4.4 t/ha), TOX 3440-164-3-3-2 (3.0 t/ha), TOX 3399-64-2-2-1 (2.6 t/ha), TOX 3552-109-2-1-3-2 (2.2 t/ha), TOX 3162-11-1-3-1-1-1 (1.3 t/ha)
Birnin Kebbi, Nigeria	TOX 33-99-64-2-21 (5.0 t/ha), TOX 3399-84-2-1-3 (4.3 t/ha), TOX 3226-5-2-2-1 (4.0 t/ha), TOX 3118-47-1-1-2-3-2 (2.9 t/ha), TOX 3440-164-3-3-2 (2.5 t/ha)
Ibadan (IITA), Nigeria	TOX 3100-12-1-3-1-2 (1.7 t/ha), TOX 3716-5-3-1-2 (1.6 t/ha), TOX 3399-64-2-2 (1.5 t/ha), TOX 3399-84-2-1-3 (1.5 t/ha), TOX 3052-41-E1-2-1-2 (1.4 t/ha)
Rokupr (WARDA), Sierra Leone	TOX 3553-65-3-3-1 (4.8 t/ha), TOX 3100-12-1-3-1-2 (4.5 t/ha), TOX 3399-84-2-1-3 (4.2 t/ha), TOX 3081-36-1-4-3 (4.2 t/ha), TOX 3440-164-3-3-2 (4.1 t/ha)
Sutu Sinjang, The Gambia	TOX 3553-65-3-3-1 (9.5 t/ha), TOX 3399-84-2-1-3 (8.8 t/ha), TOX 3716-5-3-1-2 (8.1 t/ha), TOX 3399-64-2-2-1 (7.8 t/ha), TOX 3055-10-1-1-3-3-2 (7.8 t/ha)

Note: a Local check

resistance to field isolates of blast, was distributed to 16 sites in West Africa. Disease pressure was high at the Cameroon site and at two Nigerian sites (Ikenne and Onne) (*see* Table 23). During the year, 25-50 F_3 segregating bulks were distributed to nine collaborators for *in situ* selection of blast-resistant plants. Bulks showing promising performance included TOX 4148, TOX 4149, TOX 4188, TOX 4192 and TOX 4222 (at Mbo, Cameroon) and TOX 4063, TOX 4113, TOX 4115, TOX 4123 and TOX 4156 at Rokupr, Sierra Leone.

A total of 250 lines selected for blast resistance at Ibadan were grown at Ikenne, Onne and Ibadan. Disease pressure was high at Onne under natural infestation. For leaf blast, 14 lines showing stable resistance were selected and will be further tested in 1993. For panicle blast, 49 lines had no infection and 42 were resistant or moderately resistant. In an observational nursery, 456 lines from different yield trials were screened for blast resistance; 105 were resistant or moderately resistant and will be further tested at Onne, Ikenne and Ibadan in 1993. From the first cycle of the male-sterile facilitated recurrent selection, 38 uniform lines with blast resistance were tested for yield potential in an observational trial; individual fertile plants were selected for blast resistance from the male-sterile population. In the second cycle of the selection, which began in 1992, crosses were made with six new semi-dwarf blast-resistant donors.

Rice yellow mottle virus resistance from upland lines has been incorporated into lowland backgrounds, and 20 elite lines were tested in 1992 in a regional yield trial at six sites. The trial at M'bé had natural infestation but at Ibadan there was no infestation. The most promising varieties are listed in Table 24; the yields of some of these varieties are included in the table. In addition, 450 lines were screened in a pedigree nursery and 125 uniform lines were bulked for seed increase and yield evaluation in the following season. A new program on male-sterile facilitated recurrent selection for the virus was started in 1992. In a male-sterile population, 6182 plants were inoculated and only 20 tolerant plants were isolated for recurrent selection. Crosses were made with five improved lowland donors.

Using IRAT 144 (resistant) and ITA 335 (susceptible) as the checks, 200 lines were screened for leaf scald at Uyo and Ikenne, Nigeria. Disease pressure was high at both sites. Based on the IRRI standard evaluation system for rice, at Uyo three lines scored 3, and 32 scored 5; at Ikenne, one line scored 3, and 10 scored 5. The most tolerant lines were TOX 3050-6-E2-3-4, TOX 3109-73-4-5-4-1, ITA 256, ITA 326 and ITA 328. Leaf scald screening was also conducted at Man, Côte d'Ivoire. Four lines (TOX 3058-28-1-1, ITA 326, ITA 346 and ITA 133) scored 0-1. During 1992, 31 new crosses were made with moderately resistant donors. In 1993, the segregating generations will be grown at Nyankpala in Ghana and at Ikenne and Uyo to select for leaf scald tolerance.

Table 23 Entries selected for leaf and panicle blast resistance in a regional trial, 1992

Location	Entry (yield)
Mbo plains, Cameroon	TOX 3118-6-E2-3-2, TOX 3118-3-E1-1-4, TOX 3084-136-1-3-1-2, TOX 3388-157-5-1-3, TOX 3052-41-E1-2-1-2
Contuboel, Guinea-Bissau	TOX 3050-6-E2-3-4, TOX 3257-86-2-1-3-2, TOX 3220-1-2-4-2-1, TOX 3053-40-2-5, TOX 3233-31-6-2-3-2
Killisi, Guinea Conakry	TOX 3519-45-1-2-1, TOX 3084-136-1-3-1-2, TOX 3716-27-2-1-3, TOX 3544-8-1-1, TOX 3118-3-E1-1-4
Badeggi, Nigeria	TOX 3226-7-4-1-3-3, TOX 3249-49-5-1, TOX 3114-10-1-2-3-3, ITA 410, TOX 3073-17-1-3-3-3
Ibadan, Ikenne and Onne, Nigeria	TOX 3100-37-3-3-3-2, TOX 3107-56-1-3-2, TOX 3114-10-1-2-3-3, TOX 3118-3-E1-1-4, TOX 3118-2-E2-2-1-1

Table 24 Top-ranking entries in a regional yield trial for rice yellow mottle virus, 1992

Location	Entry (yield)
Karfiguela, Burkina Faso	ITA 306 (4.1 t/ha), TOX 3440-176-1-2-1 (3.5 t/ha), TOX 3233-31-6-2-1-2 (3.1 t/ha), TOX 3226-5-2-2-2 (3.1 t/ha), TOX 3058-41-1-1 (3.1 t/ha)
M'bé (WARDA), Côte d'Ivoire	TOX 3233-31-6-2-1-2 (6.9 t/ha), TOX 3058-28-1-1 (5.6 t/ha), TOX 3440-171-1-1-1-1 (5.4 t/ha), TOX 3049-13-1-2-3-1 (5.2 t/ha), TOX 3440-176-1-2-1 (4.9 t/ha)
Ibadan, Nigeria	TOX 3440-171-1-1-1-1 (4.5 t/ha), TOX 3058-28-1-1 (4.4 t/ha), TOX 3049-13-1-2-3-1 (4.4 t/ha), TOX 3217-69-3 (4.2 t/ha), TOX 3211-14-1-2-1-2 (4.1 t/ha)
Rokupr, Sierra Leone	TOX 3058-28-1, TOX 3055-10-1-1-1, TOX 3058-41-1-1, TOX 3211-14-1-2-1-2

Breeding lowland rice varieties for insect pest resistance

B.N. Singh

Good progress was made during 1992 in identifying lines showing resistance or tolerance to African rice gall midge (*Orseolia oryzivora*), stalk-eyed fly (*Diopsis* spp.), white stem borer (*Meliarpha separatella*) and white fly (*Aleurocybotus indicus*).

A regional trial for gall midge was conducted at seven West African sites. Infestation was severe at Contuboel, Guinea-Bissau, moderate at Karfiguela, Burkina Faso and at Ndiokpoto and Ibadan, Nigeria, and absent at Mbiabet, Nigeria and at M'bé, Cote d'Ivoire. Promising lines will be grown in on-farm trials in 1993. These lines, together with some of the yield figures, are listed in Table 25. During 1991, 18 lines with resistance to the Asian rice gall midge were screened for resistance to the African rice gall midge at Gadza, Nigeria. Tiller infestation was 2.0-27.1% at 55 days after planting. T 1477 scored 3 and ARC 6605, Phalguna, Heera, Velluthacheera and PTB 10 scored 5; ITA 212 had the highest infestation. In collaboration with NCRI, Nigeria, 200 *O. glaberrima* lines were screened under artificial pressure in a screenhouse for resistance to gall midge. Infestation reached 88.9%; 20 lines were highly resistant, showing no infestation.

Table 25 Top-ranking entries in a regional yield trial for African rice gall midge, 1992

Location	Entry (yield)
Karfiguela, Burkina Faso	Cisadane (4.7 t/ha), ITA 212 (4.5 t/ha), BW 348-1 (4.5 t/ha), TOX 3967-17-1-3 (4.2 t/ha), TOX 3073-17-1-3-3 (4.1 t/ha)
Bouaké (IDESSA) Côte d'Ivoire	TOX 3073-17-1-3-3-3 (8.2 t/ha), TOX 3093 35-2-3-3 (7.4 t/ha), Cisadane (7.1 t/ha), Bouaké 189 (7.0 t/ha), TOX 3876-56-1-4 (6.9 t/ha)
M'bé, Cote d'Ivoire	RP 1045-25-2-1 (4.6 t/ha), BW 348-1 (4.2 t/ha), TOX 3967-17-1-3, TOX 3876-58-1-2 (3.9 t/ha), Cisadane (3.8 t/ha)
Contuboel, Guinea-Bissau	RP 1045-25-2-1 (1.2 t/ha), Senquere[a] (1.2 t/ha), BW 348-1 (1.1 t/ha), ITA 306, Cisadane
Ibadan, Nigeria	TOX 3093-35-2-3-3 (4.9 t/ha), ITA 212 (4.6 t/ha), IR 46 (4.4 t/ha), TOX 3118-47-1-1 (4.3 t/ha), Cisadane (3.9 t/ha)
Mbiabet, Nigeria	Cisadane (1.0 t/ha), TOX 3118-47-1-1 (1.0 t/ha), TOX 3233-46-3-3-4-2-2 (1.0 t/ha), ITA 312 (1.0 t/ha), RP1045-25-2-1 (1.0 t/ha)
Ndiokpoto, Nigeria	TOX 3441-96-1-1-3 (1.0 t/ha), ITA 306 (1.0 t/ha), ITA 312 (1.0 t/ha), TOX 3073-17-1-3-3-3 (1.0 t/ha), TOX 3053-40-2-5 (1.0 t/ha)

Note: a Local check

For stalk-eyed fly resistance, 132 individual selections from various lines were screened in two replications under screenhouse conditions. Flies were collected regularly from the field and released in the screenhouse. Infestation varied from 2 to 62%. Based on the average tiller infestations from three scorings dates, nine lines showed good resistance (TOX 3337-30-1-2-1-2-3, TOX 3107-39-1-2-2-4, TOX 3211-51-1-3-1-2, TOX 3226-10-2-3-1-1, TOX 3264-78-3-1-1-3-2, TOX 3337-30-1-2-1-2, TOX 3399-131-1-1, TOX 3440-90-1-3-2 and TOX 3440-133-2-3-2-1) were selected for further study in 1993.

For stem borer resistance, 36 lines selected from the 1991 screening trials were evaluated in three replications under field infestation. Dissections were made at maturity and data on tiller infestation and larval and pupal populations were recorded. Most of the damage was caused by the white stem borer rather than the pink stem borer. White stem borer infestation varied from 67 to 99%, and larval and pupal populations from 36 to 86% in different lines.

White fly is an important rice pest in the Sahel. Early infestation damages the whole plant and can lead to wilting and plant death. Of the 415 lines screened in 1991, ITA 212 was found to be highly susceptible and 120 lines underwent further screening in the screenhouse in 1992. Tiller infestation varied from 3.8 to 93%. Based on tiller infestation, two lines were highly resistant (< 10% infestation) and 21 were moderately resistant (11-20%). Oviposition was monitored in all lines being screened; 42 moderate to highly susceptible lines were not preferred for egg laying, while ITA 212 was highly favored for egg laying. TOX 3559-6-2-1-1 was least infested with white fly.

Breeding lowland rice varieties for iron toxicity tolerance

B.N. Singh

From the 1991 evaluation for iron toxicity tolerance, 20 lines were selected for regional yield trials at 14 sites in West Africa. Leaf bronzing symptoms were severe at sites in Nigeria (Anfani and Edozhigi), Cote d'Ivoire (Korhogo), Guinea Conakry (Kilissi) and Sierra Leone (Rokupr). The trial at Itoikin, Nigeria was severely affected by African rice gall midge as well as iron toxicity. The best entries, with some yield data, are listed in Table 26; upland lines included in the trial performed very poorly, with low tillering and early maturity. A regional trial to evaluate 12 selected lines will be conducted in 1993.

Seed of 24 F_3 bulk populations involving donors for iron toxicity tolerance were distributed to three collaborators for *in situ* selection of tolerant plants. Promising bulks included TOX 4128, TOX 4140, TOX 4150, TOX 4160 and TOX 4305 (at Rokupr, Sierra Leone), TOX 4320, TOX 4118, TOX 4108, TOX 4107 and TOX 4248 (at Ikot Obong, Nigeria) and TOX 4131, TOX 4183, TOX 4172, TOX 4184 and TOX 4248 (at Edozhigi, Nigeria).

An observational yield trial of 135 lines was conducted at two sites in Nigeria. At Itoikin, the trial was severely affected by gall midge and iron toxicity. Severe

Table 26 Top-ranking entries in a regional yield trial for iron toxicity, 1992

Location	Entry (yield)
M'bé, Cote d'Ivoire[a]	TOX 3050-46-E3-3-3-3 (6.5 t/ha), ITA 408 (6.5 t/ha), TOX 3118-47-1-1 (6.4 t/ha), TOX 3100-32-2-1-3-5 (6.4 t/ha), TOX 3052-46-3-3-1 (6.0 t/ha)
Korhogo, Cote d'Ivoire	TOX 3107-39-1-2-1-3 (5.0 t/ha), TOX 3100-32-2-1-3-5 (5.0 t/ha), Suakoko 8 (4.9 t/ha), ITA 408 (4.4 t/ha), ITA 247 (4.4 t/ha)
Killisi, Guinea Conakry	TOX 4004-4-3-3-2 (4.7 t/ha), L 26-6-9-1-1 (4.2 t/ha), CK 73 (2.2 t/ha)[c], Suakoko 8 (2.0 t/ha), TOX 3098-4-5-1-1-1 (2.2 t/ha)
Badeggi (NCRI), Nigeria	ITA 408, ITA 326, TOX 3050-46-E3-3-3-3, TOX 3052-46-3-3-1, TOX 4179-16-1-1, Suakoko 8
Edozhigi, Nigeria	TOX 3118-4-1-1 (3.7 t/ha), TOX 3107-39-1-2-1-3 (3.5 t/ha), Suakoko 8 (3.4 t/ha), ITA 247 (3.4 t/ha), TOX 3081-36-2-3-1 (3.3 t/ha)
Rokupr, Sierra Leone	ITA 326, TOX 85C-C1-10-WAS 8, FARO 8, Suakoko 8, 35214
Bakendik, The Gambia[b]	ROK 5 (5.7 t/ha)[c], ITA 326 (3.3 t/ha), ITA 234 (3.3 t/ha), ITA 257 (2.4 t/ha), ITA 408 (2.1 t/ha)

Note: a This site had little or no toxicity problem
b This site had soil salinity and iron toxicity problems
c Local check

bronzing occurred in 41 lines; 11 lines were promising, with less gall midge infestation. At Edozhigi, 28 lines scoring 1, and 41 scoring 3 were selected. Major selection criteria were non-bronzing of leaves and non-stunting. In 1993, 50 selected lines will be tested in a regional observational yield trial. Of the 3163 F_3 pedigree lines from 27 crosses grown at Itoikin, only 120 could be selected because of combined gall midge and iron toxicity damage. A total of 42 new crosses were made in 1992, involving iron toxicity-tolerant donors.

Farmer irrigating rice fields in the Sahel

Sahel Irrigated Rice Program

Substantial government investment in large-scale rice irrigation schemes in the West African Sahel in the 1980s, relying mainly on inappropriate technologies imported from Asia, led to a fall in yield levels, an erosion of the germplasm base and the need for intensified research to meet the rapidly increasing demand for rice in the Sahel. While the extreme climatic conditions of this zone provide very high yield potential, they also expose the crop to severe environmental stresses.

To address these problems, WARDA has implemented an agro-ecological characterization project, using a systems approach (combining crop physiology, agro-meteorology, agronomic experimentation, varietal characterization at key sites, and economic analysis) and has initiated a germplasm selection program to improve and diversify the region's germplasm base. Progress made in 1992 included the characterization of varietal responses to combined salinity and climatic stresses, the development of crop duration and spikelet sterility models, a preliminary economic regional study of irrigated rice production in the Sahel and the identification of varieties with superior yield and yield stabilty.

PROJECT 1: CHARACTERIZATION OF IRRIGATED RICE ECOSYSTEMS

The irrigated rice ecosystem of the Sahel is characterized by considerable disparity between production potential, in terms of yield and irrigable area, and the poor results from earlier investments in rice production. The objectives of the characterization project are to quantify this yield gap, identify its causes by sub-region and type of production system, and set priorities for future research aimed at improving productivity and sustainability.

The research approach in 1992 was based on simulation-aided, multidisciplinary analysis. Emphasis was given to model development and adaptation, involving surveys and experimental field research to calibrate and validate model components. To ensure regional coverage, a research network with NARS was initiated, based on five key sites (N'Diaye delta and Made valley in Senegal, Niono in Mali, Valley du Ku and Valley du Sourou in Burkina Faso, and Seberi in Niger). A related study examined the economic competitiveness of current rice production systems and the role of government policies in rice production. Systems research in 1992 generated model components that will be of practical use in rice breeding and the improvement of cropping systems. In 1993, work will continue on applied aspects of system characterization, while maintaining the focus on yield gap analysis.

Yield constraints in a Sahelian irrigation scheme

M. Dingkuhn

Rice grain yields in the Senegal delta vary between 0 and 9 t/ha (average 4.5 t/ha). Studies in 1991 and 1992 indicated that the major causes of low yields were weed infestation, salinity, nitrogen deficiency, temperature stress and bird damage. However, research was needed to determine the individual contribution of these constraints to low yield.

In 1992, a study was conducted on 29 farmers' fields in a 156-ha irrigation scheme at Cuvette de N'Gelle in the Senegal delta; the soil is a heavy, moderately saline Vertisol (mean pH of 5.7 in the top 30 cm). The study included surveys of cultural pratices and yields, and *in situ* measurements of floodwater electric conductivity (EC), leaf area index (LAI) of weed types and rice at heading, and losses to grain-eating birds. The varieties used were Jaya, on 27 farms, and I Kong Pao (IKP), on two farms. Pre-germinated seed was broadcast (mean 140 kg/ha) in the late hot-dry season on pre-ploughed and irrigated soils. N and P was applied at varying rates (mean 138 kg N/ha) and split ratios; most farmers used a combination of manual weed control and herbicides.

Yields ranged from 0.7 to 7.2 t/ha (average 4.7 t/ha) and the mean LAI at heading was 3.7, with 4-36% contributed by weeds. Multiple linear regression analysis ($r = 0.76$; $P < 0.001$) identified four causes of yield loss (in decreasing level of significance): partial LAI of sedges, water salinity as EC, N fertilizer split by rate, and LAI of non-sedge weeds. Yield was not significantly affected by seed rate, water

shortage or bird damage. The association between yield and N split indicates the potential of improved fertilizer management. Poor field preparation and water management probably contributed to the weed infestation. The effect of even moderate salinity (mean EC 1.25 mS/cm) confirms on-station findings that a hot-dry climate reduces the salt tolerance of rice; IKP, a moderately salt-tolerant cultivar, yielded above average despite high EC. These results highlight the need for an integrated research approach to soil, water, weed and crop management in efforts to develop high yielding, moderately salt-tolerant rice varieties.

Temperature-induced spikelet sterility

M. Dingkuhn

Spikelet sterility is one of the main causes of rice yield variability (0-9 t/ha) in the Sahel. Although potential yields for irrigated rice in this zone are high due to abundant solar radiation and low night temperatures, the plant's ability to convert growth into grain is often reduced by spikelet sterility caused by cold or heat stress, compounded by atmospheric drought and wind. In continuous-cropping 'rice garden' trials at N'Diaye and Fanaye, Senegal, spikelet sterility followed a distinct season pattern; in most cases it was caused by cold nights (*see* Figure 14). For rice sown late in the wet season (September or October), spikelet sterility reached 100%. The recommended planting date is July but many farmers in the Senegal delta plant late due to lack of water, machinery or credit, or the long duration of the previous, hot-dry season crop.

Comparisons between temperature and sterility patterns across 13 planting dates showed that booting was the most cold-sensitive growth stage and flowering the most heat-sensitive. A minimum temperature of 18°C at booting was associated with 50% sterility, and 16°C with 100% sterility. Sterility was also associated with a minimum temperature of 22°C at flowering, probably due to the heat-sensitivty of pollination which occurs in the morning. Maximum temperature was not correlated with sterility.

Models were developed to simulate spikelet sterility. Best predictions were obtained on the basis of the mean minimum temperature for 10-day periods centered around the booting or the flowering stages. The models are sensitive to stresses which are specific to arid, irrigated environments, provide a better understanding of rice yield gaps and offer powerful risk-assessment and decision-support tools for the improvement of rice-based cropping systems in the Sahel.

Figure 14 **Thermal effects on spikelet sterility for six varieties in rice garden experiments at two sites in Senegal, 1991-92**

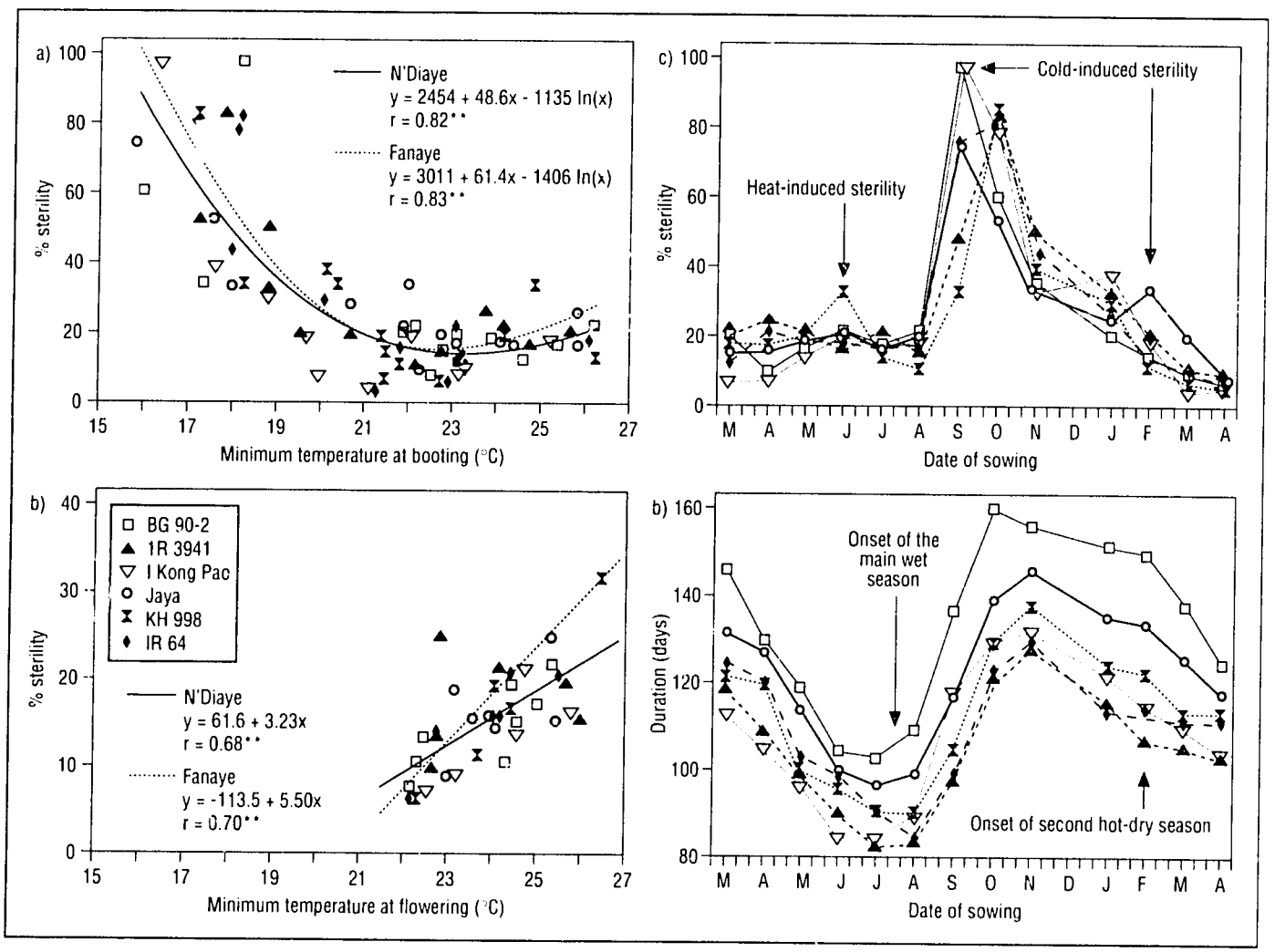


Figure 15 **Simulated total crop duration (a) and spikelet sterility (b) for direct-seeded Jaya rice at Niono, Mali (means based on 1972-81 climatic data) and N'Diaye, Senegal (1984-91)**

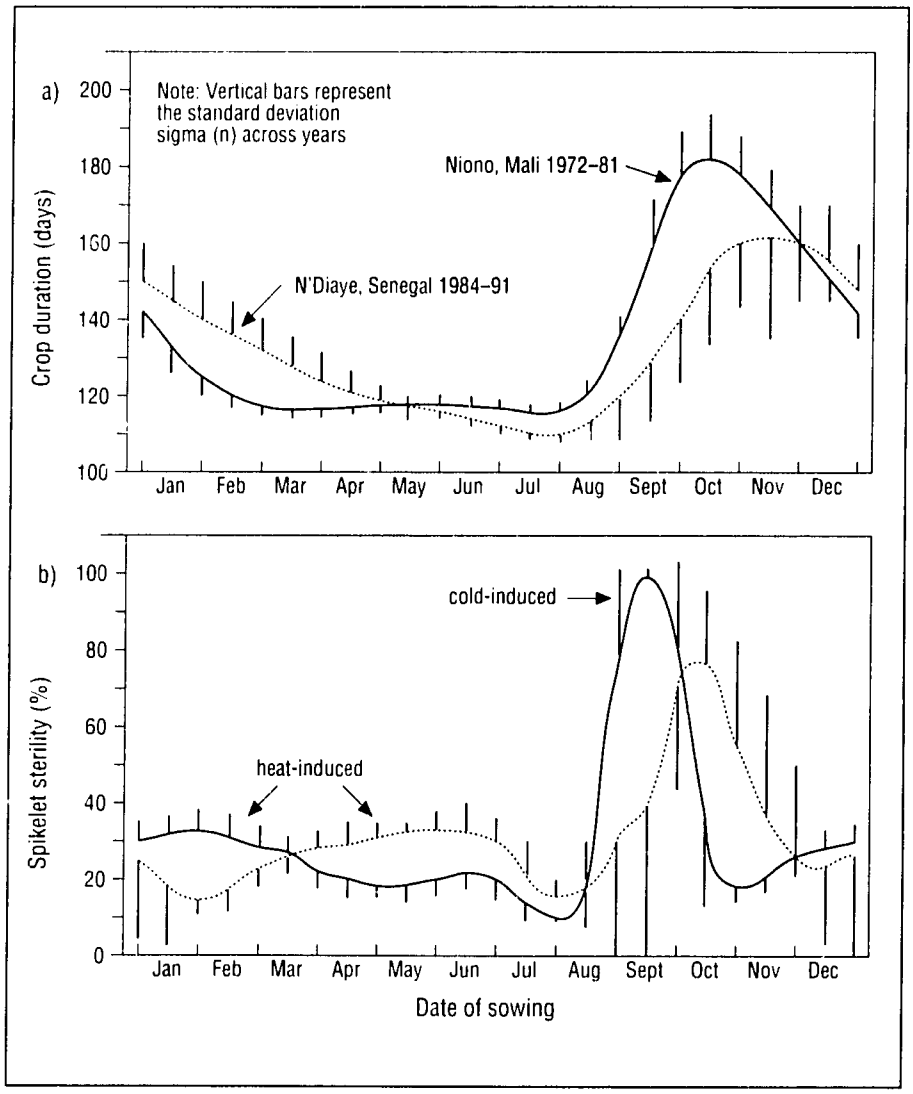


Figure 15 provides an example of variability in crop duration and temperature-induced sterility for 24 planting dates at two sites. These sites have a similar climate; the difference between them in the crop duration and sterility patterns has direct implications for cropping calendars and varietal recommendations.

Using computer modelling to predict crop duration

M. Dingkuhn

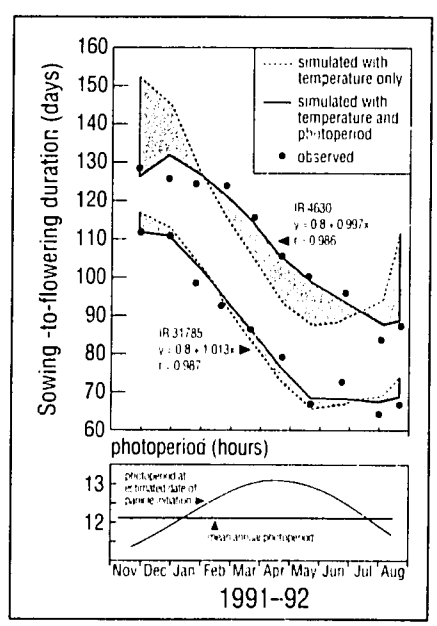
Rice-rice double cropping and diversified rice-based cropping systems in the Sahel are constrained by variable crop duration (from 30 to 70 days, depending on the season, site, cultivar and planting method). Studies were therefore initiated to develop a model to predict crop duration.

Six rice cultivars were grown in a replicated, monthly-planting scheme at N'Diaye and Fanaye, Senegal, in 1991 and 1992; in a separate trial conducted at N'Diaye, 44 varieties were planted monthly. Plant ontogeny and growth were analyzed against weather and micro-meteorological data. Sowing-to-flowering duration depended mainly on water temperatures, while flowering-to-maturity duration depended mainly on air temperatures. Transplanting increased duration by 10 days. All varieties behaved as short-day plants but, in most cases, photoperiod sensitivity was minor.

A computer program was developed to determine the varietal constants governing crop duration and a model was generated to predict duration for any site with a known climate. It was assumed that there were lower and upper temperature limits to development rate (T_{base} and T_{opt}, respectively) and a cumulative number of heat units (T_{sum}) required for flowering. T_{sum} differs for transplanted and direct-seeded rice because of transplanting shock; it is also modified by a function of a photoperiod constant (CPP) and the day-length at the end of the basic vegetative phase (BVP). In the model-generation mode, the inputs required were sowing and flowering dates, site latitude and daily minimum and maximum temperatures. Water temperatures were estimated and summations performed for the physiologically effective daily temperatures. The varietal constants (T_{base}, T_{sum}, BSV and CPP) were determined through regression analyses. In the simulation mode, the program can be used to validate the varietal constants to predict crop duration.

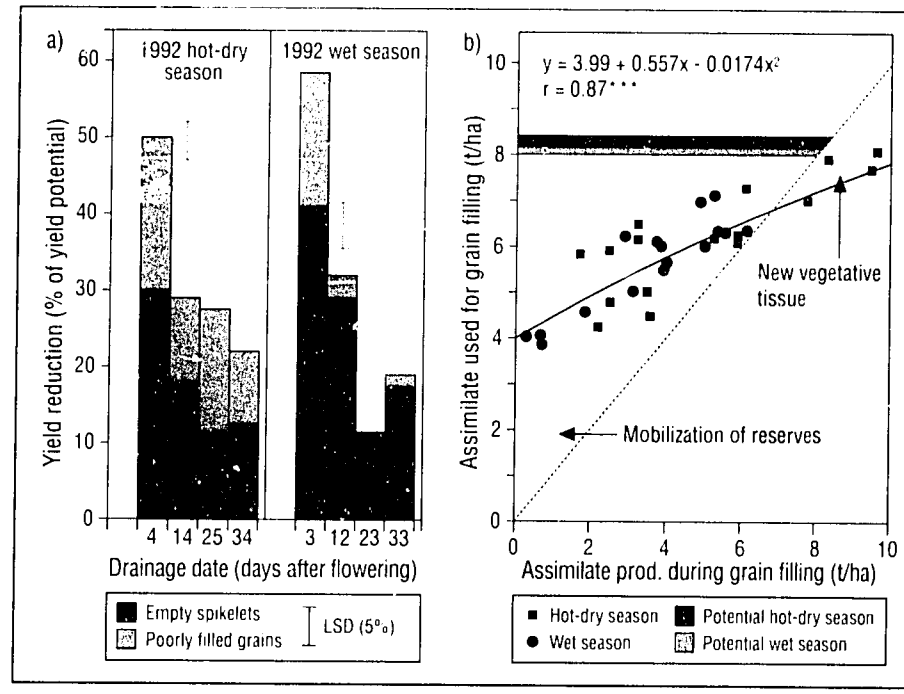
Figure 16 shows the observed and simulated durations for IR 31785-58-2-2 and IR 4630-22-2. The regression for simulated against observed crop duration

Figure 16 **Effect of sowing date on sowing-to-flowering duration for two rice cultivars, simulated on the basis of temperature only and of temperature and photoperiod**



for the same year and site was similar to that for most of the 50 materials tested. Model validation using data from different seasons rarely gave simulation errors exceeding 5 days. After further validation in various environments, the model will be made available to NARS and other reseach institutions working on irrigated rice.

Figure 17 **Yield reduction for I Kong Pao rice drained at different dates after flowering (a), and relationship between assimilate used for grain filling and net assimilate production during grain filling, as observed across treatments (b)**



Developing decision-support tools for rice-rice double cropping systems

M. Dingkuhn

Rice-rice double cropping is common in the Sahelian zones of Niger and Burkina Faso but difficult to maintain elsewhere in the Sahel because of inadequate knowledge of how to combine crop, soil and water management, choice of variety and cropping calendar to obtain economically sustainable yields. In 1991, a research project involving WARDA, ISRA, CIRAD, ORSTOM and the Catholic University of Leuven, Belgium was initiated to characterize the physical constraints to rice-rice double cropping systems and to develop simulation-based decision-support tools for these systems.

Research in 1992 focused on water management at post-flowering stage, a system component that determines time of harvesting and soil preparation for the following season. In the Senegal river delta these operations are usually mechanized and thus require dry soil; they must be performed early because of the short time between the hot-dry and wet seasons, and the early drainage requirement.

A model is being developed on the basis of plant growth characteristics. Ontogenetic models simulate flowering date, spikelet fertility and crop canopy properties. Soil drying and crop maturation are interactively simulated as they depend on drainage, climate, crop and soil properties. The model quantifies the risk implications of time constraints, soil trafficability and yield losses associated with any combination of variety, site and calendar of operations. For model calibration, two field experiments were conducted in the hot-dry and wet seasons at N'diaye, Senegal to determine drainage effects on maturity, yield, grain quality and soil drying. Drainage 3-4 days after flowering reduced grain yield by 50-60% relative to potential yield (*see* Figure 17a); yield reduction was due mainly to unfilled or partly filled spikelets. Early drainage advanced maturity by 2 weeks. Sequential sampling gave an insight into assimilate (dry matter) partitioning. With late drainage, assimilate was abundant and yield was limited by the storage capacity of grains; early drainage inhibited assimilation and mobilized stem reserves up to 4 t/ha (*see* Figure 17b). The kinetics of root-zone soil moisture were closely linked to the green leaf area and affected the rate of leaf death.

The calibrated model will be validated in 1993. In collaboration with scientists at CIRAD and ORSTOM, it will be linked to the production-scheme level decision-support system OTELO (INRA) which is being adapted to irrigated rice production systems.

Economics of Sahelian irrigated rice

T. Randolph

To improve irrigated rice production in the Sahel, a better understanding is needed of existing production systems. Information is being collected in five Sahelian countries (Burkina Faso, Mali, Mauritania, Niger and Senegal) to characterize these systems and the policy environment in which they operate. A Policy Analysis Matrix framework is being used to assess their relative competitiveness.

Most of the growth in rice production in the Sahel between 1979-81 and 1989-91 occurred in irrigated systems (*see* Table 27 *overleaf*). Irrigated production tripled during this period, mainly because of an expansion of the area under cultivation, and productivity increased by an average of 44%, with the result that irrigated sysems now provide 60% of the total rice production in the five countries studied. Production increases have been particularly spectacular in Senegal and Mauritania, where structural adjustment programs in the late 1980s reduced the influence of parastatals in irrigated rice production and encouraged private investment through land tenure reforms and credit instruments. Growth is unlikely to be sustained, however, because of contracting credit availability and declining producer profitability as subsidies are removed and prices are adjusted to liberalized markets.

In 1993, research will continue on quantifying the relative competiveness of Sahelian irrigated rice production systems and identifying the implications of the research results for biological, agronomic and soil research.

Table 27 **Annual rice paddy production in the Sahel, 1979-81 and 1989-91**

Catchment (country)	Period	All systems ('000 t)	Irrigated production systems: Production ('000 t)	Area ('000 ha)	Yield (t/ha)	Share of total production (%)
Senegal river valley	1979-81	107	44	13	3.4	42
	1989-91	255	195	44	4.4	76
Mauritania	1979-81	11	11	3	3.5	100
	1989-91	51	51	15	3.4	100
Senegal	1979-81	96	33	10	3.3	34
	1989-91	204	144	29	5.0	71
Niger river basin	1979-81	201	97	44	2.2	48
	1989-91	425	208	60	3.5	49
Mali	1979-81	169	80	40	2.0	47
	1989-91	355	148	48	3.1	42
Niger	1979-81	32	17	4	3.9	53
	1989-91	70	60	12	4.9	85
Volta basin	1989-91	41	26	7	3.6	63
Burkina Faso	1979-81	44	16	4	4.0	36

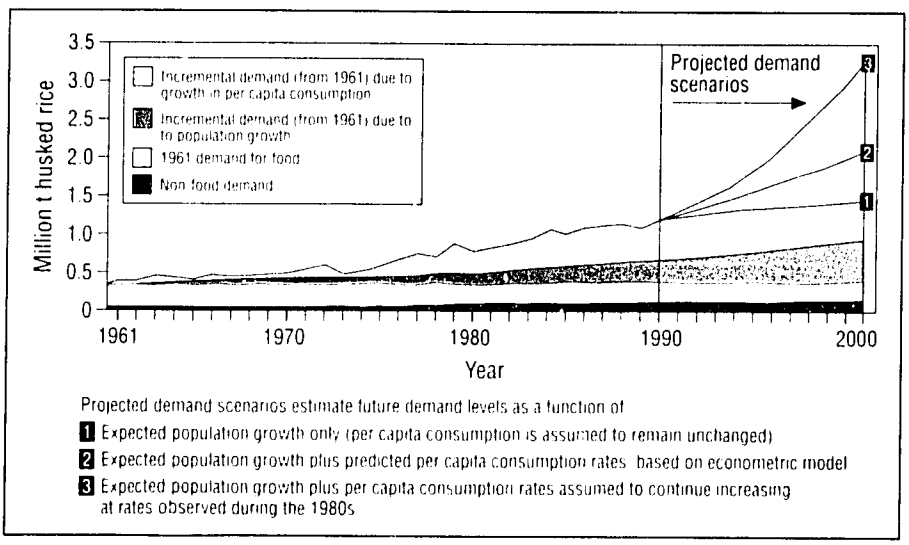
Rice consumption in the Sahel

T. Randolph

During the 1970s and 1980s rice consumption in the Sahel increased rapidly, leading to a rise in rice imports. In response to what they perceived as a threat to self-reliance, governments in the region promoted rice cultivation through substantial investments in irrigation. To acquire a better understanding of past and current trends in rice consumption and to predict demand growth to the year 2000, all available data for five Sahelian countries (Burkina Faso, Mali, Mauritania, Niger and Senegal) were reviewed.

As shown in Figure 18, rice consumption almost quadrupled between 1961 and 1989, with population growth accounting for about 40% of this increase. In the same period, annual consumption per capita rose from 17 to 31 kg, accounting for the remaining 60%. Regression analysis showed that structural factors, particularly urbanization, rather than changing prices or income levels underlie the increased importance of rice in the region's food consumption patterns. Although rice is generally more expensive than traditional grains, it requires no further processing and cooks fast, saving preparation costs and time; the time saving is particularly important for urban women whose labor time typically has a higher opportunity cost than for rural women.

Figure 18 **Demand for rice in five Sahelian countries, 1961-89, and demand projections to the year 2000**



The projected rise in regional consumption to over 2 000 000 t annually (scenario 2 in the figure) is based on an average population growth rate of 3.0% per year and the increasing per capita consumption rates predicted by an econometric model developed by the Sahel Program. Projections based on other assumptions (scenarios 1 and 3) indicate other possible trends. Increased rice consumption will enhance dependency on rice imports and generate greater demand for improved productivity in the irrigated systems, which are the main source of rice in the Sahel.

PROJECT 2: GERMPLASM IMPROVEMENT

Irrigated rice technology was introduced into the Sahel as a package which included Asian rice varieties, river regulation and diversion for irrigation, and partial mechanization. Traditional cultivars are therefore unknown in the region. Despite the relatively good performance of existing varieties, farmers' yields are still well below potential levels; in addition, the narrow genetic base of current cultivars constitutes a threat to yield sustainability. Germplasm is now needed which has high yield potential, resistance to the biotic and abiotic stresses prevalent in the Sahel, crop duration that suits local conditions and grain quality which matches consumer preferences.

As a continuation of 1991 activities, three types of nurseries were grown in 1992, based on the two main cropping seasons of the Sahel (the hot-dry season from February to June, and the wet season from July to November). Varietal selection and characterization is based on materials obtained from research institutions and INGER. Upon completion of on-going physiological and genetic studies on the component traits needed for better-adapted varieties, a long-term breeding strategy will be implemented in 1994.

Observational yield nurseries for the wet season

K. Miézan

Asia remains the main source of germplasm for irrigated rice, through IRRI and

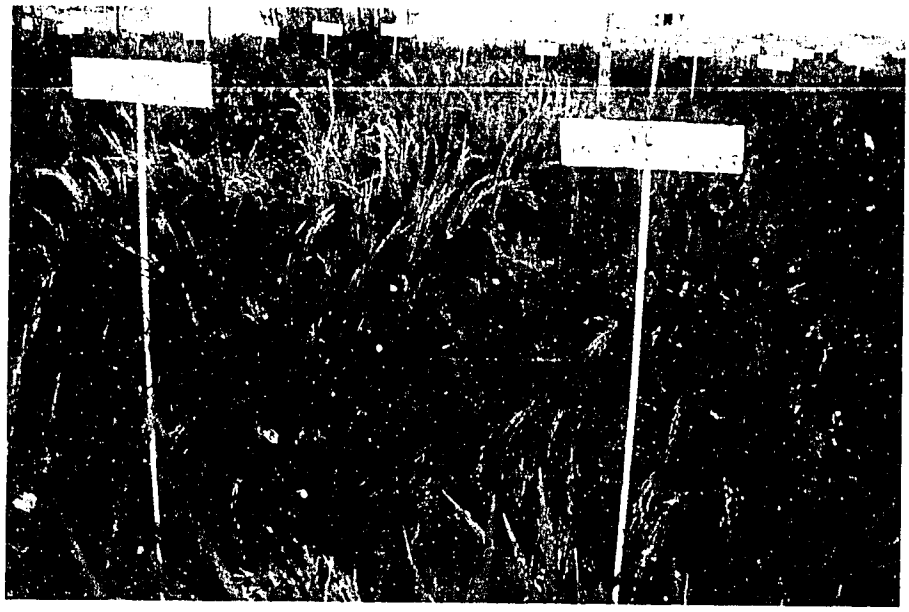
INGER. Over 300 entries are introduced annually in the Sahel Program and tested for adaptability in terms of duration, plant type and stress tolerance; well-adapted entries are then selected for observational nurseries.

In the 1992 wet season two trials were planted in unreplicated plots at N'Diaye and Fanaye in Senegal. One consisted of 84 short-duration (100-120 days) entries, with I Kong Pao (IKP) as the check; the other consisted of 60 medium-duration (125-140 days) entries, with Jaya as the check. Among the short-duration entries, only six (IR 41985-111-3-2-2, IR 50358-102-2-3-3, IR 50363-61-1-2-2, IR 57301-50-3-2, IR 57301-115-3-1 and IR 59625-68-1-3) outyielded the check, with yields ranging from 4.0 to 5.7 t/ha at Fanaye and 5.5 to 7.6 t/ha at N'Diaye. The poorer performance at Fanaye was because of a water supply failure during the cropping season. Among the medium-duration entries, over 50% outyielded the check by at least 0.5 t/ha, with yields of 3.5-5.7 t/ha at Fanaye and 5.5-6.7 t/ha at N'Diaye. Ten of these entries outyielded the check at both locations (IR 48566-147-3-13, IR 72, IR 56450-28-2-2, IR 58100-11-2-2, IR 58100-28-2-3, IR 58100-48-2-2, IR 52373-76-3-1-2, IR 53356-64-1-3-2, IR 53964-39-1-2-3-3 and IR 55604-37-2-2-2).

The comparative yield levels of short- and medium-duration entries indicate the possibility of developing several alternative rice-based cropping systems for Sahelian rice farmers. Forty-five short-duration and 35 medium-duration entries were selected for evaluation in preliminary yield nurseries in 1993.

Preliminary yield nurseries for the wet season
K. Miézan

The 1991 observational yield trials showed a number of varieties to be well adapted in terms of duration, plant type and reaction to major diseases, insects and other stresses. These varieties were advanced to preliminary yield nurseries for evaluation in 1992. Three trials were conducted, one short-duration set (23 entries) with I Kong Pao (IKP) as the check, and two medium-duration sets (20 and 23 entries) with Jaya as the check. All the trials were conducted at N'Diaye and Fanaye in Senegal, in a randomized complete block design with four replications.



Two of WARDA's best-performing short-duration selections for the Sahel, IR 13420 and 32 XUAN-5C, in a salinity trial at N'Diaye, Senegal, 1992

Among the short-duration entries at N'Daiye, the average yield of IR 31851-96-2-3-1, C 1322-28, IR 32307-107-3-2-2, IET 9702 and B 522-PN-LMS-1-KP-1 was 7.4 t/ha compared with 5.4 t/ha for IKP. At Fanaye, where there were mid-season irrigation problems, there was no significant difference between the entries and the check (overall average yield 3.2 t/ha). Panicle sterility at Fanaye was high (14-34%) compared with N'Diaye (8-19%). Among the medium-duration entries, several showed good potential in terms of plant type and yield : IR 8192-166-2-2-3, ECIA 156-84-1 and ITA 252 (7.0 t/ha); IR 13540-56-3-2-1 (7.1 t/ha); TOX 894-28-201-1-5 (7.2 t/ha); IR 24632-34-2 (7.3 t/ha); IR 28118-138-2-3, IR 28128-45-3-3-2, IR 2042-178-1 and UPR 254-85-1-TCA3 (7.4 t/ha); B 4140C-PM-186-KP2 (7.6 t/ha); IR 31851-96-2-3-1-2-1 (7.8 t/ha); and B 5322-BPN-19-MS-27-KPN (8.0 t/ha). The average yield for Jaya was 6.2 t/ha.

It is worth noting that the short-duration entries IR 32307, IET 9702 and IR 31851-96-2-3-2-1 and the medium-duration entries IR 28128-45-3-3-2, IR 28118-138-2-3 and UPR 254-85-1-TCA3 were among the highest yielding varieties in the 1991 preliminary trials at N'Diaye and Fanaye.

Each preliminary yield nursery will be tested for at least 3 years before selections are made for advanced yield nurseries. The trials will therefore be repeated in 1993.

Advanced yield trials for the wet season
K. Miézan

Short- and medium-duration varieties selected from preliminary and observational trials have to perform at least as well in advanced yield trials as I Kong Pao (IKP) and Jaya, respectively, and have better grain quality. In 1992, eight short-duration and seven medium-duration lines were evaluated at Fanaye and N'Diaye, Senegal, with IKP and Jaya as the checks, respectively; a randomized complete block design was used.

Among the short-duration materials, IR 13240-108-2-2-3 confirmed its high yield potential, particularly at N'Diaye (9.1 t/ha). High yields were also obtained at N'Diaye for TNAU 7893, TOS 103 and ITA 230 (8.1 t/ha), compared with IKP (7.0 t/ha). Yields were generally low at Fanaye (3.8-5.5 t/ha) due to a water supply failure near booting stage, which induced high spikelet sterility (43%). The lower yields of IR 31785-58-1-2-3-3 at N'Diaye resulted from susceptiblily to soil salinity, and at

Fanaye from high spikelet sterility (43%). IR 50 continued to perform well; its duration was 10 days shorter than IKP but its yield15% higher. Yields from the medium-duration materials were generally low at N'Diaye (due to salinity in a newly acquired plot) and Fanaye (water supply problems). However, BG 293-2, ITA 306 and BG 400-1, which had performed well in 1991, remained the best three entries (average yield 5.5 t/ha in 1991 and 7.3 t/ha in 1992).

This trial will be conducted for at least 1 more year and grain quality analysis will be performed prior to final selections for multilocational trials.

Advanced yield trials for the hot dry season

K. Miézan

While some progress has been made in identifying varieties that perform consistently well in the wet season, progress has been far slower for the hot-dry season. To offset high production costs, there is now increasing demand from farmers for such varieties. These varieties should have relatively short duration (maximum 130 days, despite low night temperatures) and high yield potential. In 1992, eight varieties selected from preliminary yield nurseries were planted at N'Diaye and Fanaye, Senegal, in a randomized complete block design, with four replications; the short-duration cultivar I Kong Pao (IKP) was used as the check.

Five varieties at N'Diaye and seven at Fanaye yielded as well or better than IKP. Among these, the most promising were IR 29725-40-3-2-3, IR 22107-14-2-1, IR 50 and IR 31785-58-1-2-3-3. The latter two had shorter duration than IKP; it is worth noting that they were also among the most promising varieties for the wet season, although IR 318785-58-1-2-3-3 has shown sensitivity to salinity.

In most Sahelian environments, medium-duration varieties selected for the wet season are not suitable for the hot-dry season because of their long-cycle and high cumulative water consumption. The 1992 results show, however, that in some cases short-duration varieties selected for the hot-dry season perform well in the wet season. The trial will be repeated for at least 3 years.

Mangrove Swamp Rice Network

WARDA's mangrove swamp rice research program made a significant contribution to the development of improved varieties for smallholder farmers in mangrove swamp environments. To consolidate these gains and enhance the capacity of the region's NARS to meet the need for a sustainable increase in mangrove swamp rice production, a network funded by USAID was established in 1990.

Network activities include environmental characterization to facilitate more effective targeting of improved rice technologies, and the development of well-adapted high yielding cultivars from segregating progenies. Seeds of promising varieties and breeder seeds are purified and multiplied by WARDA for distribution to NARS, extension agencies, NGOs and farmers, and varietal trials are conducted by the six countries in the network. The following summaries highlight the progress made by the network in 1992.

Farmers' assessment of improved varieties

M. Agyen-Sampong and R. Guei

In the mid-1980s WARDA developed a number of superior varieties adapted to different mangrove ecosystems but the rate of adoption of these materials has been slow, mainly because of weak technology transfer capacities of national programs. To accelerate adoption, the network initiated regional on-farm trials in 1991.

In 1992, farmer-managed on-farm trials were conducted in five network countries by national programs and rural development agencies to assess the adaptability, yield potential and consumer acceptability of 28 varieties bred or selected by WARDA, as well as 10 local varieties. The number of sites involved was 34, a 42% increase over 1991. At all sites the WARDA materials outyielded the best local varieties (*see* Table 28). As in previous years, WAR 1, WAR 77-3-2-2 and ROHYB 6 performed well in most countries under saline and acid sulfate soil conditions. ROHYB 6 and WAR 73-1-M1-4 were preferred by farmers for their high yielding ability and good plant type. ROK 5, WAR 1, WAR 77-3-2-2, BG 400-1 and RD 15 were widely accepted by farmers in Guinea-Bissau. The excellent performance of most varieties tested led to many farmers who had not been involved in the trials asking to participate in future trials.

Breeding rice varieties for mangrove swamp environments

R. Guei and M. Agyen-Sampong

During the 1980s WARDA made nearly 150 single crosses using over 200 parents

Table 28 Average yield gain (%) of the best-performing WARDA mangrove swamp rice varieties over check varieties in on-farm trials, 1992

Entry	Guinea	Guinea-Bissau	Nigeria	Sierra Leone	The Gambia
ROK 5	—	28	4	33	41
Kumba Ndingo	—	—	—	—	36
WAR 1	—	—	31	23	48
WAR 77-3-2-2	—	53	33	24	58
DJ 684D	—	—	—	—	43
ROHYB 6	26	53	12	13	—
WAR 73-1-M1-4	37	—	—	—	—
WAR 100-6-2-1	27	—	—	—	—
Balanta	31	—	—	—	—
RD 15	—	31	—	—	—
ROHYB 4	—	54	—	—	—
BG 400-1	—	20	—	—	—
BG 380-2	—	56	—	—	—
WAR 100-2-15-1	—	—	—	—	—
B 41-40-CPN	—	—	—	—	—
Kuatik Kundur	—	—	17	16	—
CP 4	—	—	—	24	—
ROK 10	—	—	—	—	—
ROK 23	—	—	—	22	—

selected for their stress tolerance and good agronomic traits. The selections were made using pedigree and modified bulk methods, and advanced to F_4-F_7 generations. Within the framework of the network, WARDA continued this selection to develop high yielding, stress-tolerant and stable varieties for *in situ* evaluation by the national programs. Selection criteria included: plant stature; tillering capacity; leaf erectness; disease, crab and lodging resistance; panicle size; and reaction to iron toxicity, acidity and salinity. The work was conducted in three salt-free zones representing short-, medium- and long-season environments.

Of the 450 lines selected, 350 were nominated in 1991 for inclusion in the African Mangrove Swamp Rice Observational Nursery (AMSRON). The remaining 100 lines were used in regional observational trials; of these, WAR 133-9-B-B-1, WAR 90-1-6-2-B-B, WAR 120-1-5-7-2-B-B-B and WAR 118-1-12-1-4-B-B-B were identified as salt tolerant. In 1992, seven short-duration, 42 medium-duration and five long-duration lines were selected. Five varieties from the short-duration WAR 115 series were found to be disease free and high yielding, with good late senescence traits; seven varieties from the medium-duration WAR 90 series showed high tillering capacity, large panicle size and erect flag leaves. These selections will be multiplied and made available to national programs through the 1994 AMSRON.

Table 29 **Number of improved mangrove swamp rice entries selected by national programs in observational trials, 1991-92**

Growth duration	Guinea	Guinea-Bissau	Nigeria	Sierra Leone	The Gambia
Short	—	—	20	15	12
Medium	7	12	11	12	11
Long	—	—	23	30	—

Table 30 **Best-performing mangrove swamp rice entries in advanced yield trials conducted in four network countries, 1992**

Growth duration (country)	Entry (yield)
Short:	
Senegal	WAR 115-1-2-10 (2.2 t/ha), IR 21855-53-2 (2.1 t/ha), WAR 81-2-1-3-2 (2.1 t/ha)
Sierra Leone	IR 10781-143-2 (3.1 t/ha), WAR 115-1-2-11 (2.9 t/ha), IR 25912-63-2 (3.0 t/ha)
The Gambia	IR 25912-63-2-2 (1.8 t/ha), BR 50-120-2 (1.7 t/ha), BG 400-1 (1.6 t/ha)
Medium:	
Guinea	WAR 39-17-2-2 (2.6 t/ha), WAR 100-6-2-1 (2.3 t/ha), WAR 42-132 (2.3 t/ha)
Guinea-Bissau	BW 248-1 (4.2 t/ha), WAR 115-1-1-8-1 (4.1 t/ha), WAR 115-1-2-5-2 (3.7 t/ha)
Sierra Leone	WAR 77-3-2-2 (3.0 t/ha), ROHYB 4 (2.9 t/ha), WAR 52-38A-3-2 (2.9 t/ha)
The Gambia	ROHYB 4 (2.1 t/ha), ROHYB 1 (1.3 t/ha), IR 31836-42-1-3 (1.1 t/ha)
Long:	
Sierra Leone	WAR 74-1-M6-7 (2.6 t/ha), WAR 74-15-1-3 (2.7 t/ha), WAR 73-1-M1-4 (2.7 t/ha)

Regional observational trials

R. Guei and M. Agyen-Sampong

Biotic and abiotic stresses vary in nature and intensity across the mangrove swamps of West Africa. There is therefore a need for improved stress-tolerant varieties to suit the range of mangrove ecosystems in the region. As most NARS working in this environment lack the capacity to develop new varieties, observational nurseries of promising materials bred or selected by WARDA are composed for the NARS for further *in situ* evaluation of stress tolerance and agronomic traits.

In 1991-92 over 200 varieties/lines were evaluated in each of the six network countries. Data were collected on: phenotypic acceptability; plant height; responses to salinity, acidity and iron toxicity; resistance to crab damage; and lodging, disease and insect reactions. Each NARS selected 20-25% of the varieties/lines, based on their performance in 1991 and 1992 (*see* Table 29). Among the varieties selected for outstanding performance in Guinea-Bissau and Sierra Leone were Pa Kolma, WAR 165-3, IR 3187-11-2-2-1-2, Tamba Wousson, Diaman and WAR 89-8-A5-11. For superior salt tolerance, UPR 79-115 and BR 50-120-2 were selected in The Gambia; WAR 90-1-6-2, WAR 120-1-5-7-2, WAR 118-1-12-1-4 and Pa Kolma were selected in Guinea-Bissau; and WAR 100-4-4-2, WAR 133-10 and WAR 133-9-b-b-1 were selected in Guinea. In Sierra Leone, WAR 89-11-5 and WAR 115-1-2-2-1-3 were among the varieties selected for acidity tolerance. Selected varieties will be further evaluated in advanced yield trials.

Regional advanced multilocational yield trials

M. Agyen-Sampong and R. Guei

Advanced yield trials were initiated in 1991 in collaboration with NARS to assess the adaptability, yield potential and yield stability of improved mangrove swamp rice varieties. In 1992, sets of short-, medium- and long-duration varieties were distributed for testing according to the requirements of individual NARS. The results in 1992 confirmed the findings in 1991 that a new generation of improved varieties was now available for distribution to farmers in the various mangrove ecosystems of the region. The yield performance of the top three varieties in each participating country is given in Table 30; with high yield potential and tolerance to acid sulfate conditions, these varieties showed excellent adaptation to the mangrove swamp environments. To confirm this adaptability, they will be intensively and extensively tested in farmer-managed on-farm trials in 1993.

TRAINING AND COMMUNICATIONS

OVERVIEW

Anthony Youdeowei

Following the preparatory work undertaken in 1991 on developing group training course curricula and organizing itinerant training courses, the focus in 1992 was on implementing these activities. The implementation of the group training program was based on: consolidating itinerant group training in partnership with national programs of WARDA member states; greater involvement of rice scientists in WARDA's research Task Forces and Working Groups in designing and implementing training courses in order to ensure that the orientation of these courses addressed the needs of NARS; and establishing a framework for developing and producing training manuals from course notes prepared by resource persons.

Significant progress was made in individual research-related training during the year. The program involved research scholars, post-doctoral scientists and visiting NARS scientists, as well as research assistants and technicians on short-term non-degree-related training. Individual research training is coordinated by the Research Division.

A WARDA/NARS training seminar was organized to coincide with the biannual meeting of the Training Working Group. Seminar participants reviewed the concept and implementation of WARDA's training program and explored ways of strengthening WARDA/NARS collaboration in organizing and managing individual and group technical training for rice science.

The installation of desk-top publishing facilities in mid-1992, accompanied by staff training in the use of these facilities, greatly improved WARDA's in-house capacity to originate and produce publications.

The Library and Documentation Center is now established as the major source of literature for rice and rice-based farming systems research in sub-Saharan Africa. During 1992, there was significant expansion in the Center's document delivery and literature search services provided for national programs. The agricultural databases on CD-ROM were updated and there was a considerable increase in the number of requests for information received from rice scientists and other agricultural researchers in the West African region. Training in information retrieval from agricultural databases was also provided for several NARS scientists.

During the year, particular emphasis was placed on consolidating collaboration in training and communications activities between WARDA and NARS in member states, both with regional organizations and with other international agricultural research centers operating in West Africa. These collaborative efforts enabled WARDA to increase its operating critical mass by fully utilizing the expertise and resources which are available within the region.

WARDA's training and communications activities continued to be strongly supported by the UNDP (project RAF/89/055). Funds were also received from CTA, a Lomé Convention institution based in The Netherlands, and from the IDRC, based in Canada.

SUMMARIES OF TRAINING ACTIVITIES

Group technical training

Six group training courses were organized in 1992, five of them with UNDP support and the sixth with funds from other sources. Table 31 gives the themes, location, language of instruction and numbers of trainees for these courses, while Table 32 presents the country distribution of training participants.

Table 31 WARDA group training courses, 1992

Title	Location	Language	Number of trainees M	F
Computer applications and statistical analysis in agricultural research	ICRISAT, Niamey, Niger	English	13	3
Water and irrigation management for rice production	EIER/IIMI, Ouagadougou, Burkina Faso	French	21	0
Training of agricultural trainers	IITA, Cotonou, Benin	English/French	15	4
Crop protection in rice	WARDA, Bouaké, Côte d'Ivoire	English/French	18	1
Upland rice production	WARDA, Bouaké, Côte d'Ivoire	English/French	15	1
Scientific writing for agricultural research scientists	INSET, Yamoussoukro, Côte d'Ivoire	English/French	26	4

Computer Applications and Statistical Analysis in Agricultural Research

This 4-week course was organized in January in collaboration with the ICRISAT Sahelian Center. Emphasis was placed on practical hands-on exercises in the analysis and interpretation of rice research data. Participants were introduced to the use of computers and statistical software packages for managing research data and to word processing packages for writing research reports.

The participants in the course were drawn from seven WARDA member states (Cameroon, Côte d'Ivoire, Ghana, Guinea, Nigeria, Sierra Leone and The Gambia) and included three women. The ICRISAT Sahelian Center and Ahmadu Bello University in Nigeria provided the resource persons.

Water and Irrigation Management for Rice Production

This course was held in March at the EIER in Ouagoudougou, Burkina Faso. Organized in collaboration with the West African station of IIMI, the 4-week course was attended by 21 participants. The participants were drawn from 12 WARDA member states (Benin, Burkina Faso, Cameroon, Chad, Côte d'Ivoire, Guinea, Guinea-Bissau, Mali, Mauritania, Senegal and Togo).

A special feature of the course was a 10-day field practical on techniques for managing rural irrigation schemes for rice production. The resource persons for this course came from international agricultural research centers and West African NARS.

WARDA and ICRISAT scientists participating as resource persons in the training course on computer applications

Training of Agricultural Trainers

In collaboration with the NARS in Benin and the IITA Biological Control Center for Africa in Cotonou, Benin, WARDA organized a bilingual Training of Agricultural Trainers (TOT) course in June; simultaneous translation was used. Among the 19 participants were four women. The participants were drawn from eight WARDA member states (Benin, Chad, Côte d'Ivoire, Guinea, Guinea-Bissau, Mali, Niger and Togo).

The resource persons included two former WARDA trainees, Wilhelmina Colley and Mohammed Jammeh, who had attended the English-language TOT course held in Liberia in 1990.

Table 32 Country distribution of participants in WARDA group training courses, 1992

Country	CA[a]	WI	TOT	CP	UP	SW	Total
Benin	—	1	5	1	1	2	10
Burkina Faso	—	2	2	—	1	2	7
Cameroon	1	2	—	1	1	5	10
Chad	—	2	1	—	—	2	5
Congo Brazzaville[b]	—	—	—	—	—	1	1
Côte d'Ivoire	1	2	2	6	5	4	20
Ghana	2	—	—	1	1	1	5
Guinea	1	2	2	1	1	1	8
Guinea-Bissau	—	2	2	1	—	1	6
Liberia	—	—	—	—	—	—	—
Mali	—	2	—	1	—	3	6
Mauritania	—	1	—	—	—	—	1
Niger	—	2	2	—	—	1	5
Nigeria	5	—	—	3	4	3	15
Senegal	—	1	—	—	—	—	1
Sierra Leone	4	—	—	1	—	2	7
The Gambia	2	—	—	1	1	1	5
Togo	—	2	3	2	2	1	10
Total number of participants	16	21	19	19	17	30	122

Note: a CA = Computer applications and statistical analysis in agricultural research; WI = Water and irrigation management for rice production; TOT = Training of agricultural trainers; CP = Crop protection in rice; UP = Upland rice production; SW = Scientific writing for agricultural research scientists

b Not a WARDA member state

Crop Protection in Rice

Using simultaneous translation, this bilingual course was conducted at WARDA's temporary training center in Bouaké in July. The course focused on modern principles of integrated management of rice pests.

The 19 participants included one woman. The participants were drawn from 10 WARDA member states (Benin, Burkina Faso, Cameroon, Côte d'Ivoire, Ghana, Guinea, Guinea-Bissau, Niger, Nigeria and Sierra Leone). The resource persons were drawn from WARDA and the national programs of Côte d'Ivoire and Nigeria.

Upland Rice Production

Held in September at WARDA's temporary training center, this bilingual course was attended by 16 participants, including one woman, drawn from eight WARDA member states (Benin, Burkina Faso, Côte d'Ivoire, Ghana, Guinea, Nigeria, The Gambia and Togo). The course was aimed specifically at young research scientists, personnel in rice development projects, and agricultural extension agents with responsibility for rice production.

Scientific Writing for Agricultural Research Scientists

Following the successful organization of the first group training course on this theme in 1991, a second course was organized in 1992 in collaboration with CTA, SAFGRAD and the AASE. Funding was provided by CTA, the Swedish-based IFS and two French-based organizations, CIRAD and ACCT. There were 30 participants, including four women, from West and Central Africa. The participants were divided into English and French language groups and the course was conducted simultaneously in both languages. Course content focused on the principles of good scientific communication and on improving participants' skills in the writing, publication and oral presentation of their research results. The resource persons were drawn from WARDA, CIRAD, CODESRIA, IBPGR and the Ethiopian Institute of Agricultural Research.

Trainee follow-up

Trainee follow-up is an essential part of WARDA's group training activities. The strategy adopted for trainee follow-up includes involving former WARDA trainees in itinerant courses as training coordinators or associate trainers; this gives them the opportunity to organize and manage group training courses and thus strengthens the training capabilities of

Upland Rice Production course, involving scientists from WARDA member states as resource persons

NARS. During the TOT course in Benin, for example, three former WARDA trainees were invited to participate, two as trainers and one as the training co-ordinator; in the Upland Rice Production course held in Côte d'Ivoire, a former WARDA trainee served as an associate training co-ordinator.

Staff from WARDA's Training and Communications Division visit former trainees at training locations in the national programs in order to assess the impact of WARDA training on their job performance. All former trainees visited in 1992 in Benin, Burkina Faso, Côte d'Ivoire and Niger confirmed that the knowledge and skills acquired from WARDA's training courses have had a significant influence on their professional competence.

Work has begun on compiling data for a *Directory of WARDA Group Training Participants, 1972-92*. This publication should serve as a useful reference source as well as a means of establishing and reinforcing links between former WARDA trainees.

One of the research scholars who benefited from WARDA's research-related training program in 1992

Individual research-related training

WARDA offers various training opportunities for young West African scientists, as well as for scientists from outside the region, to develop additional specialized skills through working with senior WARDA scientists.

Research scholars

With support from the AfDB and USAID, WARDA provides technical and financial assistance to students conducting field research related to their MSc or PhD courses. WARDA scientists work closely with the students' university advisers in designing the field research and direct all aspects this research. Six West African research scholars benefited from this program in 1992:

- Mabeye Sylla (Senegal) is working for his PhD in soil science at the Agricultural University of Wageningen in The Netherlands under the direction of Dr N. van Breemen. His research focuses on the characterization of mangrove swamp rice ecosystems in Guinea-Bissau, Senegal, Sierra Leone and The Gambia. His field work is being directed by Dr M. Agyen-Sampong, an entomologist and the coordinator of the Mangrove Swamp Rice Network, and Dr K. Sahrawat, soil scientist in WARDA's Continuum Program.

- Andre Ouattara (Côte d'Ivoire) is preparing for his Doctorat de troisieme cycle at CIRES, University of Abidjan under the direction of Dr K. Yao. His research involves the *ex ante* analysis of new rice production technologies in the Guinea savanna zone of Côte d'Ivoire. Dr A. Adesina, economist in WARDA's Continuum Program, is directing the field work.

- Alhassan Tswako Maji (Nigeria) worked for his MSc degree in crop breeding in the Department of Agronomy, University of Ibadan under the direction of Professor M.E. Aken'Ova. He evaluated a wide range of African *Oryza glaberrima* varieties for drought tolerance and other agronomic traits. The work was conducted at the IITA station in Ibadan under the direction of Dr B.N. Singh, WARDA's lowland rice breeder.

- Souleymane Nacro (Burkino Faso) is working for a doctorate in agronomy at the University of Rennes I, France under the direction of Professor J.P. Nenon. The subject of his work is the ecology and biology of the African rice gall midge, an insect which has recently become a major pest of rice in Burkina Faso and Nigeria. The work is being conducted mainly in Burkina Faso, with scientific direction from Dr E. Heinrichs, entomologist in WARDA's Continuum Program.

- Victorin Houndekon (Benin) is studying for a Doctorat de troisieme cycle in economics at CIRES University of Abidjan; his thesis adviser is Dr J. Pegatienan-Hiey. The research is being conducted in northern Benin to quantify the costs of production in the major rice production systems in that region. The field work is being supervised by Dr A. Adesina.

- Kouakou Kra Djato (Côte d'Ivoire) is working towards his Doctorat de troisieme cycle at CIRES, University of Abidjan under the direction of Dr J. Pegatienan-Hiey. He is conducting a comparative analysis of irrigated production units in central and northern Côte d'Ivoire to determine the effect of size on technical and economic efficiency. Dr A. Adesina is supervising the field work.

- Fabunmi Simeon Oladele (Nigeria) worked for his MSc degree in the Department of Agronomy, University of Ibadan under the general direction of Professor M.E. Aken'Ova. His field work was carried out at IITA under the supervision of WARDA's lowland rice breeder, Dr B.N. Singh. The focus of the research was a comparative analysis of vegetative and reproductive traits for selected upland and lowland rice varieties.

Post-doctoral scientists

Two-year assignments in WARDA's research programs are offered to scientists who have recently been awarded a PhD, giving them the opportunity to gain additional practical experience in various areas of rice science. Although preference is given to young West African scientists, researchers from outside the region are also considered. Two post-doctoral scientists participated in this program in 1992:

- Dr Robert Guei (Côte d'Ivoire) completed his PhD in plant breeding in 1991 at Kansas State University, USA. Since then he has worked in WARDA's Mangrove Swamp Rice Network, making selections from segregating populations resulting from WARDA crosses; planning and directing regional network trials of advanced rice varieties; developing training materials; and participating in individual and group training courses.

- Dr Thomas Randolph (USA) received his PhD in agricultural economics from Cornell University, USA in 1992 and won a Rockefeller Foundation post-doctoral fellowship to WARDA's Sahel Program as the team economist. His research is on the competitiveness of irrigated rice production in the Sahel. Using secondary information, he is analyzing rice production and marketing costs in Burkina Faso, Mauritania, Mali, Niger and Senegal to identify systems of irrigation and technologies, and the policy contexts within which rice production enjoys a comparative advantage.

Research assistants

WARDA offers practical training to young African researchers through fixed-term contracts, during which they work with WARDA scientists as research assistants. In 1992 two Sierra Leonian research assistants completed their final year of a 2-year attachment with WARDA's Mangrove Swamp Rice Network. Charles Dixon played a major role in characterizing mangrove soils and Robert Chakandra worked under the direction of Dr R. Guei in the selection of materials from segregating populations.

Visiting scientists

National rice scientists who require individual training in particular areas of rice science or who wish to conduct short-term research with WARDA scientists are offered the opportunity to work at WARDA as visiting scientists. Two national scientists took advantage of these opportunities in 1992:

- Dr Peter Okocha (Nigeria) was attached to WARDA's lowland breeding unit for 1 year, at the request of the NCRI. Working under the direction of Dr B.N. Singh, he made a number of crosses for his program at NCRI, and learned the screening methods for blast, stalk-eyed fly and rice yellow mottle virus.

- Dr Charles Mulbah (Liberia), a research fellow in the soils department of Louisiana State University, USA, worked with WARDA's soil chemist, Dr K. Sahrawat, for 4 weeks in July and August 1992, characterizing iron toxic lowland soils, with the emphasis on redox potential.

WARDA also provides support for national scientists to work with scientists in national programs where there is expertise in particular areas. Three national scientists benefited from this support in 1992:

- Malcom Jusu (Sierra Leone), a rice breeder at the National Rice Research Station in Rokupr, visited ISRA's Djibelor station for 2 weeks in October 1992. The objective of his visit was to familiarize himself with breeding activities in savanna mangrove ecologies and to observe on-farm research methods.

- Ousmane Kona Balde (Guinea), an entomologist in the Guinean rice research program, worked with Senegalese scientists at ISRA's Djibelor station for 2 weeks in November 1992. He studied methods of identifying and classifying rice insect pests, techniques for preserving insect samples, and insect control practices.

- Aliou Sow (Guinea), an agronomist in the Guinean rice research program, visited ISRA and WARDA's Sahel Program to learn methods of conducting on-farm trials and socio-economic surveys.

Other short-term practical training

WARDA provides short-term non-degree-related training opportunities for West African students and technicians who wish to obtain practical experience working within one of WARDA's research areas. The beneficiaries of this program in 1992 were:

- Emmanuel Tia (Côte d'Ivoire), a research assistant from the Centre d'entomologie medicale et veterinaire in Bouaké, worked with Dr E.A. Heinrichs, WARDA's Continuum Program entomologist, in June, July and August 1992. He learned various techniques for conducting field studies in rice entomology.

- Abdoul Traore (Burkina Faso) worked with Dr. E.A. Heinrichs from July to December 1992, studying yield losses due to rice insect pests, interactions between rice yellow mottle virus and insect vectors, and methods for screening for this virus and rice blast. He is working towards his MSc degree in plant protection at the State University of Karkov, Ukraine, Russia.

- Four students (N'Dri Konan, Loukou Konan, Papeu Julien Ouanglo and Ahouasso Anoh) from the Ecole national superieur des travaux public (ENSTP) in Côte d'Ivoire received practical training in WARDA's Farm Development Office under the guidance of the farm manager, C.B. Buyyala. The students were at WARDA from July to December 1992. A set of projects was prepared for each student according to his speciality; these included surveying, road construction, preparation of cost estimates, design of a sprinkler irrigation system, and construction of research farm facilities.

WARDA/NARS training seminar

To consolidate collaboration with the NARS, WARDA has developed a partnership model which operates through Working Groups and Task Forces. The Training Working Group, established in 1990 to advise WARDA on training activities, provides a channel through which NARS personnel can voice their opinions on issues relating to the strategy and content of WARDA's training program. Within the context of the activities of the Training Working Group a WARDA/NARS training seminar on 'Human resources development for rice science in West Africa' was organized in May to review training at WARDA and to formulate a plan of action for more effective collaboration in training between WARDA and the national programs of member states.

The seminar was held at WARDA's Main Research Center and Headquarters, M'bé. It was attended by 21 scientists and trainers from NARS and from international agricultural research centers based in sub-Saharan Africa. The major issues discussed included: the rice science training needs of national programs in West Africa; the scope of WARDA's training programs; the problems associated with organizing and managing in-country group training courses; and a plan of action for WARDA/NARS collaboration in individual and group training to improve the professional competence of rice researchers, technicians and extension personnel in the region. The seminar proceedings are scheduled for publication in 1993.

The Director General, Dr Eugene Terry, closing the WARDA/NARS seminar on human resources, with Dr Joseph George (center), WARDA/NARS Training Working Group chairman, and Dr Anthony Youdeowei (left), Director of Training and Communications

In-house training

In-house language training in French and English was started in 1992 in order to improve the language competence of WARDA staff. Classes are given in each language twice a week and all staff are encouraged to attend.

SUMMARIES OF COMMUNICATIONS ACTIVITIES

Publications Unit

With few staff and modest facilities, WARDA's publications program developed steadily but slowly in 1992. The output of publications was limited to some extent by the need to produce the numerous documents prepared for the EPMR.

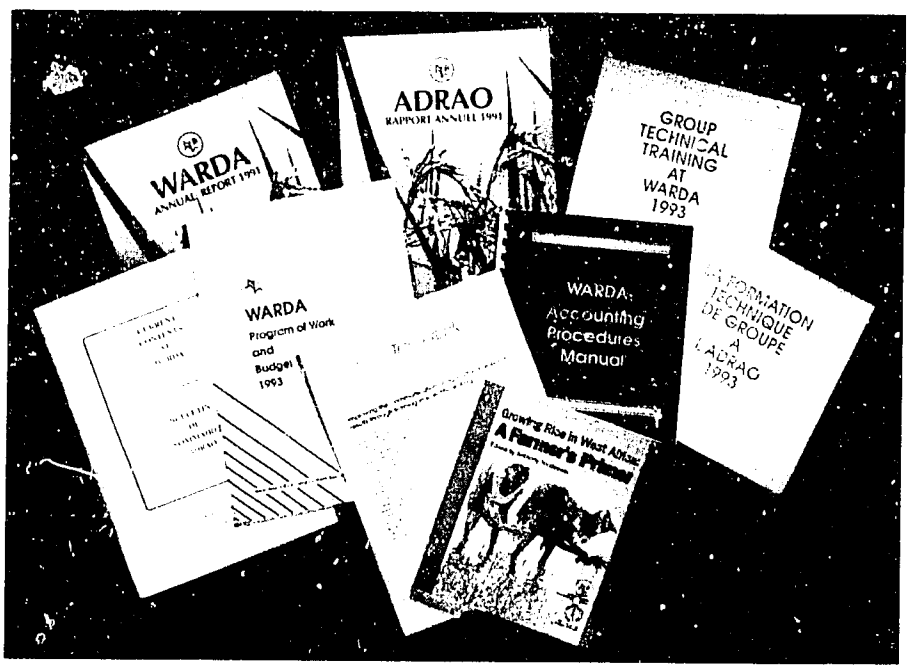
With the completion of the capital development project, the publication of the special newsletter, *WARDA Development Update*, was concluded with number 7.

The major books and booklets published during the year were:

- *WARDA Annual Report 1991* (English and French)
- *Program of Work and Budget 1993* (English)
- *Group Technical Training at WARDA 1993* (English and French)
- *Growing Rice in West Africa: A Farmer's Primer* (English)
- *Accounting Procedures Manual* (English)
- *Trainerlink* (English)
- *Current Contents at WARDA* (English and French; monthly)

Considerable progress was made on the preparation of a number of manuscripts. Among those which are scheduled for publication in 1993-94 are the following:

- *Catalogue of Rice Literature Searches 1991-1992* (English and French)
- *Training in Rice Production : Course Instructor's Manual* (English edition 1993; French edition 1994)
- *Human Resources Development for Rice Science in West Africa: Proceedings of a WARDA/NARS Training Seminar* (English and French)
- *WARDA Training Guide 1. Sampling and Preservation of Rice Insects* (English and French)
- *WARDA Training Guide 2. The Rice Plant and its Environment* (English and French)
- *Bibliography on* Oryza glaberrima (English and French)
- *Resources and Services of WARDA's Library and Documentation Center* (English and French)
- *WARDA's Publications List 1974-1992* (English and French)



Translation and Conferences Services Unit

WARDA's in-house capacity for translating from English to French was maintained. Freelancers were contracted for French to English translation work.

Figure 19 **In-house translations undertaken at WARDA, 1992**

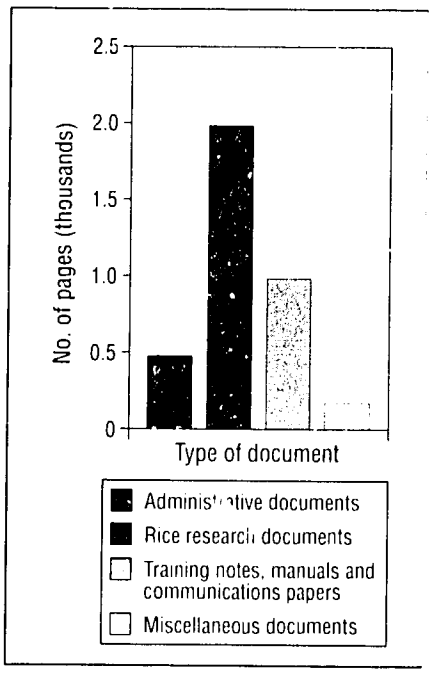


Figure 19 summarizes the range and volume of documents translated in-house during the year; the figures represent an increase of over 1500 pages in the volume of in-house translations compared to 1991.

Public awareness activities

Efforts to promote the activities of WARDA and the contribution of the CGIAR to agricultural development in sub-Saharan Africa were intensified through various means. An interview with WARDA's Director General was broadcast on the BBC Africa Service and Radio France International. There were frequent reports on WARDA's activities in regional magazines such as *West Africa* and *Jeune Afrique*, as well as in local newspapers.

Library and Documentation Center

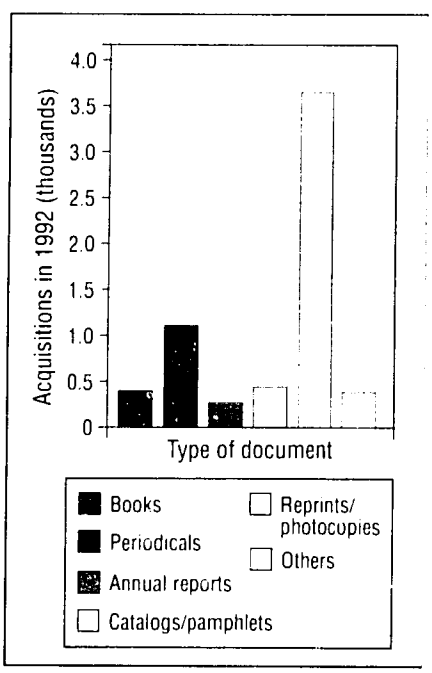
Special efforts were made in 1992 to strengthen the resources of WARDA's Library and Documentation Center and improve information dissemination services to WARDA and NARS scientists. In collaboration with CAB International, WARDA initiated the CAB International/ WARDA Project to Strengthen the Information Base for Rice Research, aimed at upgrading WARDA's capacity to serve as the primary rice-based farming systems information center for sub-Saharan Africa.

WARDA played a major role in a study commissioned by CTA and ECOWAS to assess the agricultural information needs in ECOWAS countries and formulate a regional program on STI for West Africa. A team of seven information and agricultural science experts visited regional and national institutions and prepared a monograph on each country. WARDA's Director of Training and Communications and the Documentalist participated in the surveys of Benin, Côte d'Ivoire, Guinea and Togo, and as members of the Steering Committee which met in Senegal in October. WARDA was given the responsibility of monitoring and coordinating the preparation, editing, translation, production and distribution of the national monographs in 1992 and the regional synthesis report in 1993. It is expected that WARDA will play a leading role in implementing the STI program.

WARDA's Library and Documentation Center, a major source of rice science literature in sub-Saharan Africa

Construction began at M'bé of a new building to house the Library and Documentation Center.

Figure 20 WARDA library acquisitions during 1992



Library acquisitions

The acquisition of materials on rice research and production and related subjects was intensified, with particular emphasis on publications in French and publications relevant to environmental and sustainability issues (*see* Figure 20). The acquisition of grey literature from WARDA member countries was also intensified. The library subscribed to over 150 journals and received several journals under exchange arrangements with other institutions.

Database management

The Center's three main in-house databases — WARBI, PERIO and the WARDA mailing list database — were expanded. WARBI and PERIO now contain 13 461 and 1226 records, respectively. The distribution of addresses on the mailing list database is shown in Table 33.

In May, WARDA's Documentalist attended a seminar, at the invitation of the ACCT, on the use of CD-ROM in documentation, held at the Ecole internationale de Bordeaux (EIB) in France. As part of WARDA's efforts to strengthen NARS, training on Mini-Micro CDS/ISIS software and bibliographic database definition, implementation and management was given to IDESSA's chief librarian. WARDA's Documentalist visited the Sahel Program in June and October to

Table 33 Distribution of addresses on WARDA mailing list database

Region/country		Number of addresses
Africa	2424	
WARDA member countries		2180
America	226	
USA		166
Canada		17
Latin America		43
Europe	202	
Asia	169	
Oceania	9	
Total	3030	

improve the library facilities there, introducing more efficient procedures based on scientists' needs, designing a database for the management of library resources and training the library staff. One member of staff at the Sahel Program library, Aïda Diop, came to WARDA's Library and Documentation Center for further training in library and database management. Two scientists working on PhD theses, Youssouf Dembele (INERA) and Selome Dogbe (INCV), were trained at the Center on how to retrieve information required for their work and conducted in-depth literature searches.

WARDA receives regular updates from several external agricultural databases. Financial and technical support for this activity is provided by CTA, through its CD-ROM Project, and by the IDRC. The external databases currently being used are:

- on CD-ROM
  - AGRICOLA (Agricultural On-Line Access), 1970 to present, updated quarterly
  - AGRIS (International Information System for the Agricultural Sciences and Technology), 1986 to present, updated quarterly
  - BRIO (Banque de ressources sur les technologies de l'information en langue française/Database of resources on information technology, in French)
  - CAB ABSTRACTS, 1984 to present, updated annually
  - CABPESTCD, 1973 to 1991, updated annually
  - CSIS/ICAR (Current Search Information System of the United States Department of Agriculture, and Inventory of Canadian Agri-Food Research of the Canadian Agricultural Research Council)
  - KIT ABSTRACTS/TROPAG & RURAL, abstracts on tropical agriculture and abstracts on rural development in the tropics, 1975 to present, updated quarterly
  - SESAME, French language literature on tropical agricultural research and rural development from several organizations, including CIRAD, INRA, ORSTOM, BDPA/SCETAGRI, Faculté des Sciences Agronomiques de Gembloux and ISRA
- on diskette
  - AGROSTAT.PC (FAO time series statistics), 1960 to present, updated annually
  - CURRENT CONTENTS ON DISKETTE, agriculture, biology and environmental sciences, abstracts which give immediate access to current bibliographic data from thousands of journals and books; each week, a new diskette is delivered to WARDA, ready to be loaded and read on the computer
  - RICE ABSTRACTS, prepared by CAB International and issued quarterly

Table 34 **Number of respondents in the WARIS survey and number of requests received from rice scientists for documents from WARDA, 1992**

Country	Respondents	Requests
Benin	3	9
Burkina Faso	4	23
Chad	1	2
Cameroon	5	1
Côte d'Ivoire	22	147
Ghana	8	34
Guinea	7	6
Guinea-Bissau	1	—
Liberia	—	—
Mali	—	—
Mauritania	—	—
Niger	3	1
Nigeria	8	25
Senegal	5	17
Sierra Leone	9	32
The Gambia	2	—
Togo	—	8

Based on requests from WARDA and NARS rice scientists, bibliographic information is retrieved from in-house and external databases and printed out or downloaded on to diskettes. An increasing number of requests for literature searches were submitted in 1992, and over 70 searches were made. A catalogue of the literature searches conducted during the year will be available in 1993.

Other activities

The production of a *Directory of Rice Scientists in West Africa* is an activity within the WARIS project funded by the IDRC. A questionnaire was prepared and sent to rice scientists in order to gather information to compile their research profiles. The number of responses received, by country, are given in Table 34.

The WARDA mailing list was used to distribute over 3000 copies of the *1991 Annual Report*. Other publications distibuted during the year included the *WARDA Brief*, one issue of *WARDA Development Update*, two issues of *WARDA News* and 12 issues of *Current Contents at WARDA*.

In addition to library book loan services, over 375 publications and 43 000 photocopied pages of journal articles and book chapters were sent in response to requests received in 1992. Over 500 requests for documents were received during the year (*see* Table 34). Organizations that were particularly helpful in providing materials not available at WARDA included CTA, IRRI and the Agricultural University of Wageningen.

The Library and Documentation Center staff regularly visit institutions and information services in Côte d'Ivoire to establish and strengthen collaborative links. In 1992 they participated in the activites of the Ivorian agricultural information network, REDACI, and helped design a questionnaire aimed at gathering data on information and documentation centers for publication in a national directory.

FINANCIAL STATEMENT

PRINCIPAL PERSONNEL

SHORT-TERM CONSULTANTS

PUBLICATIONS BY WARDA STAFF IN 1992

ACRONYMS

West Africa Rice Development Association

Statement of Financial Position as at 31 December 1992

(*expressed in US dollars*)

	1992	1991
CURRENT ASSETS		
Inventory	195 418	154 881
Accounts Receivable — Donors	2 100 687	2 291 547
Accounts Receivable — Other	713 837	596 920
Cash and Bank Balances	874 742	401 707
	3 884 684	3 445 055
CURRENT LIABILITIES		
Bank Overdrafts	1 623 685	880 258
Accounts Payable	2 384 373	989 472
Provisions and Accruals	1 109 091	2 671 650
Contributions in Advance	1 356 496	283 777
Project Fund Balances	192 733	192 733
	6 666 378	5 017 890
Net Current (Liabilities) Assets	(2 781 694)	(1 572 835)
Property, Plant and Equipment	12 455 494	10 112 085
NET ASSETS	9 673 800	8 539 250
Represented by:		
Capital Invested in Fixed Assets	12 455 494	10 112 085
Restricted Funds		
Capital Fund	(3 951 380)	(2 984 326)
Unrestricted Funds		
Operating Fund	1 169 686	1 411 491
FUND BALANCES	9 673 800	8 539 250

The financial statements were approved by the Board of Trustees on 13 May 1993 and were signed on their behalf by:

Director General

Acting Director of Administration and Finance

West Africa Rice Development Association

Grants and Contributions for the Year ended 31 December 1992

(expressed in US dollars)

	Unrestricted Core	Restricted Core	Complementary Projects	Capital Development	Total 1992	Total 1991
DONORS						
World Bank	1 500 000	—	—	—	1 500 000	1 785 000
Sweden	633 817	—	—	—	633 817	595 803
Canada (CIDA)	670 860	—	—	125 786	796 646	832 275
Canada (IDRC)	—	33 956	50 635	—	84 591	39 975
AfDB	—	621 932	101 180	—	723 112	724 065
The Netherlands	134 738	—	1 156	—	135 894	634 562
Germany (BMZ/GTZ)	191 718	293 498	—	1 653 779	2 138 995	1 594 101
France	277 058	1 463	—	—	278 521	1 490 012
Japan	883 309	—	54 076	623 540	1 560 925	1 309 436
Belgium	59 679	—	—	—	59 679	60 155
EEC	—	270 436	54 093	—	324 529	530 314
UNDP/FAO	—	543 917	—	—	543 917	70 570
USAID	—	512 506	—	—	512 506	525 688
Italy	105 263	—	—	—	105 263	120 299
UK (ODA)	189 904	—	—	—	189 904	180 416
Rockefeller Foundation	—	3 000	—	—	3 000	5 000
Subtotal	4 646 346	2 280 708	261 140	2 403 105	9 591 299	10 497 671
MEMBER STATES						
Burkina Faso	—	—	—	—	—	13 142
Côte d'Ivoire	63 683	—	—	—	63 683	—
Nigeria	167 254	—	—	—	167 254	50 000
Sierra Leone	—	—	—	—	—	6 011
Togo	—	—	—	—	—	18 500
Subtotal	230 937	—	—	—	230 937	87 653
SUNDRY INCOME	113 255	—	—	—	113 255	34 286

West Africa Rice Development Association

Statement of Activity by Funding Source for the Year ended 31 December 1992

(expressed in US dollars)

	Unrestricted Core	Restricted Core	Complementary Projects	Total Operating	Capital Development	Total 1992	Total 1991
REVENUE							
Grants and Contributions							
Donors	4 646 346	2 280 708	261 140	7 188 194	2 403 105	9 591 299	10 497 671
Member States	230 937	—	—	230 937	—	230 937	87 653
Other Revenue	113 255	—	—	113 255	—	113 255	34 286
	4 990 538	2 280 708	261 140	7 532 386	2 403 105	9 935 491	10 619 610
EXPENDITURE							
Research Program	2 282 913	1 675 508	256 627	4 215 048	—	4 215 048	3 319 740
Training and Communications	749 340	564 915	—	1 314 255	—	1 314 255	790 649
General Administration	2 017 114	—	—	2 017 114	—	2 017 114	1 766 097
Capital Development	—	—	—	—	734 242	734 242	563 211
	5 049 367	2 240 423	256 627	7 546 417	734 242	8 280 659	6 439 697
ADD							
Depreciation of Fixed Assets	168 404	40 285	4 513	213 202	276 775	489 977	258 831
	5 217 771	2 280 708	261 140	7 759 619	1 011 017	8 770 636	6 698 528
EXCESS OF (EXPENDITURE OVER REVENUE) REVENUE OVER EXPENDITURE	(227 233)	—	—	(227 233)	1 392 088	1 164 855	3 921 082
Extraordinary Items	—	—	—	—	—	—	80 804
Prior Year Adjustments	(14 573)	—	—	(14 573)	—	(14 573)	(55 882)
RESULTS FOR YEAR	(241 806)	—	—	(241 806)	1 392 088	1 150 282	3 946 004
FUND BALANCES AT BEGINNING OF YEAR	1 411 491	—	—	1 411 491	—	1 411 491	827 598
Bad Debts Written Off	—	—	—	—	—	—	57 974
Transfer to Capital Fund	—	—	—	—	(1 392 088)	(1 392 088)	(3 420 085)
FUND BALANCES AT END OF YEAR	1 169 686	—	—	1 169 686	—	1 169 686	1 411 491

Principal Personnel

OFFICE OF THE DIRECTOR GENERAL

Eugene R. Terry, PhD	Director General
Augustine Owusu-Sarpong	Executive Secretary

ADMINISTRATION AND FINANCE DIVISION

Gordon MacNeil, MBA [1]	Director of Administration and Finance
Kwame Akuffo-Akoto, BSc, FCCA	Financial Controller
Honore Bobo, MS, MBA	Chief Accountant
Bola Andrews, MA	Administrative Officer
Ursule Konan, ML, CFB	Personnel Officer
Boniface Ouedraogo	Administrative Assistant
Zakrizou Bredou, DUT	Accountant
Mark Etsibah	Accountant
Casimir Grouto, Ing. Bat.	Physical Plant Services Manager
Helen Nevell, BA	International Purchasing Assistant
Odette Amani, BTS/S	Executive Secretary

RESEARCH DIVISION

Research coordination

Peter Matlon, PhD	Director of Research
Edgar W. Richardson, PhD	Biometrician
Chitti Babu Buyyala, BSc	Farm Manager
Michel Briat, IA [2]	Assistant Farm Manager (Operations)
Volker Hell, MCC	Assistant Farm Manager (Mechnical Maintenance)
Vincent Elegbo, Ing. Genie. MEC [3]	Assistant Farm Manager
Maxwell Adjei-Fah, Dip GIL	Executive Secretary

Upland/Inland Swamp Continuum Program

Bouaké, Côte d'Ivoire

Elvis Heinrichs, PhD	Program Leader (until 29 November) and Entomologist
Abdoul Aziz Sy, DI., D.E.Es-Sc.	Pathologist (Acting Program Leader, 30 November to 1 March 1993)
Monty P. Jones, PhD	Upland Breeder
Akinwumi Adesina, PhD	Production Economist
Kanwar Sahrawat, PhD	Soil Scientist
Laurence Becker, PhD [4]	Geographer
Thomas Remington, PhD [5]	Cropping Systems Agronomist
David Johnson, PhD [6]	Weed Scientist
Michio Takeda, BSc	Grain Quality Analyst
Roger Diallo, IA	Research Associate, On-Farm Research
Sitapha Diatta, DEA	Research Associate, Soils
Koffi Akator, MSc	Research Assistant, Pathology
Moustapha Gaye, MSc	Research Assistant, Economics
Semon Mandé, MSc	Research Assistant, Upland Breeding
Mobio Sika, MSc	Research Assistant, Soils
Teslim Ibrahim, NDAM	Post-Harvest Assistant
Bila Belemgoabga, MA	Administrative Assistant

Ibadan, Nigeria

Baij Singh, PhD	Lowland Breeder
Oyin Oladimeji, MSc	Research Assistant, Lowland Breeding

Sahel Irrigated Rice Program

St Louis, Senegal

Kouamé Miézan, PhD	Program Leader and Breeder
Michael Dingkuhn, PhD	Physiologist
Thomas Randolph, PhD [7]	Economist
Aïssatou Samb, DUT	Research Assistant, Physiology
Alioune Nidaye, DSC	Administrative Officer

Mangrove Swamp Rice Network

Rokupr, Sierra Leone

Martin Agyen-Sampong, PhD	Network Coordinator and Entomologst
Robert Guei, PhD	Breeder
Robert Chakanda, BSc	Research Assistant, Breeding
Charles Dixon, MSc	Research Assistant, Soils
Sorie Kamara, BA [8]	Administrative Assistant
Lamin Kargbo, CIS	Administrative Assistant

TRAINING AND COMMUNICATIONS DIVISION

Anthony Youdeowei, PhD, FAAS	Director of Training and Communications
Madeleine Yesso, BTS/S	Executive Secretary

Training

Zainabou Cole, BSc	Trainer

Communications

Alassane Diallo, MSc	Documentalist
Christiane Soufflet, MA	Translator/Reviser
Solange Bembatoum, DESS [9]	Translator
Messan Dossekou, MSc	Desk-Top Publishing Assistant

CAPITAL DEVELOPMENT

Peter Mather, ARIBA	Development Officer

Notes:

1 Left in September 1992
2 Left in August 1992
3 Joined in November 1992
4 Left in April 1992
5 Left in July 1992
6 Joined in April 1992
7 Joined in February 1992
8 Left in May 1992
9 Left in September 1992

Short-Term Consultants

Research

Mr Follard Asch	Research project on the physiology of salt tolerance in rice plants in the Sahel
Dr J.C. Griesbach	Soil erosion and conservation at M'bé research farm

Training and Communications

Dr Osebekwin Asiribo	Coordination of group training course in Computer Applications and Statistical Analysis in Agricultural Research
Ms Wilhelmina Colley	Trainer (WARDA alumnus)
Mr Emmanuel Edu	Copy editing of training manual
Mr Albert Gogan	Training coordinator (WARDA alumnus)
Mr Barry Hall	Technical photography
Mr Mohammed Jammeh	Trainer (WARDA alumnus)
Mr Anguette Kouame	Associate training coordinator (WARDA alumnus)
Dr Joseph Kwarteng	Preparation of training materials
Mr Ludovic N'Cho	Technical coordination of Upland Rice Production training course
Mrs Kay Sayce	Writing and editing
Dr Edward D. Spiff	Technical coordination of group training course on Crop Protection in Rice
Dr Roger Stern	Organization of group training course in Computer Applications and Statistical Analysis in Agricultural Research
Ms Joanna Traynor	Installation of desk-top publishing facilities and staff training
Dr Bansh Tripathi	Preparation of curriculum for group training course on the Development of Training Materials
Dr Valentine Yapi	Preparation of database on WARDA's group training participants
Dr Rainer Zachmann	Preparation of curriculum for group training course on the Development of Training Materials

Publications by WARDA Staff in 1992

Journal articles

Adesina, A.A. 1992. Oxen cultivation in semi-arid West Africa: Profitability analysis in Mali. *Agricultural Systems* 38: 131-47

Heinrichs, E.A. 1992 Rice insects: The role of host plant resistance in management systems. *Korean Society Appl. Entomol.* 31: 256-75

Jones, M.P., Leutong, F. and Tchatchoua, J. 1992. A survey of rice diseases in Cameroon. *Plant Disease* 77: 133-36

Sahrawat, K.L. 1992. Transformations of surface-applied urea in three soils of varying pH. *J. Indian Society of Soil Science* 40: 368-70

Dingkuhn, M., Schnier, H.F., Javellana, R., Pamplona, R. and De Datta, S.K. 1992. Effect of late season nitrogen application on canopy photosynthesis and yield of transplanted and direct-seeded tropical lowland rice. I. Growth patterns and yield components. *Field Crops Res.* 28: 223-34

Dingkuhn, M., Schnier, H.F., Javellana, R., Pamplona, R. and De Datta, S.K. 1992. Effect of late season nitrogen application on canopy photosynthesis and yield of transplanted and direct-seeded tropical lowland rice. II. Canopy stratification at flowering stage. *Field Crops Res.* 28: 235-49

Book chapters

Adesina, A.A. 1992. Village-level studies and sorghum technology development in West Africa: Case study in Mali. In Moock, J.L. and Rhoades, R.E. (eds) *Diversity of Farmer Knowledge and Sustainability.* New York, USA: Cornell University Press.

Agyen-Sampong, M., Jones, M.P. and Fomba, S. 1992. Rice improvement in the mangrove swamps of West Africa. The state of the art at WARDA Rokupr, Sierra Leone. In *Developing World Agriculture.*

Proceedings

Adesina, A.A. and Zinnah, M.M. 1992. Adoption, diffusion and impacts of modern mangrove swamp rice varieties in West Africa: Results from Guinea and Sierra Leone. In *Towards a New Paradigm for Farming Systems Research and Extension.* Michigan, USA: Association for Farming Systems Research and Extension/Michigan State University.

Heinrichs, E.A. 1992. Rice insects: The role of plant resistance in integrated pest management systems. In *Proceedings of the International Symposium on Entomology, Suweon, Korea, October 1992.*

Heinrichs, E.A. 1992 Multiple pest resistance in crop cultivars. In *Proceedings of the R.H Nelson Symposium Annual Meeting of the Entomological Society of America, Baltimore, Maryland, December 1992.*

Remington, T.R. and Sahrawat, K.L. 1992. *Chomolaena odorata*: A troublesome weed in upland rice or a multipurpose shrub? In *Agronomy Abstracts.* American Society of Agronomy annual meetings, Minneapolis, Minnestoa, November 1992.

Acronyms

AfDB	African Development Bank
AICAF	Association for International Cooperation in Agriculture and Forestry (Japan)
ATSAF	Arbeitsgemeinschaft Tropische und Subtropische Agrarforschung (Germany)
AVRDC	Asian Vegetable Research and Development Center (Taiwan)
BDPA/SCETAGRI	Sociéte d'études et de conseil pour l'aménagement rural, l'inventaire et la gestion des ressources (France)
BMZ	Bunderministerium für Wirtschaftliche Zusammenarbeit (Germany)
BNDA	Banque national de développement agricole (Mali)
CD-ROM	Compact Disc-Read Only Memory
CGIAR	Consultative Group on International Agricultural Research
CIAT	Centro Internacional de Agricultura Tropical
CIDA	Canadian International Development Agency
CIRAD	Centre de cooperation internationale en recherche agronomique pour le developpement (France)
CIRES	Centre ivoirien de recherches sociales et economiques
CNRST	Centre national de recherche scientifique et de technologie (Burkina Faso)
CODESRIA	Council for the Development of Economics and Social Research in Africa (Senegal)
CTA	Technical Centre for Agricultural and Rural Cooperation (Netherlands)
ECA	Economic Commission for Africa
ECOWAS	Economic Commission of West African States
EEC	European Economic Community
EIER	Ecole inter-etats d'ingenieurs de l'equipement rural (Burkina Faso)
ENSA	Ecole national supérieure agronomique (Côte d'Ivoire)
ENSTP	Ecole national supérieur des travaux public
FAO	Food and Agriculture Organization of the United Nations
GTZ	Deutsche Gesellschaft für Technische Zusammenarbeit (Germany)
IARI	Indian Agricultural Research Institute
IBPGR	International Board of Plant Genetic Resources
ICRAF	International Center for Agroforestry Research
ICRISAT	International Crops Research Institute for the Semi-Arid Tropics
IDESSA	Institut des savanes (Côte d'Ivoire)
IDRC	International Development Research Centre (Canada)
IFDC	International Fertilizer Development Corporation
IFS	International Foundation for Science (Sweden)
IIMI	International Irrigation Management Institute
IIRSDA	Institut international de recherche scientifique pour le développement en Afrique
IITA	International Institute of Tropical Agriculture
ILCA	International Livestock Centre for Africa
INERA	Institut de recherches et d'etudes agricoles (Burkina Faso)
INGER	International Network for Genetic Evaluation of Rice
INRA	Institut national de la recherche agronomique (France)
INSET	Institut national superieur de l'enseignement technique (Côte d'Ivoire)
IPM	integrated pest management
IRRI	International Rice Research Institute
ISRA	Institut senegalais de recherche agronomique
KIT	Koninklijk Instituut voor de Tropen (The Netherlands)
MRC & HQ	Main Research Center and Headquarters (WARDA)
NARS	national agricultural research systems
NCRI	National Cereals Research Institute (Nigeria)
NRI	Natural Resources Institute (UK)

OCCGE	Organization de coordination et de coopération pour la lutte contre les grandes endémies en Afrique de l'Ouest
ODA	Overseas Development Agency (UK)
ORSTOM	Institut français de recherche scientifique pour de développment en cooperation (France)
PERIO	Periodicals database (WARDA)
SAFGRAD	Semi-Arid Food Grain Research and Development
SDI	selective dissemination of information
SPAAR	Special Program for African Agricultural Research
TAC	Technical Advisory Committee (CGIAR)
TOT	Training of Agricultural Trainers
UNDP	United Nations Development Programmme
USAID	United States Agency for International Development
WARBI	West Africa Rice Bibliographic database
WARIS	West Africa Rice Information Systems

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