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WARDA

WEST AFRICA RICE DEVELOPMENT ASSOCIATION
ANNUAL REPORT 1994

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WARDA Annual Report

1994

West Africa Rice Development Association

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MESSAGE FROM THE DIRECTOR GENERAL

Significant progress has been made in the development of interspecific rice crosses. The progenies of these wide crosses show some of the best characteristics of both the Asian and African rice species.

On behalf of the Board of Trustees, the management, and staff of the West Africa Rice Development Association, I have great pleasure in presenting our center's Annual Report for 1994.

The year 1994 was the first year of implementation of WARDA's second Medium-Term Plan. That plan was developed during a period in which worldwide resources for agricultural research were declining, and the CGIAR itself was engaged in a program of renewal. The renewal program was designed to clarify the vision of the CGIAR, refocus its research agenda, reform its governance and operations, and secure commitment for current and additional financial support for its international mission.

During that first year of our plan implementation, we were engaged in defining a long-term institutional vision for strengthening regional agricultural science capability. This vision called for the development of partnerships and institutional mechanisms for the most cost-effective means of generating and transferring new rice technologies within the region.

Three major food security challenges faced West Africa at the time the second Medium-Term Plan was developed. The first was the growing imbalance between supply and demand for rice, and the second was the increasing degradation of the agricultural resource base as agricultural production shifts from extensive to intensive land-use systems to meet the increasing demand for food. The third challenge was to reverse the threat to the future well-being of women, who constitute an important component of rice producers in West Africa, and who depend on rice not only as a subsistence crop for their families, but as a major source of income as well.

Our response to these challenges was to develop research programs designed to generate new technology to increase the sustainable productivity of intensified rice-based cropping systems.

As for its institutional challenges, WARDA had projected that the gains from its Task Force approach to regional collaboration would be most evident by 1994. Furthermore, the prospects for increased benefits from the Open Center structure were already manifest in 1994.

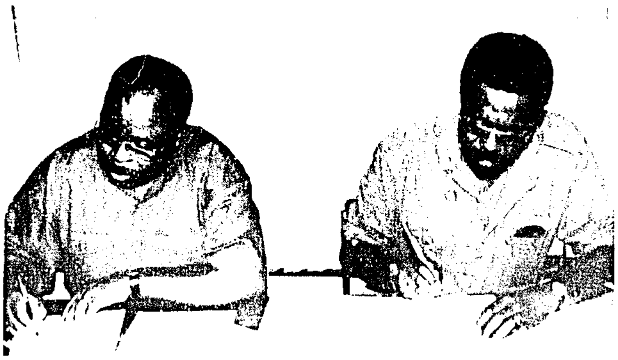
We are pleased to summarize here the results of our research, training, and communications activities, which clearly demonstrate significant progress towards resolving some of the region's food security challenges. We also present tangible evidence that our institutional innovations are addressing some of the institutional challenges that confronted us at the time we initiated the implementation of our own second Medium-Term Plan.

We report here significant progress in the development of new rice plant types through interspecific crosses that hold tremendous hope for resource-poor farmers. The progenies of these wide crosses combine the high yield potential of *Oryza sativa* with the multiple stress resistance of the African rice species *O. glaberrima*.

WARDA recognized how urgently we needed to address the resource base degradation that has resulted from farmers' use of inappropriate practices as farming has become more and more intensive. Our cropping systems research, therefore, is designed to determine the critical balance between productivity gains and sustainability in the farming systems of the region. Capsule summaries in this report contain results from preliminary studies on a range of sustainability topics. They include computer modelling studies to determine trade-offs between income and risk for rice cropping in the savanna zone, and studies on the management of nitrogen use efficiency in lowland rice ecosystems.

We present in this report important scientific achievements through the use of physiological simulation models that improve the prospects of rice double-cropping in the Sahel. This pathbreaking physiological approach is now being used to predict

MESSAGE FROM THE DIRECTOR GENERAL



Dr. E.R. Terry (right), Director General of WARDA, and Dr. D. Assoumou Mba, Director of CTA, signing the Memorandum of Understanding between WARDA and CTA at WARDA headquarters, in January 1994

growth duration, percentage sterility, and the yield potential of a large number of promising rice varieties that can be grown in the Sahel.

Women farmers' limited access to extension services, capital markets, and new technologies continue to marginalize them, threatening their well-being and that of their children. The argument often used to justify this marginalization is that female farmers are less efficient than male farmers. In this annual report we present preliminary results from studies to test this hypothesis. Our data clearly show that the efficiency of women approximates that of men farmers. It supports the argument that the so-called "efficiency-based" bias against women farmers should be eliminated.

With regard to training activities, WARDA's task in 1994 was to consolidate and fully exploit the very effective WARDA/NARS training links that had been developed in the first Medium-Term Plan. Significant effort was devoted to assisting the NARS in assuming the lead responsibility for production-oriented courses.

In 1994 we were increasingly involved in collaboration with our sister CGIAR centers in sub-Saharan Africa, to optimize the benefits from an integrated CGIAR training program for sub-Saharan Africa. In this connection, in 1994, WARDA co-hosted and/or co-sponsored a series of joint training activities with sister CG centers: ICRAF, ICRISAT, IRRI, and IIMI; and with non-CG institutions: CTA, SAFGRAD, IFS, and IDRC.

We are highly indebted to UNDP for providing the major portion of the funding for training in 1994.

WARDA's Library and Documentation Unit provided a wide range of rice science information to rice scientists in the region in 1994. The West Africa Rice Information System (WARIS), which was established with funding from the CGIAR, IDRC, and CTA, draws upon the resources of the WARDA Library and Documentation Unit at M'be. WARIS provides access to a comprehensive library of information on rice, and to a variety of computer-based current awareness services.

In many ways, 1994 marked the beginning of an exciting period for WARDA as a full partner within the network of CGIAR centers operating in sub-Saharan Africa. WARDA's board, management, and staff took deliberate steps to establish its presence and to execute its programs in support of the CGIAR's efforts in the region.

WARDA's role as an effective technology delivery mechanism for the CGIAR was underscored when the Technical Advisory Committee (TAC) of the CGIAR held its sixty-fourth meeting at WARDA headquarters in June 1994. That meeting served as the first occasion for the full TAC to hold consultations with directors of agricultural research and research scientists from the region. The consultation was sponsored by WARDA, ISNAR, and SPAAR.

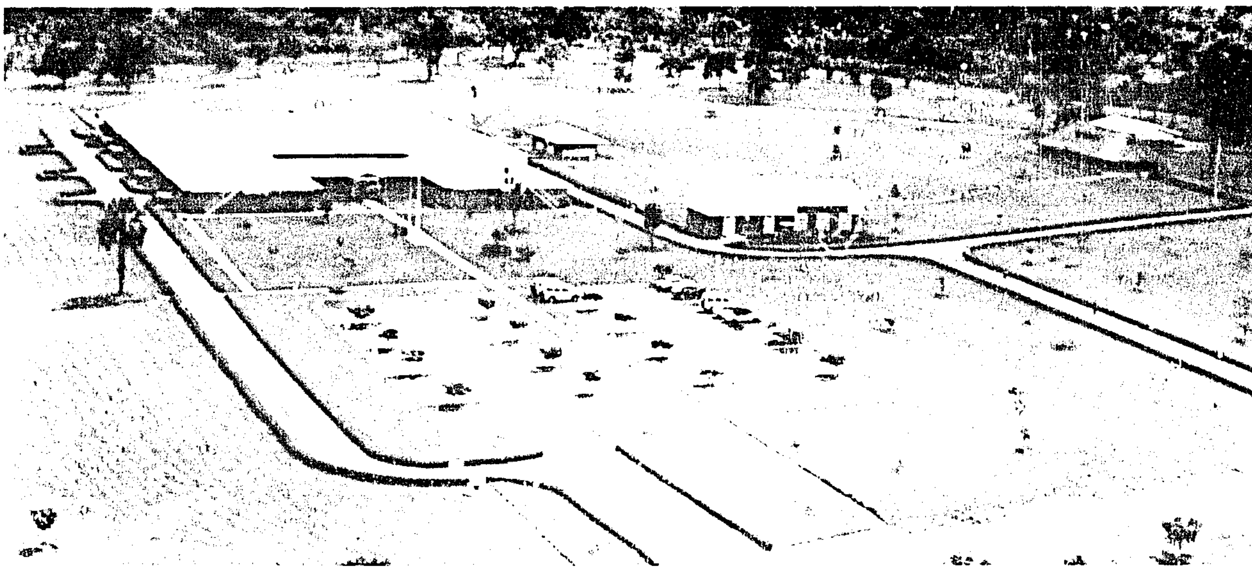
The CGIAR chairman, Dr. Ismael Serageldin, paid an official visit to WARDA in July 1994, as part of his familiarization tour of all Africa-based CG centers. The visit was a morale booster for staff and spouses, since the chairman in his address to the WARDA family seized the opportunity to assure everyone of his relentless search for continued financial and moral support for the CGIAR.

As you review the contents of this annual report, which covers a wide range of WARDA's activities in 1994, I hope you will sense the vitality of our programs. We are confident that the results of our work presented here, whether preliminary or definitive, will contribute to the worldwide efforts of the CGIAR to alleviate poverty, hunger, and malnutrition.

Eugene R. Terry, Ph.D. (Illinois)

ABOUT WARDA

Aerial view of WARDA's main research center and headquarters at M'bé, Côte d'Ivoire.



The West Africa 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. The Association is a member of the network of 16 international agricultural research centers supported by funds from donors of the CGIAR.

WARDA's goal is to strengthen West Africa's capability in rice production science, technology, and socio-economics. Through these efforts, it hopes to improve the livelihood of small farming families, increase the opportunities for rural employment, and enhance the prospects for food security.

The headquarters of WARDA are in M'bé, Côte d'Ivoire. WARDA maintains regional research sites near St. Louis in Senegal and at IITA, Ibadan in Nigeria.

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International Development Research Centre
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Rockefeller Foundation
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The Netherlands
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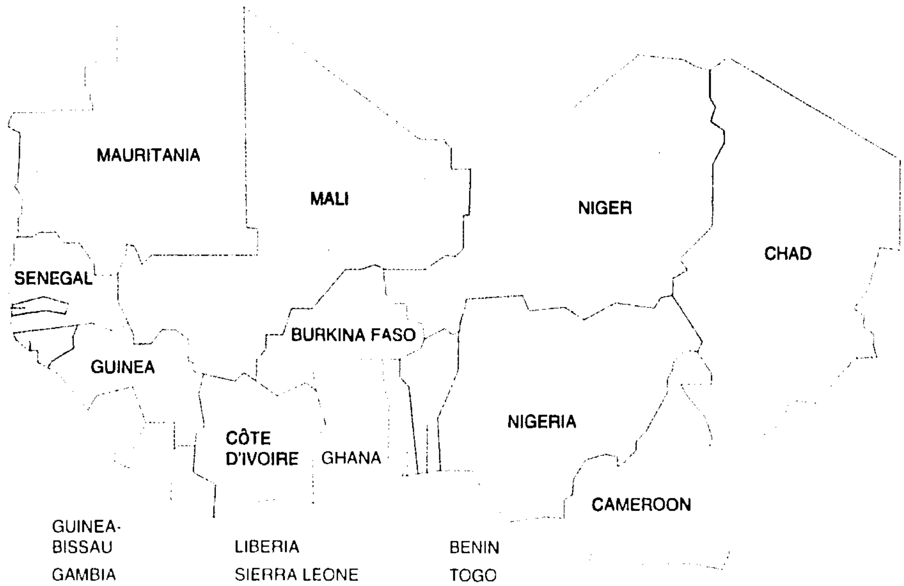
United Nations Development Programme
United States of America
World Bank

WARDA MEMBER COUNTRIES



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Rear row: *A. Basler, E. Terry, H. Kauffman.*

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RESEARCH

OVERVIEW

Peter J. Matlon
Director of Research

The fifth and final year of the new WARDA's first Medium-Term Plan, approved by TAC in 1989, was to have been 1994. We step back and evaluate what the research division has achieved in 1994, against the larger perspective of changes since 1990. The changes have been many and profound.

New Members of the WARDA Scientific Team

At the end of 1990, when worldwide recruitment of new scientific teams was initiated, our human resources stood at only 10 senior scientists. By 1994, our overall scientific strength had grown to 21, with 11 core scientists, seven researchers attached to WARDA from collaborating centers, one postdoctoral scientist, and two doctoral-level associate scientists recruited from within West Africa. Ten new scientists joined WARDA in 1994 alone. WARDA has now finally attained the critical mass necessary for addressing the most important rice-production constraints in the region.

Two senior researchers have been added to our core staff, and one core scientist has taken on a significant new role.

- During 1994 Dr. Marco Wopereis became our cropping systems agronomist in the Sahel Irrigated Rice Program. His research focuses on understanding and reversing the processes of salinization and alkalinization which threaten the sustainability of intensive rice production in the Sahel. The addition of Dr. Wopereis represents a significant broadening of our research agenda in the Sahel to place greater emphasis on resource management issues.

- After nearly four years of joint planning with PEEM/WHO, our Human Health Project commenced in late 1994 when Dr. Thomas Teuscher, a physician and public health researcher, became project coordinator. The project involves a consortium of national and international institutions in Mali, Côte d'Ivoire, and Europe working together to reduce the malaria and schistosomiasis risks associated with lowland rice cultivation.

- Dr. Michael Dingkuhn has moved from the Sahel Program to program leader of the Continuum Program. Serving also as systems analyst within the program, he is working toward achieving a more complementary and rigorous integration of scientists' efforts in the program's interdisciplinary team projects.

Our rapid growth in scientific strength also represents the successful implementation of WARDA's "open center" concept. We visualize WARDA as a West African center of excellence which can attract, focus, and facilitate the efforts of other advanced research institutes to help us solve the problems facing the region's rice farmers. Through the open center construct, five new scientists joined WARDA in 1994. Selecting the new researchers and planning for their scientific activities were thoughtfully negotiated between WARDA and our partners to ensure that the focus of the new research thrusts was an integral part of WARDA's core research agenda.

- Dr. Alain Audebert joined us as plant physiologist on attachment from CIRAD, through assistance of the French government. Dr. Audebert is collaborating closely with WARDA breeders and other WARDA scientists on the stresses caused by drought and excess water. His research will attempt to open the black box of plant responses to these stresses by identifying the underlying mechanisms at play. This work will help WARDA plant breeders develop new varieties better adapted to cultivation in unfavorable environments.

- WARDA launched its first concentrated effort on rice nematodes with the arrival of Mr. Danny Coyne, who comes to us from the International Institute of Parasitology, with financial support of the Overseas Development Administration of the United Kingdom. He has initiated a series of studies to characterize the species distribution, infestation rates, and yield losses caused by rice nematodes. The goal of his work is to develop low-cost integrated nematode control practices.

- Dr. Jean-Yves Jamin has taken up the post of coordinator of the Inland Valley Consortium. A cropping systems agronomist, he is on attachment from CIRAD, with financial support from the French government. He is charged with overall approval of activities of eight national research systems in West Africa and five international research centers collaborating in the consortium (see box page 24).

- Mr. Pieter Windmeijer joined the Inland Valley Consortium in 1994 as agro-ecologist and scientific animator. On attachment from the Winand Staring Centre (Wageningen) and with support from government of The Netherlands, he is responsible for ensuring close coordination among consortium partners in regional research on the characterization and intensification of inland valleys.

- Following a two-year Rockefeller Fellow appointment in WARDA's Sahel Program, Dr. Tom Randolph has moved to the Continuum Program, where he has become WARDA's first policy economist. Team leader for a project being executed by Development Alternatives Incorporated (USA), and with support from the African Development Bank, he is examining how the economic comparative advantage of rice production in seven West African countries may be influenced by changes in technology and policy.

WARDA also introduced a new category of scientific staffing in 1994 with the initiation of an associate scientist program. The program focuses on the recruitment of doctoral-level researchers from within West Africa and young postdoctoral scientists from within or outside the region.

- Dr. Abdoulaye Adam took up his new assignment as WARDA biometrician in 1994, based at our main research center. He came to WARDA from INRAN, the national agricultural research institute in Niger, where he had served as statistician and scientific director.

- WARDA's germplasm exchange activities were greatly strengthened in 1994 with the recruitment of Dr. Robert Guei, a rice breeder. Dr. Guei is supporting regional trials conducted by Breeding Task Force members, through overall coordination of seed multiplication, composition and dispatch of nurseries, and analysis of trial results. He is also working to ensure the closest possible complementarity between Task Force activities and those of INGER in West Africa.

- A major disciplinary gap in WARDA's continuum program was filled in 1994 with the recruitment of Dr. Nick van de Giesen as a postdoctoral hydrologist. He is working within the Inland Valley Consortium and in several continuum program team projects to characterize the very complex hydrological dynamics of continuum toposequences. His work aims at guiding the development of low-cost water-control methods to help stabilize and improve productivity in valley bottoms.

With this rapid growth in staff numbers comes the challenge to manage the new activities in a way that will maintain the coherence and focus of our core research agenda. We are confident that our selection of partners and jointly defined collaborative research themes will ensure that this indeed will be the case. Our confidence was reinforced throughout 1994 as the new scientists took up their assignments with a sense of excitement and team spirit.

Collaboration with National Partners

A major challenge faced by WARDA when developing its Medium-Term Plan in 1990 was to develop a new vision and new more participative mechanisms for collaboration with national research programs. Certainly one of WARDA's most important achievements during the last five years has been to design and implement the Task-Force approach to partnership (see box on page 57). Experience has demonstrated the utility of the Task Forces:

- National scientists value their participation in planning and decision-making, and they have already cited significant impacts on their own programs.

- The Report of WARDA's External Program and Management Review, conducted in 1992/93, praised the Task Force initiatives as representing a *"sound new approach"* for NARS/IARC collaboration.

- A joint meeting of SPAAR, CORAF and USAID-supported networks held in Banjul in April 1994 examined six research networks in Africa supported by USAID. The proceedings of that meeting *"broadly endorsed"* the WARDA Task Forces as an *"example of the successful application"* of past lessons learned in regional cooperation. No other network was so endorsed.

- Moise Mensah, in a paper presented at the International Consultation on the NARS Vision of International Agricultural Research (IFAD, Rome, 12-14 December 1994), states:

  > *Over two decades of experience in collaboration between IARCs and NARSs have shown that the relationship has not always been easy. However, despite some understandable frustrations on both sides, IARCs and NARSs have managed, in some cases, to overcome problems and build collaboration on a mutually accepted basis. One striking example of such a pattern of collaboration was established by the West Africa Rice Development Association (WARDA) with a group of National Agricultural Research Systems.... The WARDA experience offers a good answer to the issue of possible conflict between IARC transnational mandates and the need to address national priorities by offering a mechanism for National Research Systems to share priority programmes on agreed issues.*

We are gratified that the Task Forces are gaining this kind of recognition, both within and outside of Africa.

To remain relevant and effective, however, the Task Forces must be dynamic and responsive to changing needs and opportunities. A new Cropping Systems Task Force was launched during the year, with the participation of agronomists from 11 national rice research programs. The Task Force is focusing on the diversification of cultivation through legume-based improved fallows and the introduction of other crops in pre- and post-rice niches which will contribute soil nitrogen and organic matter and interrupt the build-up of rice pests as systems intensify.

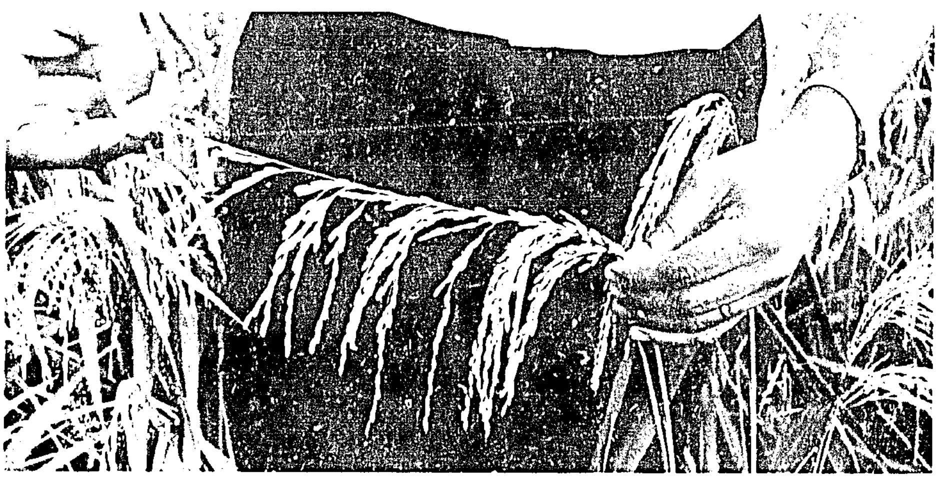
A major institutional experiment was launched in 1994 with the devolution of responsibility for technology-generation research to the national rice research program of Sierra Leone. With research activities designed in close consultation with members of the Mangrove Swamp Rice Task Force, and with financial support from USAID, the Rice Research Station in Rokupr, Sierra Leone, took the baton from WARDA to continue a regional program of varietal improvement focused on the unique mangrove swamp environment. The scope and quality of work conducted this year is very encouraging.

Development of Technologies

Growth in staffing and institutional innovation are only means to an end. The bottom line for WARDA must be whether we are delivering solid scientific results that increase our knowledge and get new technologies to national researchers and farmers. Over the last five years we have seen an exponential improvement on this criterion alone. This year's annual report presents an overview of our achievements in 1994 and sets out the directions for work in 1995 and thereafter. To place this work in perspective, we highlight just four areas in which significant, exciting gains have been made.

- Rapid progress has been made by WARDA breeders in the development, selection, and transfer of improved rice varieties to national research and development agencies: seven high-yielding upland rice varieties with multiple stress tolerances are being multiplied by national agencies for on-farm demonstrations and release in Côte d'Ivoire, Nigeria, The Gambia, Guinea Bissau, Cameroon, and Zaire; two rainfed lowland varieties and two irrigated varieties are in the pipeline for release in Nigeria, The Gambia, and Côte d'Ivoire; three high-yielding varieties with superior performance in the acid sulfate and saline soils of mangrove swamps are being multiplied for demonstrations and release in Sierra Leone, Guinea Bissau, Nigeria, Senegal, and The Gambia; and three high-yielding and more stable varieties have been released in Senegal for production in the Sahel.

- WARDA scientists have recently achieved a major breakthrough by developing new plant types suited for use by resource-poor farmers through interspecific crosses between *Oryza sativa* (of Asian origin) and *O. glaberrima* (the traditional African rice species). Combining anther culture and embryo rescue techniques with conventional backcrossing, we have developed new plant types that combine the high yield potential of *O. sativa* with the multiple stress resistance of *O. glaberrima*. These revolutionary new varieties will meet the particular needs of resource-poor farmers who have too often been bypassed by modern agricultural research.



WARDA scientists have achieved a major breakthrough by developing new plant types through interspecific crosses between *Oryza sativa* and *O. glaberrima*. The fertile progeny combine many of the most desirable characteristics of both species.

- Excellent progress has been made toward characterizing the climatic stresses that contribute to yield instability and limit double-cropping in the Sahel. Physiological simulation models have been developed which predict growth duration, percentage of sterility, and yield for more than 50 of the most promising varieties in the Sahel. The models provide development officials an invaluable management tool and help breeders to understand the physiological bases of rice plant response to extreme temperatures.

- Very substantial progress has also been made to identify the major pests and pathogens of rice and to understand their biology. Sources of genetic resistance to blast, rice yellow mottle virus, and stem borers have been identified and made available to national programs. This knowledge is now leading to the development of integrated pest-control packages that minimize the use of chemicals.

In reviewing this year's annual report, we hope you share with us a sense of accomplishment for what has been achieved in the last five years. We also hope you share our sense of excitement for the work that is now under way and our confidence in future directions and impact.

GENDER AND RELATIVE FARM EFFICIENCY: ARE WOMEN LESS EFFICIENT THAN MEN IN RICE FARMING IN CÔTE D'IVOIRE?

Akinwumi A. Adesina and Kouakou K. Djato

The importance of women farmers in the agriculture of developing countries is widely recognized. Women provide a significant share of the labor (both family and hired) for farm activities, and they are important as primary producers of food crops. Studies have shown that women also play major roles in farm-level decision-making, as farm managers managing their own fields and as "effective decision-makers" even in households in which the household head is a male, either because of their specific skills or when the husbands are absent during employment in urban areas.

Despite their importance, women farmers face daunting constraints to their productivity, arising out of limited access to extension, to capital markets, and to new technologies. The argument often used against female farmers is that they are less efficient than male farmers. Efficiency has three components: technical, allocative, and economic. Technical efficiency can be defined as the ability to achieve a higher level of output, given a similar level of production inputs. Allocative efficiency has to do with the extent to which farmers make efficient decisions by using inputs up to the level at which their marginal contribution to production value is equal to the factor cost. Economic efficiency combines technical and allocative efficiency. Technical and allocative efficiency are necessary, and when they occur together, they are sufficient conditions for achieving economic efficiency.

WARDA studies have shown that women farmers are as efficient as their male counterparts.

Whether men are more efficient than women is passionately debated. A few studies have examined this issue in Africa, generally with variable results. Using Cobb-Douglas production functions with dummy variables to represent the sex of either the field owner or the head of the household, earlier studies found that the coefficient of the gender variable was insignificant in Kenya and Burkina Faso. Studies in Nigeria had mixed results, with the gender variable not significant when the data for total farm output at the household level was used, but was significantly higher for men when the total value of production at the plot level was used.

Critics of these studies have pointed out that the reliance on production function methods to test for allocative and economic efficiency suffers from problems of simultaneity bias because input levels are endogenously determined. No previous research has used the profit function method to test for whether technical, allocative, and economic efficiency differences between men and women farmers exist in African agriculture. This partly reflects the lack of appropriate gender-disaggregated field data. Given that rice in West Africa is often referred to as a "woman's crop"—because of the importance of women as primary producers and decision-makers on the rice fields—it offers itself as an interesting crop with which to examine this question. The objective of our work, then, was to examine whether female rice farmers are less efficient than male rice farmers in Côte d'Ivoire, using the restricted normalized profit function method.

Data

The gender-disaggregated data used for the analysis were collected in 1993-1994 from a random sample of 347 men and 63 women rice farmers in three districts of northern Côte d'Ivoire. The data covered fertilizer applications, labor use (family and hired), access to extension and credit, farm size, paddy prices, wages, fertilizer prices, capital assets, input use, and the farmer's

TABLE 1. Average characteristics of female and male rice farmers in the sample. Côte d'Ivoire, 1993.

	Men N=347	Women N=63
Age (years)	41	45
Years of experience in rice farming	15	11
Contact with extension (percent of farmers)	98	91
Access to credit (percent of farmers)	86	59
Access to education (percent of farmers)	21	2
Cultivated rice area (ha)	2.3	1.1
Number of labor person-days worked on the owner's field	94	109
Wage rate for labor (CFA/day)	540	555
Price of seeds	124	235
NPK use per farm (kg)	334	159
NPK (kg ha^{-1})	148	126
Urea use per farm (kg)	117	67
Urea (kg ha^{-1})	70	73
Price of NPK (CFA kg^{-1})	111	100
Price of urea (CFA kg^{-1})	108	104
Value of paddy (CFA kg^{-1})	71	62

Source: Survey results, 1993.

education level (Table 1). We found no significant difference in women's access to extension services; 98% of the men have access to extension compared to 96% of the women farmers. Significant differences were found in the access to education and credit, however. Only two percent of the female farmers are educated (i.e., have ever attended school) compared to 21% of the male farmers. The issue of whether farmer education significantly enhances efficiency in rice production in Côte d'Ivoire is nevertheless still debatable (see Adesina and Djato, page 30 in this Annual Report).

Women are also at a disadvantage in their access to credit services. Eighty-six percent of men farmers have access to credit compared to only 58% of the women. Women also appear to receive less for their output than men: the average price received for paddy by men was 71 CFA/kg, compared to a mean farm-gate price of 61 CFA/kg for women. The higher prices obtained by men may reflect the fact that men are better organized into farmer cooperatives than women, differences in the timing of sales, or the type of market outlets used.

We found no significant differences in the use of chemical fertilizer. Men applied 149 kg NPK ha^{-1} compared to 126 kg ha^{-1} for women, whereas the application of urea was 70 kg ha^{-1} for the men and 73 kg ha^{-1} for women. Average expenditure on the use of other inputs (insecticides and herbicides) was similar for both men and women farmers. Indeed, women spent an average of 15,600 CFA ha^{-1} on these inputs compared to 11,200 CFA ha^{-1} for men. Women in the sample also have access to the use of mechanized equipment (oxen or tractors) mainly through an equipment rental market that is active in the region of the study. The average yield obtained by female farmers was 1.5 tons ha^{-1} compared to 2.0 tons ha^{-1} for the male farmers. These mean values show substantial inter-farm variability in yields, resource endowments, and factor-use proportions across fields, of female and male farmers. As such, when used alone they are not appropriate measures of relative farm efficiency. More appropriate comparisons are possible through profit function analyses.

Empirical Models and Hypotheses

We estimated a system of equations consisting of a normalized (restricted) profit function and factor share equations for the two major factors of production: labor and fertilizer. The dependent variable in the profit function equation was normalized profit, defined as revenue of the farm minus variable costs, divided by the price of paddy. The explanatory variables were the price of fertilizer divided by the price of paddy, wage rate divided by the price of paddy, value of all capital inputs (i.e., costs of seeds, insecticides, and animal and mechanical power), cultivated land area, and a dummy variable for the sex of the field owner. The factor share equations were estimated simultaneously with the normalized restricted profit function, using the Seemingly Unrelated Regression (SUR) method in order to obtain asymptotically efficient regression estimates. We imposed appropriate theoretical restrictions on the system of equations.

The results of the estimated equations are presented in Table 2. The coefficients all have the expected theoretical signs, and 10 of the 11 variables are significant at between the five and one percent levels. Thus, as the prices for fertilizer and labor increase, profits will decline as expected. Capital and land are highly significant in the profit function.

Hypothesis number one was whether or not there exists any difference in economic efficiency (i.e., both technical

TABLE 2. **Estimated simultaneous regressions (SUR) of systems of normalized restricted profit function and factor share equations for male and female rice farmers. Côte d'Ivoire, 1993.**

	Model I Unrestricted	Model II 2 restrictions	Model III 4 restrictions
Normalized Profit Function			
Wage rate	-0.455	-0.454	-1.386
	(-1.65)*	(1.65)*	(-7.83)**
Fertilizer price	-2.016	-2.019	-0.880
	(-3.92)**	(-3.93)**	(-8.67)**
Capital	0.123	0.123	0.136
	(2.31)**	(2.31)**	(2.67)**
Land	0.682	0.682	0.655
	(8.52)**	(8.52)**	(8.30)**
Sex of farmer (1=male, 0=female)	0.173	0.142	0.159
	(1.32)	(1.46)	(1.54)
Constant	7.263	7.292	8.739
	(8.96)**	(9.02)**	(11.19)**
Factor Share Equations			
Labor share equation			
Factor share parameter for men	-2.593	-2.504	-1.386
	(-7.14)**	(-7.49)**	(-7.83)**
Factor share parameter for women	-2.017	-2.504	-1.386
	(-2.36)**	(-7.49)**	(-7.83)**
Fertilizer share equation			
Factor share parameter for men	-1.220	-1.262	-0.880
	(7.67)**	(-8.63)**	(-8.67)**
Factor share parameter for women	-1.496	-1.262	-0.880
	(-4.01)**	(-8.63)**	(-8.67)**

Note: Values in parentheses are the respective t-values of the associated parameters.
* = significant at 5%, ** = significant at 1%.

and allocative efficiency) between male and female farmers in the sample. This implies that the coefficient of the gender dummy in the normalized restricted profit function is equal to zero. The test results show that men and women farmers have equal relative economic efficiency.

The second hypothesis tests for equal relative allocative efficiency between male and female farmers (i.e., are they equal in the degree to which they equate the values of marginal products of labor and fertilizer to the wage rate and fertilizer price?). This involved examining if there are significant differences in the parameters of the labor and fertilizer share equations (i.e., wage and fertilizer prices) and comparing these parameters with the corresponding marginal-value products for labor and fertilizer in the profit function. The test results showed that the hypothesis of equal relative allocative efficiency of men and women rice farmers is accepted at the five percent level. This implies that women equate the values of marginal products for labor and fertilizer to the factor prices to the same degree as men.

Hypothesis number three tests for whether male farmers have absolute allocative efficiency (i.e., that they equate the value of their marginal products to factor prices). The test results show that the hypothesis is rejected at the five percent level, indicating that men in the sample do not have absolute allocative efficiency.

TABLE 3. Relative productivity effects of production factors used by rice farmers (men and women). Indirect production elasticity estimates from the dual profit function. Côte d'Ivoire, 1993.

Elasticity Production Factor	Production
Labor	0.42
Fertilizer	0.27
Land	0.20
Capital	0.04

The fourth hypothesis tests whether women rice farmers have absolute allocative efficiency. As with the previous test, this hypothesis was rejected, implying that women also do not have absolute efficiency in the degree to which they use inputs.

To determine the effects of individual production factors on paddy output for the sample farmers, we used identities that link the self-dual profit function with the primal production function. Using the pooled sample of farmers (male and female) we estimated indirect production elasticities. Our estimates (Table 3) show that the elasticity of paddy output is highest with respect to labor (0.42), followed by fertilizer (0.27), land (0.20), and capital (0.04). An increase of labor use by 10% will increase paddy output by 4.2%. Similarly, a 10% increase in fertilizer, land, and capital is expected to lead to 2.7%, 2.0%, and 0.4% increase in paddy output. The highly inelastic response to land and capital may reflect the presence of other technological and infrastructural constraints that limit rice productivity. These results also show that labor is the most limiting factor in rice production, suggesting that the technologies that enhance the productivity of labor are likely to achieve significant positive effects on rice production.

Conclusions and Implications

The findings from this study have several implications for strategies to improve rice production in Côte d'Ivoire. First, the relative degree of efficiency of women is similar to that of men farmers. One of the major reasons for the neglect of women in rice development projects is the erroneous, yet pervasive, assumption that female farmers are less efficient than male farmers. Thus, even in regions where women are the traditional rice growers and rice is considered to be a woman's crop, rice development projects choose to focus on men and not women. Our results suggest that there is no technical, managerial, or economic rationale for biasing technologies towards male farmers, because female farmers, when they have access to similar inputs, have equal levels of efficiency.

Second, we observed that for both men and women farmers there exists some degree of economic inefficiency. Economic inefficiency may arise from mistakes in maximization (i.e., allocative decisions), imperfect markets, or differences in managerial inertia. To reduce such inefficiencies, it would be important to invest in the provision of better farm management information to farmers.

Third, results from the analysis show that for both female and male farmers, the elasticity of rice output to labor was the highest of all the production factors. To significantly increase labor productivity in rice production (for both women and men), improved labor-saving technologies are essential.

This work provides empirical evidence that supports the need to eliminate the so-called "efficiency-based" bias against women farmers. WARDA believes that female rice farmers have a major role to play in improving rice production in West Africa and must be given the same opportunity as males.

SPATIAL AND TEMPORAL VARIABILITY OF POTENTIAL YIELDS FOR IRRIGATED RICE IN THE SAHEL

Michael Dingkuhn, Marco Wopereis, and Abdoulaye Sow

Irrigated rice in the Sahel is known to have a high physical potential for increased cultivated area and yield. At the same time, it is arguably West Africa's most controversial rice production system. The high yield potential for rice in the Sahel derives from high solar radiation and full water control. These formed the rationale for massive public investments in irrigation schemes, beginning in Mali in the 1920s, and across the whole region in the 1970s and '80s, when severe droughts devastated rainfed crops and livestock.

In many cases, results fell short of expectations: mean grain yields of 3.5 $t\ ha^{-1}$ were below anticipated levels; and in some cases, scheme designs were inadequate for water resources, or they contributed to soil degradation due to lack of drainage. One of the main discrepancies between projected and actual productivities, however, is in cropping intensity, which was planned to be between 1.5 and 2. In fact, intensities rarely exceeded one in the large irrigation schemes of Senegal, Mauritania, and Mali.

WARDA's research during the past four years has identified a complex of climatic and management problems which render the establishment, management, and harvesting of two successive rice crops in one year extremely difficult (Annual Reports for 1991, '92, and '93). The risk assessment and planning model RIDEV was developed to simulate the duration and losses to temperature-induced sterility for any combination of rice genotype, site, planting date, and planting method scenario in the Sahel. Utilizing an analysis of the spatial and temporal climatic diversity of the Sahel and using RIDEV, we identified variety types for cropping in the wet or dry season, or both, and to which agronomically appropriate site-specific crop and crop management calendars it can be fitted (Annual Report for 1993). These tools, however, provided no information on potential rice grain yields.

A complementary simulation-based study was conducted in 1994 to determine the potential grain yield of irrigated rice as a function of planting date and site in the Sahel. Yield potential of irrigated rice in the tropics depends mainly on solar radiation, nitrogen nutrition, and rice variety grown. It is generally believed that in favorable environments and under good management, the dry (sunny) season enables much higher yields than the wet season. The yield ceiling for today's improved rices under favorable tropical dry-season conditions is about 10 $t\ ha^{-1}$. This commonly accepted view, however, is based on observations in the monsoonal humid tropics of Asia.

In the Sahel, in contrast to monsoonal Asia, actual rice grain yields are frequently lower in the dry season than in the wet, and yield stability is generally poor in the dry season. Although this seemingly inverted situation might be due in part to management problems in the off-season, what the biological potential for rice production actually is in the Sahelian dry season, is an obvious question.

The present study sought to determine spatial, seasonal, and year-to-year variability of potential rice grain yield in the Sahel using crop growth simulation.

We applied the classical approach of selecting an existing rice model that suited the required level of detail, modifying it on the basis of physiological observations in the target environment, validating it with crop observations at key sites and, finally, using it for spatial and temporal extrapolative analyses.

The empirical basis for model development

To develop a rice growth and yield model for the Sahelian environment, on the basis of existing models, we needed the following sets of information.

(1) The fit of existing models to the Sahelian environment; or conversely, their respective gaps and inaccuracies.

(2) In order to adapt and calibrate the model, quantitative coefficients expressing relationships between critical environmental parameters and crop responses. These included the relative

growth rate during exponential growth relative to temperature; leaf nitrogen concentration at various developmental stages under given input co[illegible]: the number of spikelets formed during panic[illegible]evelopment.

(3) In order to validate the model, detailed field observations on growth dynamics and yield for key varieties across the spectrum of climatic conditions encountered in the Sahel.

(4) Real-time daily weather records as background data for (1) through (3).

The main source of our empirical observations was rice garden trials conducted at WARDA's experimental stations at Ndiaye (arid-coastal) and Fanaye (arid-continental) in Senegal, based on a continuous monthly planting schedule for key varieties under optimal management (Annual Reports 1991-93). Routine crop observations provided growth curves for bulk leaf blade, stem and panicle dry-matter fractions; the dynamics of leaf nitrogen content, based on measurements of leaf chlorophyll content and specific leaf area; tiller number; and yield and yield components. The model was developed using 21 planting dates in 1991 and 1992.

Among the genotypes planted in the rice garden trials, we selected the cultivars Jaya (a medium-duration local check widely grown in Senegal and Mauritania) and IR64 (a short-duration international check) for model development and parameterization. Daily minimum and maximum air and water temperatures, air humidity, wind speed, and solar radiation were recorded at both experimental sites.

Characteristics of the improved model OryzaS

We developed the rice model OryzaS ('S' for Sahel) from two existing models: the growth-and-yield model Oryza1 developed at IRRI, and the microclimate-driven rice phenology and spikelet sterility model RIDEV (Annual Report for 1993). OryzaS is a deterministic dynamic model which simulates the growth of plant organs at daily increments, taking leaf canopy architecture into account. Emphasis is on the energy,

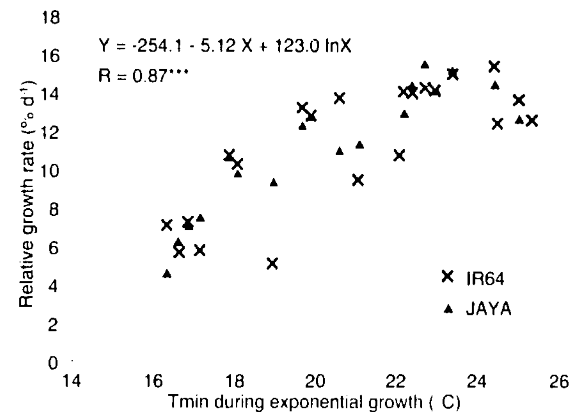


FIGURE 1: Relationship between the relative growth rate of IR64 and Jaya rice and the minimum air temperature (Tmin) during exponential growth across 21 sowing dates in 1991 and 1992 at Ndiaye.

temperature, and nitrogen dependency of growth processes. Because the model simulates energy-limited and temperature-limited potential yield, no stresses such as drought or toxocities are considered.

Model inputs are solar radiation, minimum and maximum temperatures, geographical latitude (to calculate photoperiod), some properties of the initial plant (seedling) population, and a number of genotypic constants. Since the uptake of nitrogen is not simulated, the model operates with forced-time courses of leaf nitrogen content, based on empirical observations.

We introduced a number of new functions to improve the model's sensitivity to the variable temperatures in the Sahel. Major modifications, as compared to Oryza1 and RIDEV, include the following factors.

Transplanting shock

Transplanting causes a physiological shock which temporarily affects growth and development. To account for this, we simulated a reduction in the maximal photosynthetic rate and the rate of phenological development during a temperature-dependent period. An additional reduction in growth resulted from the low nitrogen content of leaves during the shock period.

Direct temperature effects on leaf area development

Exponential growth during the early development stages is limited by the leaf area index (LAI). Leaf area growth, in turn, is generally driven by temperature and only to a lesser extent by carbon assimilation. Oryza1 in its original version simulates early (exponential) growth of LAI as a fixed function of temperature, and switches to photosynthesis-driven leaf expansion once mutual shading of leaves (LAI > 1) becomes a limiting factor to carbon assimilation.

To avoid such a radical (and physiologically improbable) decoupling of leaf weight and area growth, we assumed LAI to be generally driven by assimilation and partitioning, but forced a temperature-dependent upper limit to the relative daily increase of LAI. The forcing mechanism mainly takes effect during exponential growth because the relative daily changes in LAI and dry matter are generally highest during this period. Very low night temperatures (e.g., 15° C and below) still affect LAI directly at all stages. A major effect of the forcing mechanism is that leaves not only expand, but they also get thicker during cold periods, and they gradually return to their normal, stage-dependent thickness as temperatures increase.

This additional physiological function of the model is crucial in the Sahelian environment because existing models were found to substantially overestimate relative growth rates (RGR) of rice at low temperatures. Figure 1 shows the non-linear relationship between RGR and minimum temperatures observed in the Sahel, which cannot be explained by effects on assimilation alone, because midday temperatures were usually in the optimum range for photosynthesis (20° to 30° C).

Temperature effects on assimilate partitioning

The Oryza1 model computes assimilate partitioning ratios among roots, stems, leaves, and the panicle as fixed functions of the developmental stage, thereby providing for no plasticity. Our observations, however, showed that the fraction of assimilate used for leaf growth is significantly ($P < 0.01$) positively correlated with mean air temperatare. Leaf growth, therefore, decreases over-proportionately, compared to other organs, if temperature is low. We incorporated this relatively weak effect into the model because temperature variations are very high in the Sahel. Independent studies showed that partitioning (and, therefore, the morphologic... plant type) is also affected by N nutrition and other environmental factors, necessitating a greater plasticity of partitioning phenomena in future rice models.

Also unlike Oryza1, partitioning to the panicle (storage organ) at pre-flowering was determined by the number of spikelets initiated between the panicle initiation and flowering stages. The number of spikelets initiated and the weight of the developing panicle was considered proportional to the crop growth rate during this period. Temperature affected spikelet number indirectly through assimilation rates.

Temperature effects on grain filling and yield components

For the arid Sahelian environment, the simulation of a single weight fraction for panicles does not adequately describe yield, because a large fraction of the panicle can consist of unfilled spikelets. The two main causes of high numbers of unfilled spikelets are heat- or cold-induced sterility, or severe source limitations. Three weight fractions of the panicle were simulated: filled fertile spikelets, fertile but unfilled spikelets, and sterile spikelets. Fertile spikelets were supposed to be filled sequentially, resulting in a decrease of unfilled and an increase of filled spikelet number. Spikelet sterility was simulated as a function of temperature at critical stages, using the phenological model component RIDEV.

Sink capacity of the panicle was determined by the number of fertile spikelets, multiplied by the potential grain weight, a genotypic constant. Potential kernel weight was gradually adjusted after the flowering stage, to account for observed temperature effects on grain weight distribution.

Reinvigorated vegetative growth under sink limitation

The original model Oryza1 terminates the simulation once all grains are filled or the source is exhausted. In the Sahel, however, sink size can be severely restricted by spikelet sterility which is accompanied by reinvigorated vegetative growth during the later stages

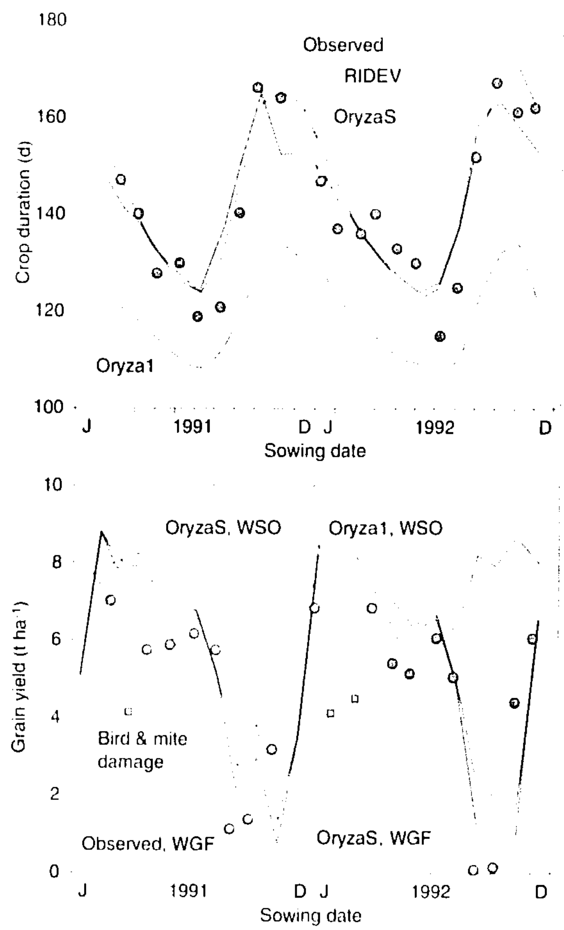


FIGURE 2: Top: Changes in crop duration for transplanted IR64 rice sown on 21 dates in 1991 and 1992. Field observations are compared with simulations using the phenological model RIDEV, the growth model Oryza1, and the combined model OryzaS. Bottom: Changes in grain yield for the planting dates. WGF, dry weight of filled grains; WSO, weight of the storage organ (whole panicle). Ndiaye, Senegal.

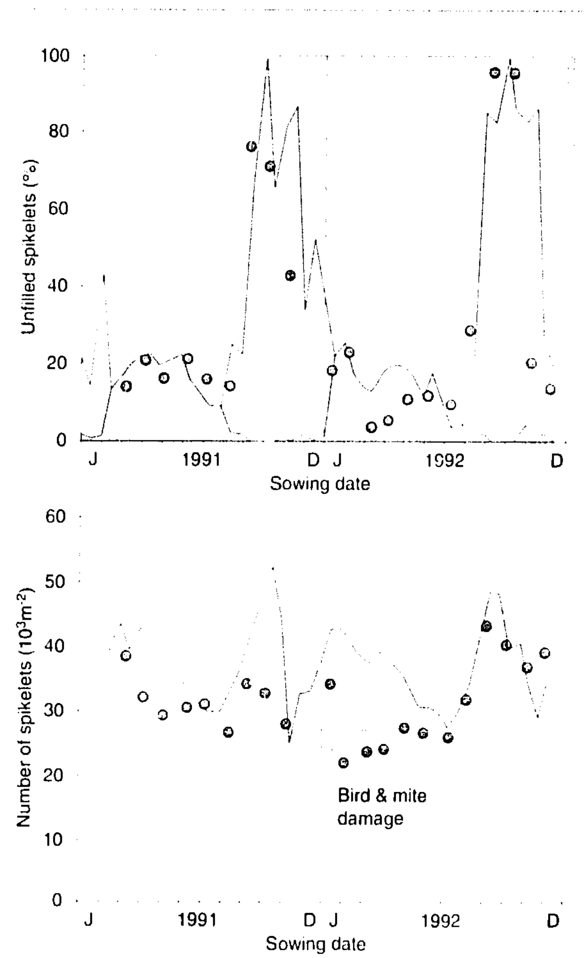


FIGURE 3: Top: Fraction (%) of unfilled spikelets for IR64 rice sown on 21 planting dates as observed in the field (dots) and simulated with the model OryzaS. Shaded zones represent spikelets that were not filled because of source limitations; the remaining fractions are the result of temperature-induced sterility. Bottom: Observed (dots) and simulated total number of spikelets per ground area. Ndiaye, Senegal.

of ripening. We simulated this phenomenon, which affects the harvest index, by redirecting unused assimilates to shoot growth.

Approach to extrapolative crop simulation

We used OryzaS to simulate potential yields under transplanted conditions for the local check variety Jaya, on the basis of 10 years of historical weather records (1970-79). Simulations were conducted for more than 30 sites in the Sahel and 12 monthly sowing dates.

The present study focuses on four key sites in the Senegal River delta and valley (St. Louis, Rosso, Podor, and Bakel), and four key sites in the Niger valley (Niono, Tombouctou, Gao, and Niamey). The phenological time courses of leaf N content, as observed in Senegal, were thereby projected onto the other sites because N uptake was not known for these sites.

Validation of OryzaS: Comparison of the models OryzaS and Oryza1 at Ndiaye

Figure 2a shows that the model modifications were crucial. Crop duration for IR64 at Ndiaye was underestimated by 10 days in the wet season (planting in July) and by 30 days in the cold-dry season (November) if the original model Oryza1 was used. The phenological model developed by WARDA for the Sahel, RIDEV, came much closer to the observations, largely because of the inclusion of floodwater temperature as a determinant of crop duration. The adapted yield model OryzaS, which includes components of RIDEV, also performed satisfactorily.

Yield simulations of Oryza1 were close to observations for sowing dates between February and August, but they failed to predict the extreme yield reductions observed between September and January (Figure 2b). OryzaS accurately simulated the seasonal variations in grain yield but showed a general tendency to overestimate yield. Because these overestimations were partly caused by crop management problems that were not simulated (the objective was to simulate potential, not actual, yields), we made no efforts to further approximate the observations.

Simulation of yield components

The distinction made in OryzaS between the weight of the filled grain (WGF) and the panicle (storage organ, WSO) was of little importance for dates associated with high yields. However, for sowing dates in September to November, when yields were reduced by cold-induced spikelet sterility, the unfilled spikelets accounted for up to one t ha^{-1} of panicle weight (Figure 2b).

Simulations generally matched the observed percentage of unfilled spikelets (Figure 3a). The simulated number of unfilled spikelets consisted of two components, one caused by sterility and one by assimilate source limitations. The two components are difficult to distinguish in the field, but they show very different seasonal patterns (shaded and unshaded zones in Figure 3a). The corresponding seasonal patterns of total numbers of spikelets per unit ground area are shown in Figure 3b.

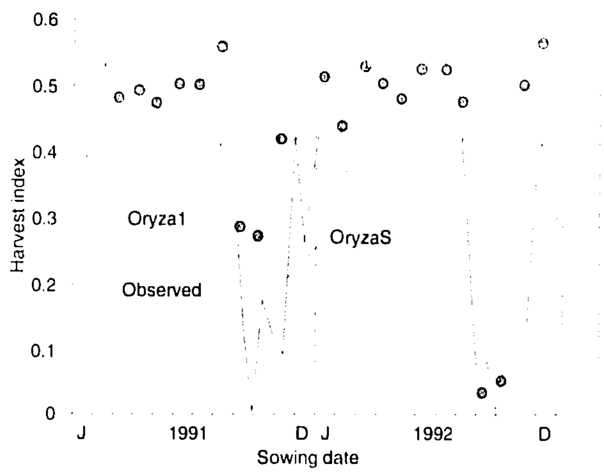


FIGURE 4: Harvest index of IR64 rice as observed for 21 sowing dates in 1991 and 1992 (dots), and as simulated with the models Oryza1 (broken line) and OryzaS (solid line).

The most important agronomic indicator of crop performance, apart from yield itself, is probably the harvest index (HI). The observed HI was around 0.5 for most planting dates but dropped to values close to zero for planting dates in September and October (Figure 4). OryzaS simulated these patterns accurately, whereas the original model Oryza1 predicted a HI of about 0.4, with little seasonal variation.

Validation of yield predictions for Ndiaye, Fanaye, and a site in the Philippines

Model tests simulating yields for two sites (Ndiaye and Fanaye in Senegal) and for two varieties (IR64 and local check Jaya) are presented in Figure 5. Observed yields were between six and nine t ha^{-1} at both sites, except for sowing dates that were associated with cold-induced sterility (September to November).

Simulations were generally accurate for Jaya in 1991 and 1992 at Fanaye, and for IR64 in 1991 at Fanaye. IR64 yields in 1992 at Fanaye, however, showed inconsistent patterns because of management problems, including irrigation pump failures in the hot-dry season and

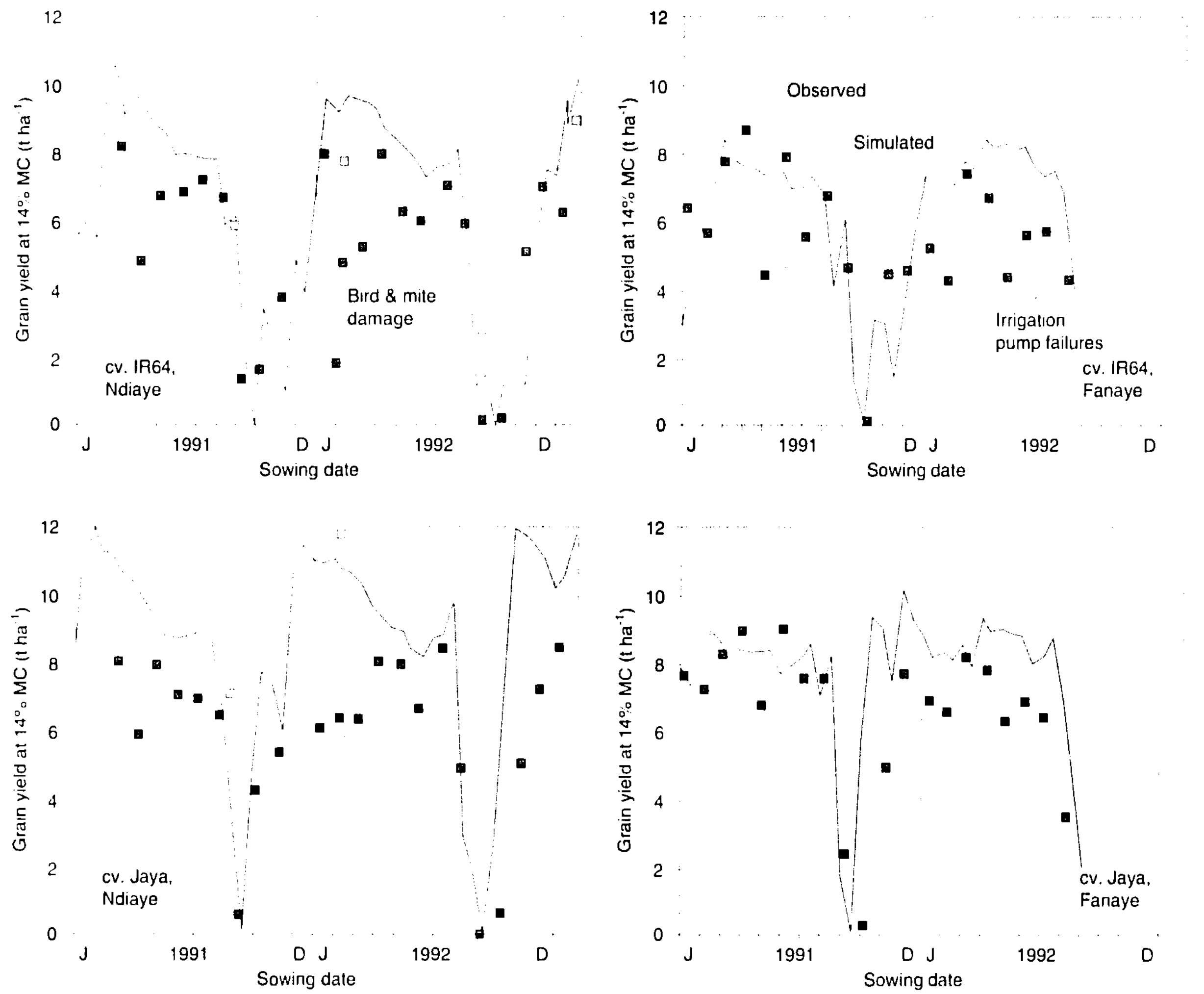


FIGURE 5: Grain yield as observed (solid squares) and simulated with OryzaS (lines) for IR64 and Jaya rice grown at monthly intervals in rice garden trials at Ndiaye and Fanaye in Senegal. Open squares indicate yields observed in an adjacent trial under birdnets.

inundation in the wet season. The local check Jaya was also to some extent affected, but performed better, probably because of better general adaptation to the environment. Spider mite attacks were observed in the hot-dry season (February to May) in both years and were controlled with acaricides, but growth reductions were still seen, because the fine webs on the leaf surface accumulated dust. At Ndiaye, observed yields for Jaya were generally below simulated yields. This may be attributable to soil salinity at the experimental site. Jaya is highly salinity susceptible and IR64 is moderately tolerant (Annual Report for 1993).

The model was also validated with a data set for IR64 in the Philippines, based on a N rate of 150 kg ha^{-1} and the leaf N contents actually observed (1988 dry season in Maligaya, Nueva Ecija; authors' data). The model slightly under-estimated grain yield (8.3 vs. 8.8 t ha^{-1}) and biological yield (16.1 vs. 16.4 t ha^{-1} dry

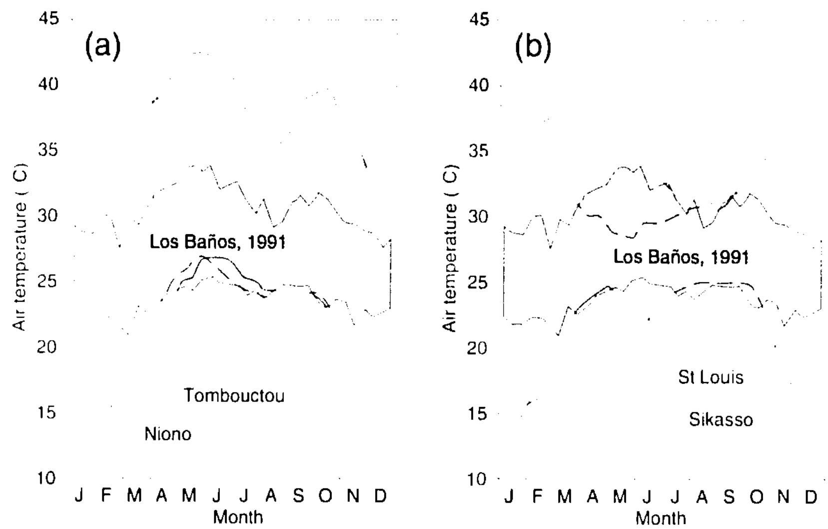


FIGURE 6: Annual minimum and maximum air temperature profiles for 1950 to 1983 in Niono, Tombouctou, and Sikasso in Mali, and for St. Louis in Senegal. The shaded zone indicates temperatures in Los Baños, Philippines, for 1991, as a comparison.

weight) and, more significantly, under-estimated the LAI at the heading stage (8.3 vs. 9.9). Considering that OryzaS was specifically developed for arid conditions, however, this yield prediction for a site in the humid tropics was considered satisfactory.

The validation of the model under Sahelian conditions was confounded by a number of stresses that could not be simulated because they are difficult to measure (e.g., dust accumulated on the leaf surface). Furthermore, the dry climate aggravated any crop and water management errors. In environments prone to multiple stresses, it is generally difficult to experimentally validate potential yield models. The extrapolative exercises using OryzaS as described in the following section should therefore be interpreted with appropriate caution.

Thermal characteristics of the test sites

Annual patterns of daily maximum (Tmax) and minimum (Tmin) temperatures are shown for key sites in the Sahel and compared with a humid-tropical site, Los Baños in the Philippines (Figure 6). Two typically "Sahelian" environments in which irrigated rice is grown are represented by Tombouctou (Mali, 16° 49′ N), at the fringe of the Sahara desert, and Niono (Mali, 14° 18′ N), located at the center of a large irrigation scheme (Figure 6a). These sites are characterized by annual patterns of Tmin that follow symmetric bell-shaped curves, roughly reflecting (with a one-month lag) changes in day length. Annual Tmin extremes are less than 15° C in January and about 26° C in June. Patterns for Tmax constantly exceed those of Tmin by more than 15° C, except for the short rainy season centered in August, during which the diurnal variation in temperature is much less.

Three different types of annual thermal patterns occur in the Sahel (Figure 6b). First, the coastal climate (e.g., St. Louis in the Senegal River delta, 16° 1′ N) is characterized by a long cool season and moderate Tmax between 28° and 33° C throughout the year. Second, the great floodplains of the Sahel ranging from 13° to 17° N have extremely high diurnal temperature fluctuations and Tmax up to 45° C except during a short wet season. Third, the slightly more elevated plateau at the southern fringe of the Sahel has a much cooler and longer wet season between June and September (e.g., Sikasso in Mali, 11° 18′ N).

These patterns stand in marked contrast to the climate of the monsoonal tropics (e.g., Los Baños in the Philippines; superimposed in Figure 6), particularly if compared with the critical temperatures for tropical rice. The critical Tmin for spikelet sterility of 18° C (Annual Report for 1993) is virtually never experienced in Los Baños, whereas in the Sahel, Tmin is below 18° C during three to four months of the year. Minimum temperatures below 18° C also limit leaf area growth and potential kernel weight if they coincide with critical growth phases.

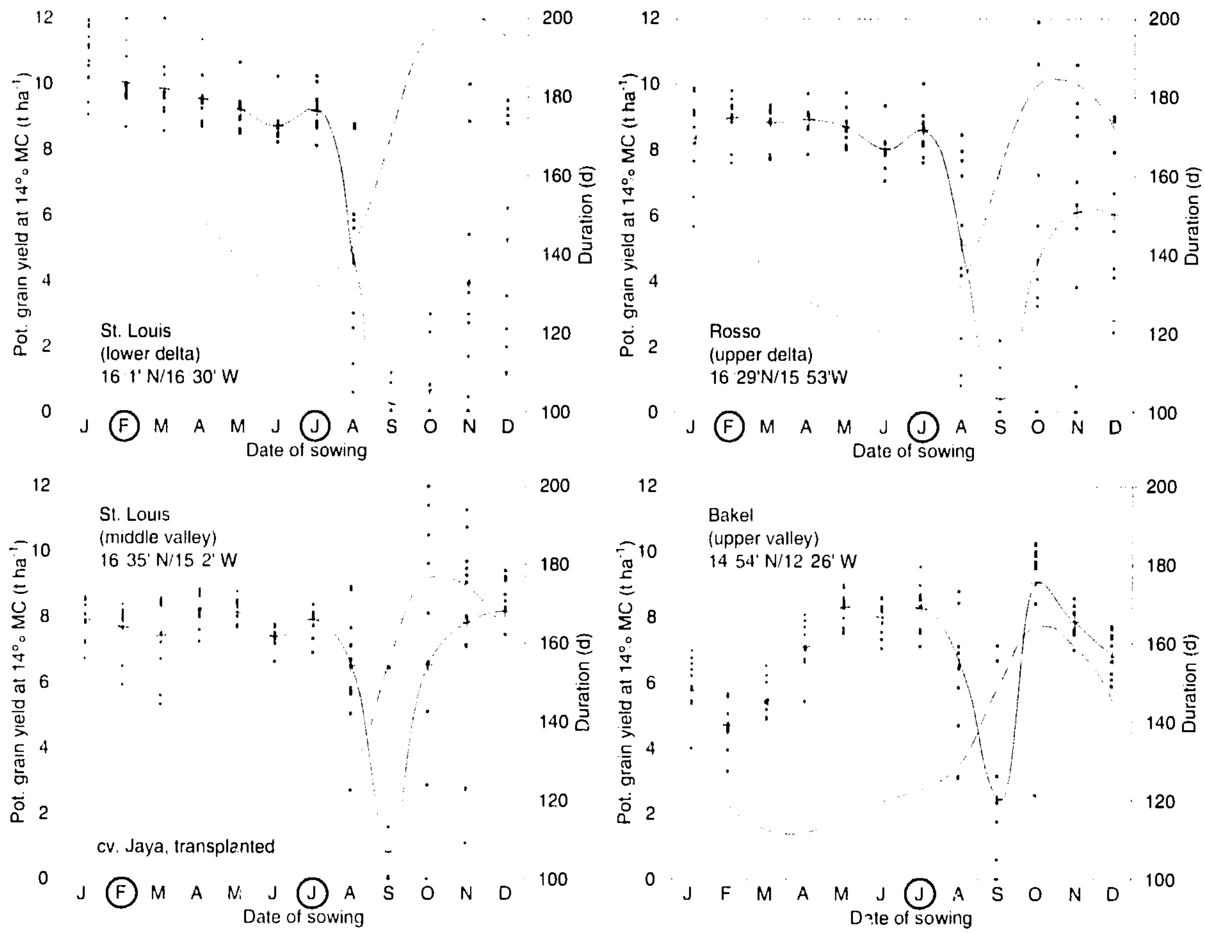


FIGURE 7: Simulated potential grain yields (solid lines) and crop duration (broken lines) as dependent upon sowing date for transplanted Jaya rice at four sites along the Senegal River (means for 1970-1979 weather data; individual years are represented by points). Enhanced months indicate common planting dates for the respective sites.

Potential yields in the Senegal River system

Simulated potential grain yields for the locally grown variety Jaya showed strong seasonal and spatial variations in the Senegal River valley (Figure 7). All sites between the delta (St. Louis) and the upper valley (Bakel) reflected a dramatic yield depression for September sowing dates due to cold-induced spikelet sterility. The planting period associated with this prohibitive yield depression, however, was longer in St. Louis, located on the Atlantic coast, than in the upper valley, which has a more continental climate.

Potential yields for the wet season (WS; sowing in July) averaged nine t ha^{-1} in the Senegal delta and eight t ha^{-1} in the middle and upper valley. They fluctuated within a relatively narrow range of about two tons among the 10 annual scenarios (1970-79).

Currently recommended rice double-cropping schedules for the Senegal River delta and middle valley call for the second crop to be sown in February (hot-dry season (HDS). Potential yields in the HDS were 10 t ha^{-1} in St. Louis, nine in Rosso, eight in Podor, and five in Bakel, indicating that the HDS crop is most productive in the coastal zone and least productive in

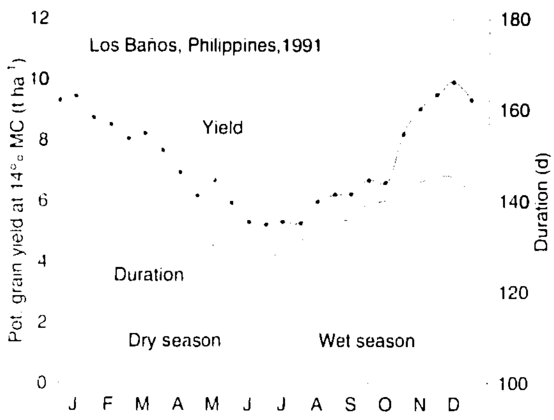


FIGURE 8: Relationship between grain yield (solid line) and sowing date, as simulated with OryzaS for transplanted Jaya rice in Los Baños, Philippines, in 1991. The broken line indicates the respective crop durations.

the continental climate of the upper valley. This phenomenon was caused by two physiological effects of high temperatures: a short duration of the main (linear) growth phase as it fell into extremely hot periods in the upper valley; and heat-induced spikelet sterility. Within the climate sequence of the river valley, therefore, rice double cropping would have the highest annual yield potential in the delta (up to 17 t ha^{-1} in Rosso). Actual farmers' yields in this environment, however, average about nine t ha^{-1} in double-cropping schemes and five t ha^{-1} where only one wet-season rice crop is grown, indicating a gap between potential and actual yields of 40 to 50%.

We simulated an annual cycle of sowing dates using the same varietal parameters for 1991 in Los Baños, Philippines (Figure 8). Yield potential was highest at about nine t ha^{-1} in the dry season (sowing dates in January), and lowest at 5.5 t ha^{-1} in the wet season (sowing in June or July). These results fully agree with results obtained under high inputs for a medium-duration variety at IRRI's lowland farm. In contrast to the Sahelian sites, where annual temperature patterns shaped the patterns of yield, potential rice yields in Los Baños were driven by solar radiation.

Potential yields in the Niger River system

The Niger River, along which irrigated rice is grown, is characterized by a continental climate. Rice is usually sown in June, the beginning of the wet season. Rice-rice double cropping on a larger scale is practiced only in Niger, represented in this study by Niamey (13° 32' N) (Figure 9). In Niger the second, cold-dry-season, crop is commonly sown in November or December. Although large public irrigation schemes are found around Niono in Mali (14° 18' N), rice double cropping is relatively uncommon. Between these two important rice-producing areas, the "knee" of the Niger River reaches as far north as 17°, harboring small village-based rice irrigation schemes exposed to a desert climate. These locations are represented by Gao and Tombouctou in the present analysis.

At the two sites with more moderate climate, Niamey and Niono, the highest potential yields were simulated for sowing dates in May. Mean potential yields for that month were between nine and 10 t ha^{-1}. Yields are only slightly lower for sowing in June and July, followed by a sharp decline caused by cold-induced sterility for sowing in August and September.

Sowing dates in the cold-dry season (October to December) were associated with high but variable yields. Yield variability during the cold-dry season was caused by low temperatures which permitted high biomass production due to the long duration, but poor sink capacity due to sterility and reduced potential grain size. Yield variability in the cold-dry season in Niono renders rice production extremely risky, suggesting a delay in sowing until January. Both predictions fully agree with observed cropping calendars at the respective sites.

At the near-desert sites Gao and Tombouctou, thermal constraints to potential rice yields were further accentuated. At Tombouctou, the long and intense cold season appears to prohibit rice planting between August and December, whereas a single wet-season crop sown in June may potentially yield about eight t ha^{-1}. At Gao, one of the hottest sites in the Sahel, the period during which low temperatures strongly reduce yield potential is comparatively short (sowing dates in September). But potential yields for the other seasons were generally low, such as 4 t ha^{-1} in the hot-dry season and less than seven t ha^{-1} in the wet season. Low yields were caused by heat-induced sterility and short crop duration.

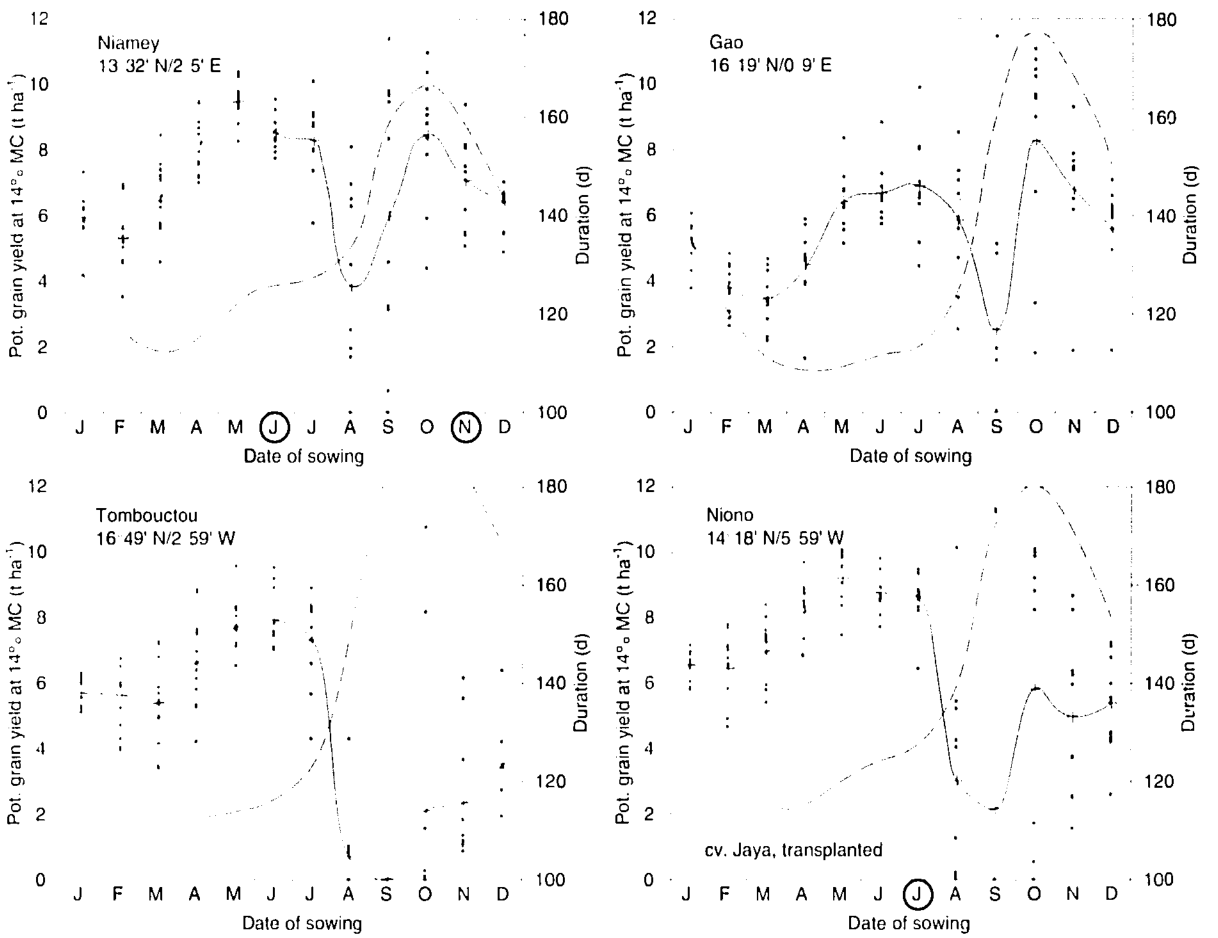


FIGURE 9: Simulated potential grain yields (solid lines), and crop duration (broken lines) as dependent upon sowing date for transplanted Jaya rice at four sites along the Niger River (means for 1970-1979 weather data; individual years are represented by points). Enhanced months indicate common planting dates for the respective sites.

North-South yield gradients

Simulations for the Niger River valley indicated lower potential yields for the northern locations of Gao and Tombouctou (> 16° N), as compared to Niono and Niamey (Figure 9). To further characterize this N-S gradient, we compared 11 sites located in the same river system between 11° to 17° N (Figure 10).

We found that potential yields for the main cropping seasons (hot-dry, wet, and cold-dry) consistently decrease as latitude increases, ranging from 4 to 10 t per hectare. The causes for this gradient, however, were not the same for the different seasons. In the wet main season at lower latitudes, such as in Sikasso, a slightly longer crop duration (ca. 140 d), comparatively cool nights (about 21° C minimum temperature) which reduce respiration losses, and the absence of sterility caused by extremely high or low temperatures, permit high potential yields of around 10 t ha^{-1}. The lower yields at higher latitudes were due to higher minimum temperatures, which caused a shorter duration and higher respiration rates.

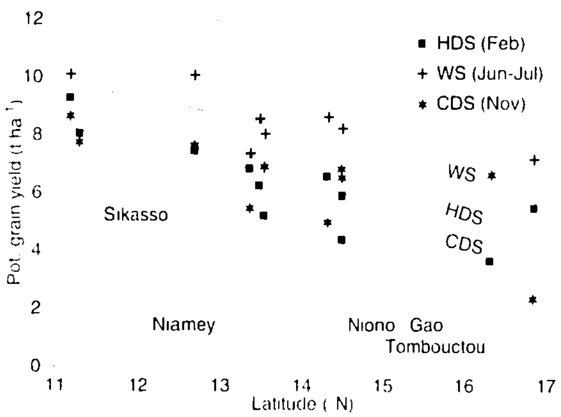


FIGURE 10: Relationship between simulated potential grain yield of transplanted Jaya rice and geographical latitude in the continental Sahel, separately for the hot-dry season (HDS), wet season (WS), and cold-dry season (CDS).

The hot-dry and cold-dry seasons were found to be potentially less productive than the wet season by 1.5 (11° N) to 2.5 t ha^{-1} (17° N), because of more severe thermal constraints. In the hot-dry season, high maximum temperatures that fall into the reproductive phase (April to May) reduce the duration of the linear growth period and induce sterility, particularly in the north (e.g., Gao). Solar radiation, in such cases, does not limit yields because of intensity, but through a shorter period during which radiation can be intercepted.

In the cold-dry season, the duration of the exponential growth phase is extended by low temperatures in December to February, causing slow leaf-area growth and low light interception. This is followed by hastened development during the main growth phase, caused by heat in March and April.

The Senegal River delta (ca. 16° N), represented in this study by St. Louis and Rosso (Figure 7), deviates markedly from the N-S gradient shown in Figure 10. The hot-dry season is highly productive because the proximity of the sea moderates air temperatures, even in March to June. At these sites, however, rice double cropping based on a single medium-duration variety is difficult because of extended crop duration in the hot-dry season. In practice, therefore, some of the extremely high yield potential in the hot-dry season is lost because short-duration varieties are required.

Synopsis of simulation results

At all typically continental-Sahelian test sites (Niamey, Gao, Tombouctou, and Niono on the Niger River; Bakel on the Senegal River), potential grain yields are lower in the hot-dry season than in the wet season. A timely planted wet-season crop is potentially more productive because spikelet fertility is not threatened by extreme temperatures, and grain filling falls into a favorable period after the cessation of rains, associated with high solar radiation, moderate day temperatures and cool nights in October and November. To fully utilize the superior yield potential in the wet season, late planting must be avoided because low temperatures at the booting and heading stages can cause total crop failure. The cold-dry season offers a superior yield potential in many years, but inter-year variation can be high.

We note that these results differ from the generally higher productivity of dry-season crops in monsoonal Asia, and even to the roughly equal observed performance of the wet- and dry-season rice crops in Niger. Our results are plausible, however, if we take into account that the wet-season crop in monsoonal Asia generally suffers from low solar radiation, which is not the case in the Sahel, and that the wet-season rice crop in Niger and Mali is much more affected by diseases than the dry-season crop.

The situation is again markedly different for the coastal climate in the Senegal River delta, where the cold-dry season is not suited to rice cultivation, and where the highest potential yields are observed in the hot-dry season (which, as compared to the continental Sahel, is not very hot). Here the main constraint is not yield potential but a long crop duration in the dry season, which renders rice double cropping extremely difficult.

Where rice double cropping is possible, combined annual potential yields vary between 11 t ha^{-1} (fringe of the Sahara desert, ca. 16° N) and 18 t ha^{-1} (transition to the subhumid zone, ca. 11° N). An economically important exception with very high potential yields in both dry and wet seasons is the Senegal River delta.

Outlook for future research

Our results suggest that in arid environments such as the Sahel, a high yield potential for rice under irrigated conditions should not be taken for granted — despite the abundance of water and solar radiation. The ability of the plant to actually utilize the radiation is limited by several mechanisms. The most important constraints are sink limitations (heat- or cold-induced sterility), a poor cumulative light harvest at midseason due to hastened development under hot conditions, and long growth lags and poor leaf area development at the seedling stage under cool conditions.

This study, in combination with previous economic studies and analyses of the biophysical feasibility of rice double-cropping calendars in different zones of the Sahel (Annual Reports for 1992 and '93), will guide WARDA's applied research for irrigated rice in the future. The results suggest four foci.

(1) The development of sustainable technology packages that would exploit the superior yield potential of rice double cropping in the climatically moderate southern portions of the Sahel, wherever irrigation water is available during both seasons.

This objective requires placing greater emphasis on the biotic constraints to yield, particularly in the wet season, through integrated pest management and enhanced varietal resistance to diseases, such as blast and rice yellow mottle virus. Constraints in the wet season resemble those in the humid zone, but the dry season requires varieties that are also cold tolerant at the seedling stage. The same medium-duration variety can be grown in both seasons if it combines the necessary adaptations.

(2) The development of sustainable technology packages that would exploit the superior yield potential of rice double cropping in zones where the climate is moderated by the sea and irrigation water is not limiting.

This objective requires a continued focus on the photothermal (phenological) responses of genotypes to climate, in order to develop options for either a bivarietal system (one short- and one medium-duration crop) or a monovarietal system (one intermediate variety with stable duration), depending on the socioeconomic context. Substantial progress has been made at WARDA in recent years towards achieving this objective.

(3) The development of cropping systems based on a single, highly productive rice crop per year for zones in the Sahel that have extremely high and low temperatures in the dry season.

This objective requires more conceptual refinement because of little past attention. A number of planting-time calendrical options and varietal duration (or photothermal) types can be considered which might be combined with a different crop grown in the cool season. Simulation can provide valuable assistance for screening options *ex ante*.

(4) The development of cropping systems based on a single, highly productive rice crop per year where not the climate, but water availability and/or socioeconomic considerations, stand against rice double cropping.

This objective has been pursued by WARDA's lowland breeding program in Ibadan, and it will be expanded to the Sahel as appropriate. Vegetable or wheat crops might be considered for before or after the rice crop.

We are aware that these preliminary conclusions have been derived from research tools that do not take into account all relevant parameters. Complementary studies on the management of the natural resource base have been initiated (soil conservation and the rehabilitation of degraded soils). But crop simulation will continue to guide us in further refining the applied concepts and in achieving full research coverage of the Sahel environment's diversity.

THE CONSORTIUM FOR SUSTAINABLE USE OF INLAND VALLEYS IN SUB-SAHARAN AFRICA

Consortium Coordinating Unit

SEMIDETAILED AGROECOLOGICAL CHARACTERIZATION OF INLAND VALLEYS IN CÔTE D'IVOIRE

P.N. Windmeijer (SC-DLO), N. van Duivenbooden (AUW), and J.Y. Jamin (CIRAD)

Agricultural research and development of improved technologies in West Africa is challenged by high spatial and temporal variability across agroecosystems. That is, many research results and improved technologies tend to be location specific, and unlikely to transfer to other areas within the broad agroecological zones. Characterization research is designed to describe key parameters within such spatial diversity and to classify agroecosystem similarities at various scales. Spatial classification, in turn, permits the extrapolation of research results to known areas and the more efficient targeting of new technologies.

The Consortium for Sustainable Use of Inland Valleys conducted several characterization activities in 1994. These included reconnaissance characterization in Ghana, Mali, and Benin, semidetailed characterization in Sierra Leone, and detailed characterization in Burkina Faso. Semidetailed characterization in two key areas in Côte d'Ivoire was completed in 1994. One of the major objectives of this project was to test the methodology developed for this level of characterization.

Methodology of the multiscale agroecological characterization

The objective of our agroecological characterization is the comprehensive description of physical (climate, lithology, landform, soils, and hydrology) and biotic (vegetation and land use) parameters of agroecosystems. Land use (primary and secondary production) is described, including its socioeconomic identifiers (labor, capital input, and management). The degree of detail depends on the scale of characterization. A multiscale approach has been developed because data collection, interpretation and, later on, planning, always take place at various levels.

The multiscale agroecological characterization consists of four levels: macro (scales between 1:1,000,000 and 1:5,000,000), reconnaissance (1:100,000-1:250,000), semidetailed (scales 1:25,000-1:50,000), and detailed (1:5,000-10,000). Each level has its specific method of data collection and its own minimum data set.

Semidetailed characterization

The semidetailed characterization uses field surveys by transects and farmer interviews to describe the physical environment and land cover/use. We conducted surveys in four inland valley systems per key area, selected on the basis of the macro-characterization, reconnaissance characterization, and site selection missions. The inventory began with the interpretation of recent aerial photographs. In each of the identified valley systems four to five transects were selected for field description. The transects cut across different valley segments, from crest to crest. Along with the various land subelements occurring in the transect, several physical characteristics were described or measured, and soils were sampled. Land cover and use were described for a strip of land 200 to 400 m wide along the transect line. Farmer interviews provided additional information on physical and land-use parameters.

We quantified key valley characteristics to facilitate the comparison of different valleys or different land subelements within valleys. The Valley Bottom Ratio (VBR) is the ratio of the area occupied by the higher parts of the valley (crests, slopes, and fringes) over the area of the valley bottom. It is a possible measure for the potential amount of water, related to the total rainfall, that may flow as runoff or as groundwater from the higher parts of the valley into the valley bottom.

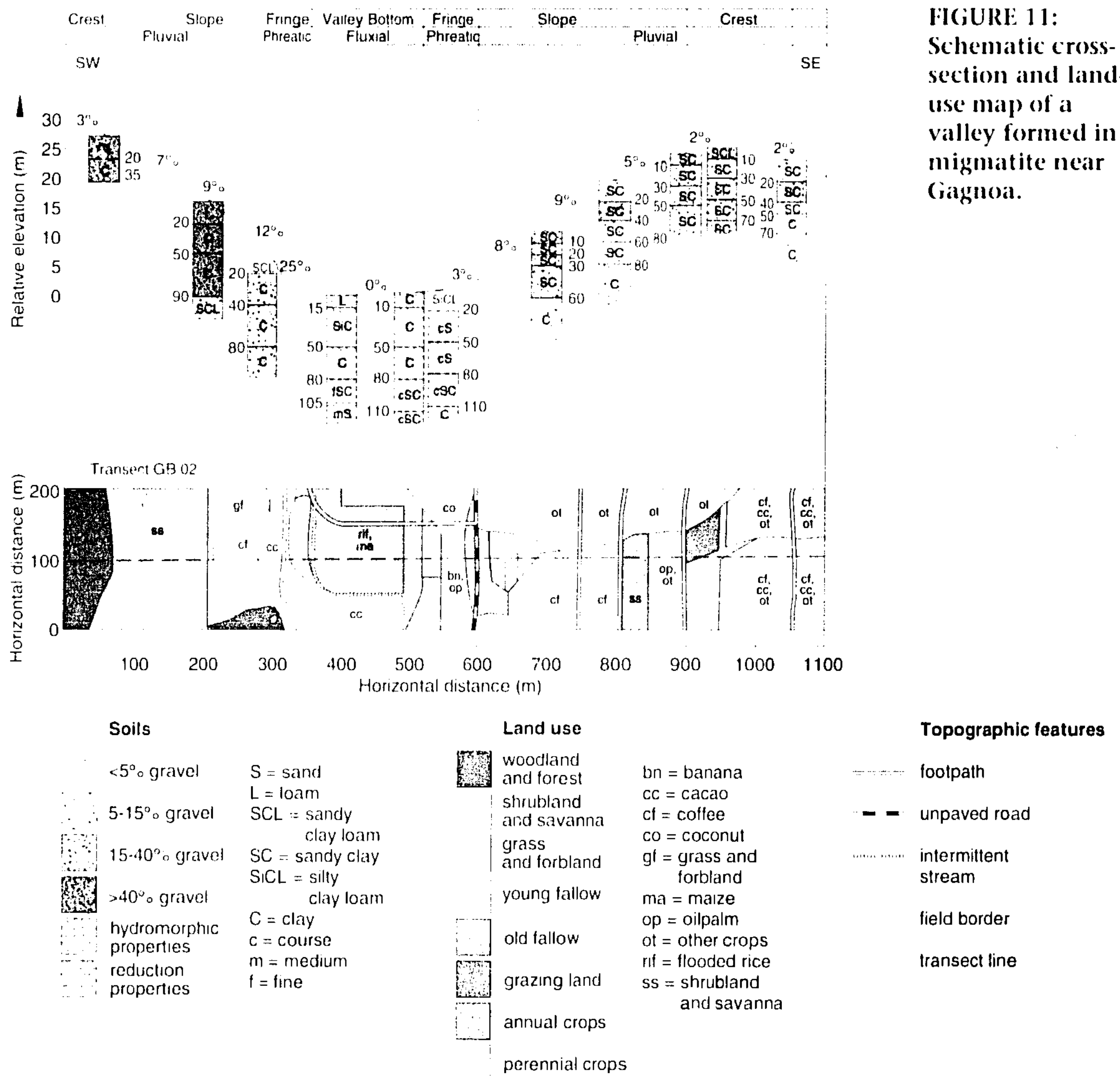


FIGURE 11: Schematic cross-section and land-use map of a valley formed in migmatite near Gagnoa.

We also calculated land-use class ratios to express the relative area of the individual land-use classes over the total area of the land subelement. From these individual land-use class ratios, the Land Use Ratio (LUR, in %) was calculated as the sum of cropped area, prepared land, grazing land, and young fallow (< 10 years), divided by the total area of the land subelement. By excluding the grazing and young fallow components from the LUR, the rate of actual crop cultivation is expressed in the Actual Production Ratio (APR, in %). The Fallow Index (FI) expresses the importance of fallow in the cropping system. The FI is zero in the absence of fallow, and 0.5 when fallow and cropped land cover the same area. Finally, the Soil Preparation Intensity (SPI, %), expressed as the area plowed or ridged, or where mounds and soil beds were constructed, is a measure of land-use intensity.

Results of the semidetailed characterization in Côte d'Ivoire

We implemented surveys in two key areas. The first area is located near Boundiali in the Guinea savanna

TABLE 4: Selected physical and land-use characteristics of valley systems in the Boundiali and Gagnoa key areas, Côte d'Ivoire.

	Boundiali		Gagnoa	
	Schist	Granite	Schist	Migmatite
Physical characteristics				
Average width (m):				
total valley	1646 (± 477)	1383 (± 354)	842 (± 104)	980 (± 249)
crests and slopes	704 (± 189)	571 (± 238)	309 (± 124)	390 (± 189)
fringes	32 (± 37)	33 (± 33)	46 (± 42)	54 (± 54)
valley bottom	42 (± 27)	31 (± 34)	157 (± 58)	105 (± 60)
Valley bottom ratio (VBR, -)	64 (± 51)	81 (± 55)	5 (± 3)	13 (± 15)
Slope gradient (%)	1-4	2-7	4-10	4-12
Land-use characteristics				
Land Use Ratio (LUR, %)				
total valley	28	33	76	61
crests	17	24	75	44
slopes	30	32	82	63
fringes	11	42	83	71
valley bottoms	28	46	51	50
Actual Production Ratio (APR, %)				
total valley	11	11	53	33
crests	4	2	24	25
slopes	11	11	65	35
fringes	9	8	63	34
valley bottoms	20	28	21	30
Fallow Index (FI, -)				
total valley	0.75	0.71	0.31	0.5
crests	0.89	0.96	0.68	0.46
slopes	0.74	0.71	0.21	0.51
fringes	0.53	0.85	0.25	0.55
valley bottoms	0.32	0.4	0.59	0.4
Soil Preparation Intensity (SPI, %)				
total valley	75	62	0	5
crests	62	100	0	1
slopes	79	74	0	4
fringes	19	76	0	9
valley bottoms	50	13	0	9

(± 477): standard deviation

zone (growing period of 165-270 days). The second area is situated in the equatorial forest zone (growing period > 270 days), near Gagnoa. Both areas have the same total annual precipitation, about 1400 mm/year in Boundiali (a monomodal rainfall regime) and 1500 mm/year in Gagnoa (a bimodal rainfall regime). Population density in the Gagnoa key site (26-35 persons/km^2)is higher than near Boundiali (< 16 persons/km^2). Using the reconnaissance characterization, we subdivided the key areas into agroecological subunits: schist and granite in Boundiali, and schist and migmatite in Gagnoa. Information from the individual transects was processed into agroecosystem diagrams. These diagrams show a cross-section with a number of physical parameters, and a map showing the actual land use. An example is shown in Figure 11. Information on individual transects was then aggregated to the level of the key area.

THE INLAND VALLEY CONSORTIUM

The Inland Valley Consortium (IVC) was officially established on the first of April 1994. Preceded by two years of intensive discussions between national and international agricultural research institutes, several workshops, and a pre-project phase, funded by The Netherlands. The present members of the Consortium are the national research institutions of Benin, Burkina Faso, Côte d'Ivoire, Ghana, Mali, Nigeria, and Sierra leone, and five international research institutions, the West Africa Rice Development Association (WARDA), the International Institute for Tropical Agriculture (IITA), the DLO Winand Staring Center (SC-DLO), the Wageningen Agricultural University (WAU), and the Centre de Coopération Internationale Recherche Agronomique pour le Développement (CIRAD). Because the Consortium is an open structure for cooperation, new members are expected in the near future.

Consortium oversight is provided by the Steering Committee, which obtains its executive mandate from the Annual Workshop. Daily management is carried out by the Consortium Coordinating Unit (CCU). The CCU has direct links with National Coordinating Units, through National Coordinators, representing the involved national institutions. The CCU is responsible for fund raising, while the Steering Committee allocates budgets to Consortium activities. The CCU is hosted by WARDA, in M'be, Côte d'Ivoire.

The immediate objectives of the IVC program are: (1) to develop a structure for cooperation between NARS, ICAR, and other institutions; (2) to develop common methodologies for research, data storage and interpretation, and the exploration and transfer of results; (3) to implement complementary multidisciplinary agroecological characterization; (4) to develop and test improved low-cost water management technologies; and (5) to transfer and test at field level improved agronomic technologies in inland valleys.

In 1994, the Consortium was financially supported by the Government of the Netherlands (DGIS). DGIS has committed to support the Inland Valley Consortium during the first five-year program. In 1995 French Cooperation will also begin funding the Consortium. Also for 1995, the Technical Advisory Committee of the CGIAR approved the Consortium program as one component of an ecoregional initiative for the humid and sub-humid tropics in sub-Saharan Africa for which IITA is the convening center.

MAJOR CONSORTIUM PUBLICATIONS AND REPORTS UP TO THE END OF 1994

Publications

Windmeijer, P.N. and Andriesse, W. (Eds). 1993. Inland valleys in West Africa. An agroecological characterization of rice-growing environments. Publication 52. International Institute for Land Reclamation and Improvement, Wageningen, The Netherlands, 160 pp.

Andriesse, W., Van Duivenbooden, N., Fresco, L.O., Windmeijer, P.N. 1994. A multi-scale approach to characterize inland valleys agro-ecosystems in West Africa. *Netherlands Journal of Agricultural Science* 42: 159-179.

Reports

Windmeijer, P.N., Van Duivenbooden, N., Andriesse, W. 1994. Semi-detailed characterization of inland valleys in Côte d'Ivoire. Characterization of rice-growing agro-ecosystems in West africa. Technical Report 3, Volume 1: Main Report; Volume 2: Basic Data. SC-DLO, Wageningen, The Netherlands.

Van Duivenbooden, N. and Windmeijer, P.N. 1994. Manual for semidetailed characterization of inland valleys. Characterization of rice-growing agro-ecosystems in West Africa. Technical Report 4. WARDA/IITA/SC-DLO/WAU. SC-DLO, Wageningen, The Netherlands.

Van Duivenbooden, N. and Windmeijer, P.N. 1994. Final report on project activities by SC-DLO and WAU. Characterization of rice-growing agro-ecosystems in West Africa. SC-DLO, Wageningen, The Netherlands.

The figures in Table 4 show average values and variability of valley system characteristics at the key area level. In the Boundiali key area, the valleys are much wider than in Gagnoa, in accordance with the various drainage densities observed in the two key areas. The valley bottoms, however, are much wider in Gagnoa: the VBR in Gagnoa ranges from 5 to 13, whereas in Boundiali the VBR varies between 64 and 83. Moreover, valley slopes are steeper in Gagnoa (4-12%) than in Boundiali (1-7%).

Table 4 does not show all differences found in the field. For instance, valley bottoms in the Boundiali key area have a stepped longitudinal profile. In parts of the valley systems relatively deep incised streams were found, resulting in a short flooding period, if flooded at all. In Gagnoa, all the valley systems have a smooth longitudinal profile. Soils near Boundiali all have a compact topsoil, whereas near Gagnoa, the micro soil structure is much stronger, resulting in low compaction of the topsoil, after clearing the vegetation.

Differences in physical characteristics between agroecological subunits are much less pronounced than between units, but they do occur. In the Boundiali key area, for instance, valley bottoms in the granite subunit have a longer humid period than those in the schist area, because of the greater lithologically induced interflow from the uplands. Because of their finer texture, the soils formed in schist show higher organic matter contents compared with soils found on granite.

A number of land-use differences between the key areas were also observed. For example, land use in the Gagnoa key area is much more intensive (average LUR: 62-73%) than in Boundiali (LUR: 28% to 33%). The LUR values for the different land subelements show that slopes and fringes are more intensively used in Gagnoa (LUR range: 63-83%) than in Boundiali (11-42%). Farmers in Boundiali appear to prefer cultivating valley bottoms. This is particularly apparent from the APRs. These also show low values for the crests, most clearly in the Boundiali area (APR: 2-4%).

Because of the higher land pressure in Gagnoa, less land remains under fallow than in Boundiali. FIs vary between 0.31-0.50 in Gagnoa and 0.71-0.75 in Boundiali.

A striking difference was found in the soil preparation index. Probably because of the more compact soil structure, between 62% and 75% of the area under cultivation in Boundiali was plowed or ridged, or mounds and beds had been constructed. In Gagnoa only five percent of the fields showed this kind of land preparation.

Conclusions

The semidetailed characterization is used as a relatively rapid appraisal for collecting information on variable inland valley agroecosystems. The results of our characterization activities in the two key areas of Côte d'Ivoire show that the method can be an effective tool for describing and analyzing differences between inland valley agroecosystems, and between and within agroecological subunits. The tested methodology will be applied in the national programs of the seven consortium member countries.

Although this level of detail is far from comprehensive, particularly with respect to dynamic processes, enough information was collected to guide the selection of one inland valley system for subsequent more detailed characterization. The detailed characterization will produce information on variability and dynamic components. It will also show whether describing only four to five transects will be sufficient for optimal coping with the variability at the semidetailed level.

In 1995, detailed agroecological characterization will be carried out in one inland valley system in each key area: a schist valley near Boundiali and a migmatite valley near Gagnoa. These valleys have been selected for their representativeness and their potential for increased sustainable agricultural production.

The characterization of inland valley agroecosystems is not an objective in itself. The knowledge gained from these activities will form the scientific basis for implementing research on water management technology development and for testing existing improved agronomic technologies. Information collected by characterization will be used to describe the agroecosystems. A number of key parameters, however, will be used for developing a generalized typology of inland valleys. This typology will subsequently serve as a tool for guiding the development and testing of new technologies.

SUMMARIES OF RESEARCH ACTIVITIES

UPLAND/INLAND SWAMP CONTINUUM PROGRAM

Most of the rice grown in the humid and subhumid zones of West Africa is cultivated on small fields with low management inputs. Such fields occupy narrow, hydrologically variable, transitory segments of toposequences, thereby depending on rainfall and the water movement within small watersheds. This complex and highly diverse environment stands in marked contrast to the more homogeneous floodplains associated with major rivers and their delta regions in Africa and Asia. It can only be understood through an integrated multidisciplinary approach that carefully considers the scale specificity of biophysical phenomena on the one hand, and the diversity and intertwinedness of farmers' objectives on the other hand. This was the basic rationale for WARDA's decision in 1989 to address the rainfed lowland, seasonally hydromorphic, and free-draining upland ecosystems through one combined research effort, the "Continuum Program", which encompasses about 82% of ricelands and 75% of rice production in West Africa.

Each of the program's five main projects cuts across the different ecosystems found in the continuum: the agroecological and socioeconomic characterization project, the cropping systems project, the soil fertility management project, the integrated pest management (IPM) project, and the varietal improvement project. Each project involves a range of disciplines and includes problem-oriented subprojects with explicit timeframes and output projections.

The year 1994 saw a considerable expansion of the disciplines involved in the Continuum Program's research; the invigoration of WARDA's agroecological characterization project through the effective establishment of the cross-institutional Inland Valley Consortium (IVC); and the activation of research in a number of crucial subprojects which will increasingly define WARDA's research in the medium term.

All of the Continuum Program's projects benefited from the secondment of a physiologist from CIRAD, although his main research focus will be on varietal drought resistance and the characterization of drought-prone environments. An EC-funded hydrologist joined the program to provide crucial research links between the crop and the dynamics of water resources along toposequences and within watersheds. An ODA-funded nematologist will fill an important gap in our knowledge on the interaction of soil-borne nematodes with above-ground biotic stresses and their edaphic and cultural determinants. A systems analyst was recruited and made program leader to help in integrating discipline- and scale-specific components of research, thereby introducing systems research tools such as crop and resource modelling, geographical information systems (GIS), and remote sensing. Systems research will also provide important links between WARDA's detailed research foci and the IVC, whose objective is to develop a masterplan for the development of inland valleys based on the extensive regional characterization of watersheds.

Probably the most significant highlight of 1994 research in the Continuum Program, WARDA scientists lifted the lid off a largely ignored black box, the unexpectedly rich genepool of the African indigenous rice species *Oryza glaberrima*. For the first time, this species is now being fully and systematically characterized for its cultural, physical, and biological adaptations. Remarkable adaptation to biotic stresses has been revealed, such as to rice yellow mottle virus (RYMV), blast disease, the African rice gall midge (ARGM), and weed competition; and to abiotic stresses such as drought, acid oxisols, and iron toxicity. Moreover, improved methods of interspecific hybridization with *O. sativa* adopted by WARDA scientists now seem to make possible the selective elimination of traits that in the past have prevented the improvement of *O. glaberrima*: its characteristic branching panicle, which severely limits yield potential; and grain shattering, dormancy, and lodging.

Significant progress was also made in the characterization of a well-developed but potentially vulnerable equilibrium of natural pest-control mechanisms in the upland; the development of a network of key sites representing important agroecological and socioeconomic rice environments at which yield gaps are studied and technologies tested on farmers' fields in collaboration with NARS; and the generally increasing interaction between WARDA's station research and Task Force-based research at NARS sites throughout the region.

In 1995 we will further sharpen our focus on key research tasks, and we will strengthen our collaboration with advanced research centers abroad, particularly in the fields of biotechnology, systems research, and the management of soil fertility.

PROJECT 1: CHARACTERIZATION PROJECT

The rice-growing ecosystems of the upland-inland swamp continuum are highly diverse. Their potential for production is determined by the interplay of many factors, including geology, climate, soil types and hydrology, vegetation, and a range of socioeconomic factors. Within these ecosystems, farmers have developed a variety of rice-based cropping systems that typically cut across toposequences in the inland valleys. The development of technologies for these farmers requires a thorough understanding of the socioeconomic and biophysical conditions under which they operate, and of how they perceive risks and employ resources to achieve their multiple objectives.

To appropriately prioritize and aggregate research objectives, in 1990 WARDA initiated a multidisciplinary characterization project that addresses rice production environments, at the detailed micro (key site) and macro (subregional) scales, and on the socioeconomic and biophysical levels. Beyond the initial phase which included literature and survey-based inventories, this project moved towards detailed analyses of farmers' objectives and perceptions of production constraints from 1992 through 1994, and towards onfarm yield-gap studies at representative key sites in 1994. The socioeconomic analyses during 1994 focused on the technical fit and relative profitability of rice systems within existing farming systems; on gender roles in different rice-production systems; and on farmers' perception of biotic constraints to rice production and the control options they know. Biophysical characterization studies in 1994 included the integration of researchers' plots into farmers' fields having different cultivation histories, in order to provide a time dimension to the observed yield gaps.

From 1995 onwards, the characterization project will work in close collaboration with the Inland Valley Consortium (IVC), a multi-institutional ecoregional initiative, in order to systematically raise key-site-based knowledge to the regional level. In this activity we will spatially project and overlay environment typologies in order to identify environments with common features, for which land-use scenarios are then evaluated by simulation and experimentation. This program, which involves the NARS of eight West African countries, IITA, CIRAD, and research institutes at Wageningen, aims at developing a master plan for the sustainable utilization of inland valleys in the region.

Effect of cropping intensification on constraints in upland rice

M. Becker, E. Heinrichs, and D. Johnson

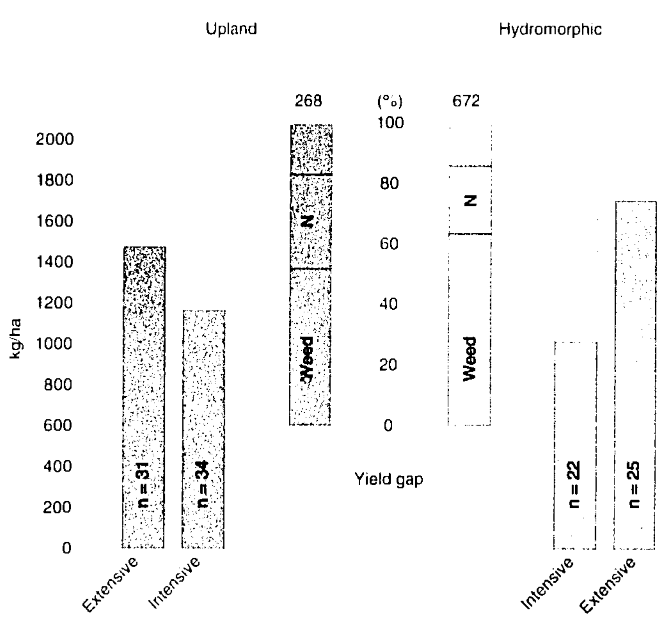
Traditional upland rice-based cropping systems in West Africa rely on extended periods of bush fallow to restore soil fertility and prevent the buildup of pests. Population growth and land shortage are forcing many farmers to reduce these periods as they intensify their rice production systems. Among surveyed farmers in the forest zone of Côte d'Ivoire, fallow length decreased from about 12 years in the mid-1980s (extensive system), to typically six years at present (intensive system). In the savanna zone, the number of successive crops grown before leaving the land to fallow has increased from three to five in the same period. We hypothesize that intensified cropping will lead to higher weed infestation, lower organic matter content and nitrogen supply capacity, and may influence insect pests and their natural enemies. To test these hypotheses, we conducted diagnostic studies during 1994 in three agroecological zones in Côte d'Ivoire (humid forest, forest-savanna transition, and moist savanna). A total of 116 farmers' fields were included in the study, representing various fallow lengths (1-35 years) and a range of preceding crops.

To determine the response of rice to the application of mineral nitrogen (30 kg N ha^{-1}) and to improved weed control (hand weeding at 28, 56, and 84 days), researcher-managed subplots were superimposed on farmers' fields. Rice growth and yield parameters were recorded, and weed growth (species composition and biomass) was described at monthly intervals. Insect pests in the rice canopy were studied by the use of sweep nets, and the species composition and abundance of stem borers were determined by plant dissection and the incidence of dead hearts. Leaf feeding was recorded by assessing percentage of defoliation, and termite damage was assessed visually. Predaceous arthropods were caught in pitfall traps and counted.

Comparing fields following long and short fallows, we observed that weed biomass in the forest zone and forest savanna significantly increased with cropping intensification. Short-fallow fields in the forest zone were dominated by broadleaf species (e.g., *Chromolaena odorata*), whereas grasses (e.g., *Imperata*, *Digitaria*, *Andropogon*) dominated in the savanna. Adult populations of the insect pests *Diopsis* spp. were greater in the forest than in the forest savanna zone and, along with certain predaceous arthropods, were positively correlated with fallow length. Intensification of upland rice-bush fallow rotation systems (< 5 years fallow or > 3 consecutive crops) across agroecological zones and environments was associated with a significant decline in grain yield, compared to traditional long-fallow systems (> 6 years fallow or < 2 consecutive crops). Across the three zones, nitrogen application and additional weed control both gave significant increases in yield above farmers' levels. Rice in the hydromorphic zone tended to be more responsive to management interventions. Grain yields were increased by additional weeding (explaining about 60% of the yield gap between short- and long-fallow fields) and by the addition of nitrogen (explaining about 30% of the yield gap between short- and long-fallow fields).

Burning of the vegetation after a short fallow and before sowing of rice in the humid forest area near Gagnoa, Côte d'Ivoire.

FIGURE 12: Rice yield reduction and yield gaps in intensively cultivated upland and hydromorphic ecosystems, as compared to extensive cultivation. Means across sites in three agro-climatic zones in Côte d'Ivoire, wet season 1994.



Combining N application and additional weed control in intensive systems resulted in yields similar to those in extensive long-fallow systems with farmer management. We conclude that future strategies to allow the sustainable intensification of the fallow systems should aim at suppressing weeds and improving soil fertility, particularly by raising its organic matter and nitrogen content. This might be achieved through the improvement of fallow quality by introducing fast-growing cover legumes.

Sowing rice shortly after the fallow vegetation has been burned in the humid forest zone near Gagnoa, Côte d'Ivoire.

Modelling income and risk trade-offs in cropping systems of the savanna zone of Côte d'Ivoire
A.A. Adesina and A. Ouattara

Risk and uncertainty are pervasive characteristics of agricultural production. Farmers face a number of threatening biophysical factors, such as severe or unusual weather, diseases, pest infestations, changing economic environment, introduction of new crop technologies, uncertainties surrounding public institutions and their policy implementation, and changes in factor and product prices. In West Africa, the lack of institutional innovations, like crop insurance, disaster payments, and emergency loans to shift part of the risk to the public sector, makes risk management a critical part of farmers' decision-making. Farmers in the savanna zone face high rainfall risks, yet very few studies have looked at the relative income-risk trade-offs of crops cultivated in this zone of West Africa.

To better understand the effects of rainfall, yield, and price risks on the optimal cropping patterns in the savanna zone of Côte d'Ivoire, we used risk-programming whole-farm models in 1994. The models incorporate farmers' risk aversion indices and farm-resource use and cropping patterns. Data for developing the models were collected from a cost-route survey of a representative sample of 85 farm households in three villages. Three villages with different characteristics were considered: Mbengue village is located in the drier Sudanian zone, while Napie and Sirasso villages are located in the Guinea savanna zone. Napie is a village with very high population density (51 pers km^{-2}). Sirasso and Mbengue have low population pressure, with 14 pers km^{-2} and 12 pers km^{-2}, respectively. In addition, Sirasso and Napie have access to irrigation, although the irrigation capacity is higher in Sirasso. The dam in Napie is small, and farmers often face high risks for the second-season irrigated rice crop.

We developed representative farm models for three types of farms found in the savanna zone: hand-tillage, oxen-tillage, and tractor farms. Time series data on yields and prices for all crops were used to derive the income distributions of various crop enterprises. Based on the distribution of both prices and yields, the coefficient of variation of incomes to each enterprise—which gives the relative risks of crops in each village—was determined. We found that maize has the highest income risks across all the villages, followed by the second-season irrigated rice crop in Napie.

Validation of model results showed that the calibrated base model closely predicts observed cropping patterns. Risk-efficient cropping patterns were then derived, based on farmers' risk aversion: risk neutral, moderately risk averse, and risk averse. The results showed, in general, that risk attitudes affect the choice of optimal risk-efficient cropping patterns and that significant reduction in income risks (and increased income gains) can be made by re-allocation of the existing crop mix to the risk-efficient portfolios. Risk-averse farmers sharply reduce cultivation of maize in the risk-efficient optimal solutions and re-allocate to crop portfolios that give lower income risks for the farm. In general, expected incomes and income risks follow an inverse pattern as the level of risk aversion increases.

For risk-efficient solutions for both manual and oxen farms in Napie, it was found that the cultivated area in the second-season irrigated rice crop declined for highly risk-averse farmers, reflecting the higher risks of the second-season crop in this village. This result suggests that farmers who are currently cultivating irrigated rice in Napie are most likely to have low levels of risk aversion or to be risk neutral. When the results of Napie and Sirasso are taken together, they imply that given the monomodal rainfall patterns in the savanna zone, farmers who live in areas with good irrigation will cultivate the second-season rice crop; but in areas with limited water capacity, double cropping rice in the second season becomes a highly risky decision, and risk-averse farmers will reduce cultivated area or abandon the second-season rice crop altogether.

Farmers may be unable to adjust their cropping patterns to the risk-efficient portfolio mix due to imperfect information on the distribution of relative income risks of various crops, inadequate ability to predict market shocks that alter the structure of product and input prices, and/or culturally determined traditional food habits that may override the need for crop-mix reallocation based solely on market factors.

We conducted simulations on the effects of changes in paddy price incentives for rice production on the three farm types in the study villages. Using simulated model results, we computed normative market supply and acreage response elasticities. The results show that optimizing farmers would respond to price incentives by bringing significantly more upland areas into cultivation. The inelastic supply of lowlands and the perfectly inelastic land supply for irrigated lands limits expansion possibilities in these ecosystems. When averages of the two villages in the Guinea savanna are used, results showed that farms in this zone have higher acreage response elasticity than those in the lower-potential Sudanian zones. The market supply elasticities for oxen farms are higher than for hand-tillage farms in all the villages. In both Mbengue and Sirasso villages, the estimates of the market supply elasticities are lower than the acreage response elasticities. This indicates that although the elastic land supply situation (for uplands) in these villages allows rice production expansion—by bringing more upland areas into cultivation—the output effect of such a process on market supply is likely to be mitigated by low yields in the uplands.

The results have three implications for technology development strategies in the savanna zone. First, in evaluating technology options in the cropping systems, it is important to consider not only the yield of alternative crops, but also the yield-, price-, and income-risk that farmers are likely to face in changing their cropping patterns. Second, to reduce risks faced by farmers, especially in rainfed systems, emphasis should be placed on yield stability of technology interventions. Third, since farmers are likely to respond to rice production incentives by expanding areas cultivated in the less fertile upland rice ecosystem, it would be increasingly important to develop appropriate upland rice technologies that can ensure sustainable productivity increases in this ecosystem.

Does rice farmers' education influence the economic efficiency of rice production?

A.A. Adesina and K.K. Djato

Policymakers in Côte d'Ivoire are currently debating institutional reforms for directing technical assistance to farmers. This has led to the recent creation of the Agence Nationale d'Appui au Développement Rurale (ANADER), a governmental institution that develops strategies for agricultural extension, as well as educational and institutional support for farmers. This preoccupation with farmers' general education is common to most countries in sub-Saharan Africa and is often based on the assumption that "educated" farmers are more efficient than "non-educated" farmers. The underlying assumption is that investment in farmer education is likely to lead to substantial gains in economic efficiency under existing technology sets.

To test this assumption, and thereby provide the current debate on this issue in Côte d'Ivoire with some empirical information, we examined the relative differences in technical, allocative, and economic efficiency between educated and non-educated rice farmers. Our analysis was based on duality methods, using the normalized restricted profit function approach with factor share equations. Series of hypotheses on technical, allocative, and economic efficiency were tested using systems of simultaneous models.

Data used in the analysis had been collected from August 1992 to April 1993 from a sample of 410 rice farmers in several villages in the northern region of Côte d'Ivoire where extension agencies are quite active. Because the rice production technologies available in northern Côte d'Ivoire consist of modern rice varieties, chemical fertilizers, herbicides, insecticides and mechanization, one would expect modern education, especially literacy, to influence the levels and efficiency of use of such inputs. The use of external inputs was common across farms of both the educated and non-educated farmers. The mean level of use of urea ha^{-1} was similar for both educated and non-educated farmers (i.e., 53 kg ha^{-1} for the non-educated farmers and 51 kg ha^{-1} for educated farmers). However, the mean use of NPK ha^{-1} was slightly higher for the educated farmers (i.e., 175 kg ha^{-1} compared to 134 kg ha^{-1}), although there exists wide variability in use intensities across farms. On average, there does not exist much difference in yield ha^{-1}, with mean yields for the educated farms being 1.8 t ha^{-1}, and 2.2 t ha^{-1} for educated farmers. As with fertilizers, this mean yield masks high variability across farms.

In the initial model runs we defined educated farmers as those who had at least one year of formal schooling. On this basis, we found no differences in either relative technical, allocative, or economic efficiencies between educated and non-educated farmers. To evaluate the sensitivity of our results to the education threshold, we repeated the analysis for an education threshold of six years of formal schooling, which is commonly considered the minimum for literacy in Côte d'Ivoire and enables obtaining the "Certificat d'Etudes Primaires". The different threshold did not alter the outcome, however, indicating that our results were robust.

Three factors may explain these results. First, non-educated farmers may have an empirical knowledge obtained from cumulative farming experience, and may therefore well understand their farm settings and how to adjust factor use. Consequently, farming experience may play a greater role than formal school education in influencing farmers' allocative decisions. Second, there may be very limited search and learning costs for obtaining information on new technologies if they are available. Farmers learn about new crop varieties or alternative agronomic practices mostly from other farmers. Third, most of the technologies recommended to farmers are provided by rural extension workers in "ready-to-use" or "decoded" forms. In most cases, farmers accumulate knowledge of these practices through learning-by-doing. Thus, there may be little or no premium to education in terms of increased economic efficiency of rice production systems.

The results from our study do not support the conventionally held opinion in policy circles in Côte d'Ivoire that educated farmers are more efficient than non-educated farmers. Our analysis suggests that rural development efforts should not be biased towards "educated" farmers, as "un-educated" farmers are just as efficient. This does not mean, however, that education is wasted on farmers. It may just not be a limiting factor in rice production.

PROJECT 2: CROPPING SYSTEMS

Most rice in West Africa is produced by small farm holders who use few or no external resources and who have a varying balance between subsistence and commercial objectives. Due to demographic growth and land shortage, farmers' production objectives are increasingly short-term, with inadequate concern for maintaining the natural resource base. Particularly in traditional rainfed rice production systems, farmers increasingly move from extensive to more intensive cultivation without adapting their traditional practices to the new objectives. As a result, the natural vegetation is receding rapidly, soils are eroded and mined for organic matter and nutrients, and the weed pressure is increasing.

To meet the region's food needs and to ensure the long-term productivity of rice-based production systems, nutrient inputs and outputs in the system need to be balanced, and resources must be used more efficiently. The biophysical and socioeconomic interdependence of upland and lowland ecosystems within inland valleys calls for the development of integrated crop, nutrient, water, and weed management strategies that stabilize the fragile uplands and increase productivity of the more robust lowland ecosystems.

Effects of crop and fertilizer management on the sustainability of intensified rice cultivation in the continuum

M. Becker and D. Johnson

To ensure that the ongoing shift from extensive to intensified rice-based cropping systems in virtually all West African rice ecosystems is sustainable, improved crop and resource management practices are urgently required. The improved management practices must be socially and economically acceptable and must enable a stable performance of the cropping systems over extended periods of time. An equally important goal is to improve the use efficiency of resources, particularly that of

TABLE 5: Predicted conditional probability of adoption of chemical fertilizers on rice fields: effects of sex, ecosystem, type of cultivation, and distance of fields to village. Côte d'Ivoire, 1993. **See page 33.**

LOWLAND ECOSYSTEM

Type of cultivation and sex of plot owner	Distance of Field to the Village (kilometers) 0.5	1.5	3.0	4.0	5.0	10
Manual						
Male	0.47	0.36	0.22	0.16	0.11	0.01
Female	0.10	0.07	0.04	0.02	0.02	0.00
Mechanized						
Male	0.94	0.91	0.84	0.77	0.69	0.20
Female	0.66	0.56	0.40	0.30	0.21	0.03

UPLAND ECOSYSTEM

Type of cultivation and sex of plot owner	Distance of Field to the Village (kilometers) 0.5	1.5	3.0	4.0	5.0	10
Manual						
Male	0.01	0.01	0.005	0.004	0.002	0.00
Female	0.002	0.001	0.00	0.00	0.00	0.00
Mechanized						
Male	0.22	0.15	0.09	0.06	0.04	0.00
Female	0.04	0.02	0.01	0.01	0.01	0.00

Note: The analysis was conducted for farmers who use fertilizers on cotton, have individual fields, and who assess the soil fertility of their fields as either "good" or "average".

applied N. Diagnostic surveys on farmers' fields conducted during 1994 at different localities in Côte d'Ivoire indicated that the average use efficiency of applied mineral N is less than five kg of rice grain for each kg of N applied in upland rice, and about 10 in lowland rice.

In the 1994 wet season, WARDA scientists initiated a multidisciplinary, multifactorial experiment at M'bé to examine the interactive effects of management factors on rice yields along the continuum toposequence. The experiment comprises different levels of the following factors: variety (traditional vs. improved), plant spacing, weed control, N fertilizer rate, and N fertilizer split and timing. In the lowland, level of water control was introduced as an additional factor. All treatment combinations are implemented with three replications at each of three positions of the toposequence (irrigated lowland, rainfed hydromorphic, and rainfed upland). The site had a history of prolonged bush fallow. Treatments will be repeated on the same plots for at least three years in order to observe changes in soil fertility, N-use efficiency (NUE), weed pressure, and yield.

Results from the first year of experimentation indicate that toposequence position is the most determining factor for grain yield (4.4, 2.9, and 1.1 t ha^{-1} in lowland, hydromorphic, and upland environments, respectively) and NUE (11, 6, and 2 kg grain/kg N respectively, across treatments and varieties). In the lowland ecosystem, only the improved variety responded to improved management (N rate, N timing, spacing) which gave the highest yield (6.6 t ha^{-1}) and NUE (21 kg kg^{-1}). Also in the lowland, the traditional variety responded to applied N only at dense spacing. In the upland, no significant yield differences were observed among varieties and management levels. The hydromorphic zone represented an intermediate situation, with the grain yield and NUE of only the improved variety responding to N, and only at close spacing. Weed control levels had no effect on yield in any combination of factors across all ecosystems, although close spacing of rice did reduce weed biomass.

We conclude that in the first year of cropping after prolonged bush fallow, only the crop in the irrigated lowland, and to a lesser extent that in the hydromorphic environment, responded to the different management regimes, whereas the upland rice crop was not significantly affected. This result is consistent with independent observations on farmers' fields. Because of the prolonged fallow period, weed pressure was low and soil fertility probably high. (The latter is currently being analyzed). Both factors are likely to change in subsequent seasons. We expect management effects to become more pronounced in 1995 and 1996, particularly in the upland and hydromorphic environments. Detailed analyses of the evolution of soil properties, weed pressure, and yields will then provide key information on the varying carrying capacities of the upland-hydromorphic-lowland ecosystems for intensified rice cropping under different management.

Farm-level determinants of chemical fertilizer use in rice production systems in Côte d'Ivoire

A. Adesina

Even though several nutrient deficiencies limit rice production in West Africa, the use of fertilizer on food crops is generally very low. It is important to identify the factors that affect farm-level use of fertilizers in rice systems in order to better target soil fertility management research interventions.

In 1994 we examined the factors that affect farmers' use of chemical fertilizer in rice production systems in Côte d'Ivore, using detailed plot-level data. The data for the study were collected from a random sample of 120 rice farm households located near towns (Gagnoa, Touba, and Boundiali) in the humid-forest, forest-savanna, and savanna agroecological zones of the country. The study villages form key sites at which detailed biophysical characterization research (e.g., agronomic, hydrologic, cropping systems, weeds, diseases, insects) is being conducted by WARDA scientists.

We used a Logit regression model to examine farmers' decisions to adopt fertilizers, whereas a Tobit model was used to model the determinants of fertilizer use intensity (as opposed to initial adoption decision). Our results showed that cultivated rice area, lowland (versus upland) fields, and mechanization are all positively related to adoption and use intensity of chemical fertilizers. In contrast, distance of the field to the homestead, fertilizer use on cotton, communal (rather than individual) field status, and female plot management were found to be negatively related to adoption and use intensity. Thus, those farmers cultivating larger farms, occupying lowlands, using either oxen or tractors, and having fields closer to the village, are more likely to adopt and use chemical fertilizers on their rice fields. The negative sign on female-managed farms may reflect capital constraints faced by women. The positive sign on communal fields may be linked with a desire for ensuring household food security from these fields.

In order to guide soil fertility management research, we derived conditional probabilities of

TABLE 6: Predicted conditional probability of adoption of chemical fertilizers on rice fields: effects of cultivated farm size, type of cultivation, and type of field ownership for a lowland rice ecosystem. Côte d'Ivoire, 1993.

	Cultivated area (hectares)					
	0.5	1.5	3.0	5.0	10	30
Manual						
Communal (male)	0.17	0.32	0.62	0.90	0.99	1.0
Individual (male)	0.14	0.27	0.57	0.87	0.99	1.0
Individual (female)	0.02	0.04	0.14	0.47	0.98	1.0
Mechanized						
Communal (male)	0.78	0.89	0.96	0.99	0.99	1.0
Individual (male)	0.74	0.87	0.95	0.99	0.99	1.0
Individual (female)	0.26	0.45	0.74	0.94	0.99	1.0

Note: This analysis was conducted at a mean distance of fields of 3.1 km from the village, for farmers who judged the soil fertility of their fields as either "good" or "average", and who also used chemical fertilizers on cotton.

adoption of chemical fertilizers for a number of scenarios. The results of these analyses are summarized in Table 6.

Our results have three important implications for the targeting of improved soil fertility management practices. First, the uplands are subject to the high risk of soil fertility degradation, because the likelihood of farmers using chemical fertilizer inputs on such fields is extremely low. As population pressure increases and fallow periods on upland fields shorten, degradation may become increasingly severe, given that farmer investment in chemical fertilizers is precariously low. New improved fertility management practices which don't rely on purchased inputs are most needed in this ecosystem.

Second, fields that are farthest from the village form a second distinct group of high-risk fields. Fields that are very far from the village are also often located on marginal lands with higher risks of soil degradation.

Third, new soil fertility management strategies need to be designed with an understanding of how intra-household field tenure influences chemical fertilizer use. Extension agents have always favored communal fields under the control of the male-headed households, because men are more likely to use chemical fertilizers. But neglecting individual-female fields keeps the likelihood of using chemical fertilizers low, and a bias is created against women's access to both chemical and non-chemical-based sources for maintaining soil fertility. Women's fields deserve greater attention in on-farm testing of alternative technologies for soil fertility maintenance.

PROJECT 3: SOIL FERTILITY MANAGEMENT

Most soils used for rice cultivation in West Africa are low in organic matter and available P and N. Because farmers rarely apply sufficient fertilizer to replace the nutrients removed form the soil by the crop, soil fertility tends to decrease rapidly under intensified rice cropping. In the highly weathered and frequently acid upland soils, P and N deficiencies are generally severe, although at times the deficiencies are masked by drought, which temporarily reduces the crop's demand for nutrients. Crop responses to N application on such soils, therefore, depend strongly upon rainfall and P inputs.

The lowland and hydromorphic soils in the inland valley bottoms are more resilient and less prone to erosion than the upland soils. In contrast to floodplains and delta regions, which make up the bulk of the fertile lowlands in tropical Asia, the fertility of the inland valley bottoms in West Africa depends much on the physicochemical properties of adjacent slopes. For example, seepage of iron-rich water from the crests during the wet season frequently causes iron toxicity and secondary nutrient imbalances in the lowland crops, such as K, P, Ca, Mg, and Zn deficiencies.

Varieties vary widely in their capacity to tolerate or avoid such stresses, and the development of adapted germplasm is a key element in WARDA's efforts to render rice production more sustainable on acid upland and iron-toxic lowland soils. This approach is complemented by research on improved soil and nutrient management methods, both onstation and in collaboration with NARS partners in the Problem Soils Task Force.

In 1994, WARDA's soil fertility research focused on the diagnosis of nutrient disorders in different key localities and positions along the continuum toposequence, and the interactions between variety and management interventions. This research resulted in the identification of clear varietal differences in tolerance to iron toxicity and acid upland soils, and of marked effects of a range of nutrients on the expression of these tolerances. During 1995, we intend to complement these ongoing activities with in-depth experimental and modelling studies on key processes that underlie the observed interactions among chemical stresses, genotype, and nutrient applications.

Nutrient management and season affect soil iron toxicity

K.L. Sahrawat and S. Diatta

Iron toxicity, a common soil-chemical stress in West African inland valley bottoms, is caused by excess amounts of ferrous iron in the soil solution. It is essentially a

TABLE 7: Effects of applied plant nutrients on the yield of Bouaké 189 in an iron-toxic soil at Korhogo, Côte d'Ivoire, 1994

Treatment	Dry season		Rainy season	
	Grain yield t ha^{-1}	Iron toxicity score	Grain yield t ha^{-1}	Iron toxicity score
Check (no fertlizer)	3.69	5	5.03	3
N	3.43	4	5.50	3
NP	4.59	4	5.60	2
NK	4.08	4	5.74	2
NZn	3.93	4	6.39	2
NPK	4.86	4	6.29	1
NPZn	3.90	4	5.29	3
NKZn	3.71	4	6.99	1
NPKZn	4.86	3	6.00	1
LSD (0.05)	1.304		0.729	
CV (%)	22		9	

condition caused by soil reduction under flooded conditions which transforms insoluble Fe^{+++} into soluble Fe^{++}. Iron toxicity is a complex nutrient disorder involving physiological deficiencies of other nutrients such as P, K, Ca, Mg, or Zn which, under certain conditions, can cause adverse symptoms. This phenomenon, although poorly understood at present, may provide opportunities for effective integrated management of iron toxicity through a combination of tolerant cultivars and nutrient and water management techniques.

During the 1994 dry and wet seasons we tested the individual and combined effects of applied N, P, K, and Zn on the response of Bouaké 189, a high-yielding but susceptible local check variety, to iron-toxic lowland conditions at Korhogo in Côte d'Ivoire. A second variety tested, the traditional tolerant check Suakoko 8, provided no tangible results because of severe lodging when fertilized. Table 7 summarizes the performance of Bouaké 189 under nine nutrient treatments for the two seasons. Leaf-based scoring at the vegetative stage indicated that iron-toxicity stress was more severe in the dry season than in the wet. Scores varied between 3 and 5 in the dry season, and between 1 and 3 in the wet season. Leaf scores were significantly correlated with grain yield across both seasons ($r = -0.92$; $P < 0.01$) and within the wet season ($r = -0.82$; $P < 0.05$). The combined application of NPK increased the yield of Bouaké 189 over the check and N treatments in the dry season. In the wet season, iron-toxicity pressure was generally lower and yields higher by about 2 t ha^{-1}. Various combinations of NPKZn significantly increased yields relative to the zero check. In both seasons, however, N application alone did not affect grain yields. Lowest iron-toxicity scores were observed, in both seasons, when the full range of nutrients, N, P, K, and Zn, was applied.

These preliminary results will be complemented in 1995 with detailed soil chemical and physical analyses and plant tissue analyses to determine plant uptake of iron and the applied elements. We will then initiate physiological studies on the traits responsible for nutrient effects on the iron toxicity tolerance of rice, and agronomic studies on the possible translation of this knowledge to improved cultural practices.

M&M: The varieties tested were Suakoko 8 (tolerant) and Bouaké 189 (susceptible). The effects of nine plant nutrient treatments (Table 7) were tested in a randomized complete block design, with four replications. The plot size was 24 m^2. Nitrogen was applied as urea at a rate of 100 kg N ha^{-1}; P as TSP at a rate of 50 kg P ha^{-1}; K as KCl at a rate of 80 kg K ha^{-1}; and Zn as ZnO at a rate of 10 kg Zn ha^{-1}. All nutrients except N were added as basal applications.

Varietal response to residual P in an ultisol in the humid forest zone

K.L. Sahrawat, M.P. Jones, and S. Diatta

Phosphorus deficiency is one of the most significant nutrient disorders in the acid uplands of West Africa's humid forest zone. Availability of P in these soils to the rice plant is reduced by reactions of soluble P with Al and Fe oxides. WARDA's approach to sustainably improving the productivity of rice-based cropping systems on ultisols is based on the integration of two components. First, we seek to increase the P-use efficiency of upland rice cultivars through breeding and improved crop management. Second, we are exploring management options to improve the availability to the plant of soil-borne and applied P;

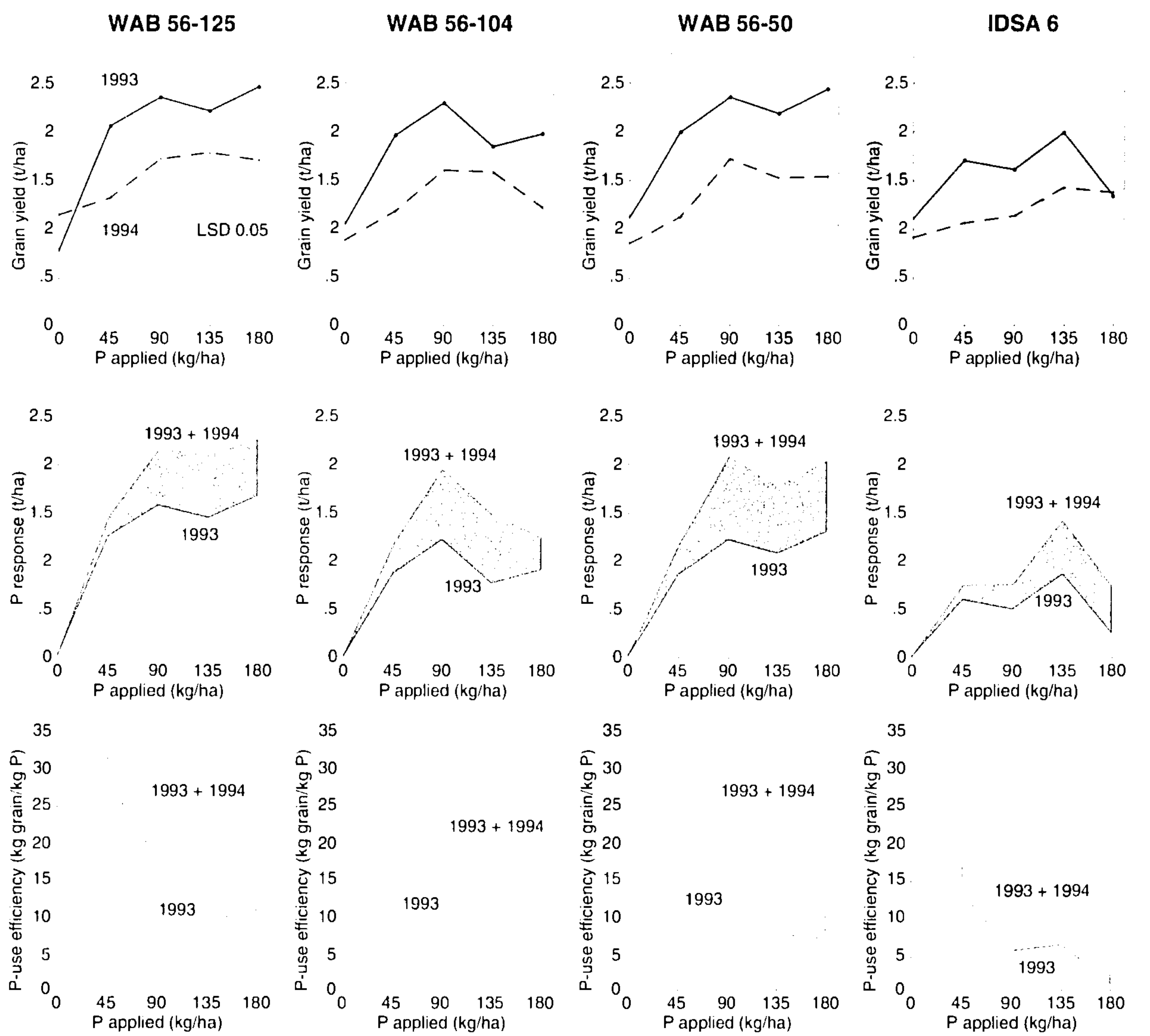


FIGURE 13: Response of four upland rice varieties to fresh (1993) and residual (1994) P.

for example, by means of leguminous fallow species that shift more P to the organic-matter fraction of the soil.

In 1993 we reported on the response of four upland rice cultivars to triple super phosphate applied at five rates between zero and 180 kg P ha^{-1} in an ultisol low in extractable P near Man, Côte d'Ivoire. During 1994 the experiment was repeated at the same site, but without any fresh application of fertilizer P, to study the response of the four cultivars to the residues of the initial P application. Crops grown on ultisols frequently require P applications that exceed the plant's needs, but some of the excess P can be recovered in subsequent seasons due to slow sorption-desorption reactions of the mineral complex. The test cultivars included three improved upland rices bred at

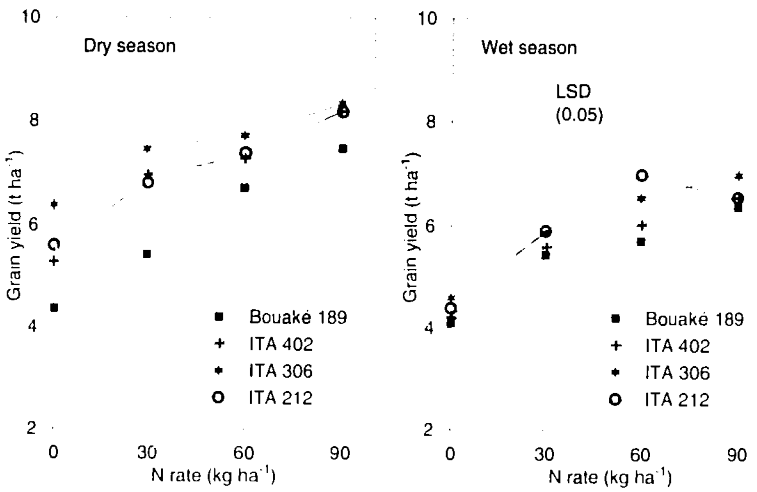


FIGURE 14: Response of four rice varieties to N during the dry and wet seasons.

WARDA (WAB 56-125, WAB 56-104, and WAB 56-50) and the local improved upland check IDSA 6.

All test varieties showed a significant ($P < 0.05$) response of grain yield to P application during the first year, with WAB 56-125 responding most and IDSA 6 least (Figure 13). The response to residual P during the second year was much weaker but was also significant for all cultivars. Residual effects on yield for the three WAB cultivars were in the order of 0.2 t ha^{-1} with an initial application of 45 kg P ha^{-1}, increased to 0.6 to 0.8 t ha^{-1} when 90 kg P ha^{-1} had been applied, and did not further respond to higher P inputs. More than 2 t ha^{-1} grain were gained with an application of 90 kg P ha^{-1}, about one-third of which was obtained from P fertilizer residues in the second season. The resulting agronomic P-use efficiency (PUE) was extremely high in the WAB cultivars, ranging from about 10 kg of grain per kg P applied (180 kg P ha^{-1} applied) to 30 kg of grain per kg P (45 kg P ha^{-1}) in WAB 56-125. The PUE of the local check IDSA 6 was only half that of WAB 56-125. The cumulative PUE of WAB56-104 and WAB 56-50 was similar to that of WAB 56-125, but there was a greater contribution of residual P in the second year.

We conclude from this study that considerable potential exists to increase the varietal response to fresh and residual P fertilizer in upland ultisols, particularly for IDSA 6, the most commonly grown improved upland rice cultivar in Côte d'Ivoire. The trial will be continued until residual effects of the initial P application have completely subsided, in order to analyze temporal changes in available and total P content, and in other soil fertility parameters. Follow-up research in 1995 and beyond will show to what extent varietal differences in agronomic PUE are due to access to soil P; for example, through mycorrhizal symbiosis; and to the physiological efficiency of P absorbed by the plant. Similar studies will be conducted on fallow species in order to improve the cropping systems' use efficiency for P and other nutrients, not only during, but also between, rice crops.

M&M: The trial was conducted near Man (humid forest zone in Côte d'Ivoire) during the 1993 and 1994 wet seasons. It had a 2-factorial RCB design with 4 replications. Factor 1 was P application during the first year (0, 45, 90, 135, 180 kg P ha^{-1} basal as triple superphosphate). Factor 2 was variety (WAB 56-125, WAB 56-104, WAB 56-50, IDSA 6). The soil was an ultisol (pH 4.9; organic C 1.35%; 2.7 ppm Bray-1 extractable P). All plots received 100 kg N ha^{-1} as urea in 3 splits during both years.

Nitrogen responsiveness of irrigated lowland varieties in the dry and wet seasons

K.L. Sahrawat and S. Diatta

With assured soil moisture and a low risk of erosion, irrigated lowlands provide a more conducive environment for high, stable rice yields than the uplands. Rice varieties cultivated in this ecosystem are generally of the improved semidwarf indica type, which are responsive to fertilizer inputs, especially N. Despite the systematic testing of high-yielding introductions from Asia during the past 20 years, however, the most successful Asian varieties (such as IR36, IR64, and IR72) were not adopted by West African farmers because of their poor adaptation to the local biotic and management-related constraints. Instead, better-suited but lower-yielding lines of Asian origin were selected and widely adopted by farmers cultivating the favorable parts of valley bottoms, such as Bouaké 189 from Indonesia. More recently,

TABLE 8: Performance of 12 rice cultivars at sites with high iron toxicity (Korhogo) and low iron toxicity (M'bé), Côte d'Ivoire, 1994.

Cultivar	Iron-toxicity score	Grain yield (t ha^{-1})	
	Korhogo	Korhogo	M'bé
TOX 3118-6-E2-3-2	1	6.66	7.57
TOX 3052-41-E1-2-1-2	1	6.30	8.12
TOX 3081-36-2-3-1	1	6.17	6.02
CK 4	1	6.05	8.33
TOX 3050-46-E3-3-3-3	1	5.99	6.24
TOX 3027-43-1-E3-1-1-1	2	5.48	7.51
CK 73	2	4.85	4.20[c]
TOX 3093-35-2-3-3(WITA2)	2	4.77	7.62
Bouaké 189[b]	3	4.69	6.50
TOX 3100-32-2-1-3-5 (WITA3)	3	4.30	7.75
TOX 3069-66-2-1-6	5	4.17	7.70
Suakoko 8[a]	2	3.73	5.31[c]
LSD (0.05)		1.10	0.77
CV (%)		15	13

Note: a = tolerant check
b = local check
c = bird damage

locally adapted and very-high-yielding varieties were bred in Africa at IITA, and since the early 1990s, at WARDA. These varieties, designated ITA, WITA and now WAB, are becoming increasingly popular in the region.

During the 1994 dry and wet seasons we studied the response to N inputs of some of the most popular lowland rice varieties bred in Africa, compared with the local check Bouaké 189. The test varieties were ITA 212, ITA 306, and ITA 402. The grain yields were higher in the dry season than in the wet season by one to two t ha^{-1} (Figure 14). The highest yields were obtained with 90 kg N ha^{-1} in the dry season, whereas in the wet season, yields levelled off at 60 kg N ha^{-1}. The agronomic N-use efficiencies (NUE) were generally high and varied between 28 and 41 in the dry season, and between 34 and 39 in the rainy season. Varieties did not differ in NUE.

The African-bred varieties generally, and in most cases significantly ($P < 0.05$), out-yielded Bouaké 189 in the dry season but not in the wet. The higher yield potential of the ITA varieties was not expressed under the lower solar radiation conditions. Yield differences among the ITA varieties were not significant, but ITA 306 was the top yielder in six out of eight treatment x season combinations, indicating that this variety has a particularly high yield potential. Its high yield stability is shown by the fact that this variety also has given consistently superior yields in the Sahel during the wet season, on both farmers' and researchers' plots, resulting in its release in Senegal during 1994.

We conclude that ITA 212, 306, and 402 have superior yield potential as compared to the local improved check Bouaké 189. The higher yields appear to have been caused by better utilization of solar radiation, rather than a stronger response to N. During 1995 we will study in detail the N uptake and distribution within the plant, and the growth patterns of key varieties, such as those tested here. Crop simulation models calibrated with these data will then help to identify traits responsible for the seasonal and N-input-dependent performance of elite varieties.

M&M: Four levels of N applied as urea (0, 30, 60, and 90 kg N ha^{-1}) were applied on plots measuring 15 m^2. All plots received a uniform basal application of P (50 kg P ha^{-1}) and K (80 kg K ha^{-1}). The experiment had a randomized complete block design with four replications.

Promising rice cultivars identified for iron toxicity in lowland soils
K.L. Sahrawat, B.N. Singh, and S. Diatta

Iron toxicity is a major stress and yield-reducing factor in irrigated and rainfed lowlands in West Africa, particularly where lowlands are bordered by iron-rich upland soils. WARDA is addressing this problem in a two-pronged approach by exploring soil/water management options to reduce plant exposure to the stress, and by improving varietal tolerance to iron toxicity. At present, however, varietal tolerance is still the most practical and cost-effective means of increasing rice yields in iron-toxic soils. WARDA's key sites for iron toxicity studies are

Promising rice cultivars are identified, cataloged, and harvested for further studies.

M'bé (low-stress control site) and Korhogo (severe stress) in Côte d'Ivoire and Badeggi in Nigeria (severe). The Problem Soils Task Force is using a broader range of sites in collaboration with NARS.

From our evaluation in 1992 and 1993 of 32 cultivars at M'bé and Korhogo, 12 elite selections were further tested at these sites in 1994. The cultivars tested are among the best available in the region, and this was reflected in their performance at the Korhogo site (Table 8). Three TOX lines and CK 4 achieved grain yields in excess of 6 t ha^{-1} at Korhogo, where iron toxicity is generally severe. CK 4 was the top yielder (8.33 t ha^{-1}) at the more moderate M'bé site. The results demonstrate that varietal tolerance to iron toxicity is physiologically compatible with high yield potential.

Across all entries, except for the tolerant check Suakoko 8, which had low yields because of its traditional tall plant type, grain yields at Korhogo were significantly correlated to the leaf-based iron toxicity score at the vegetative stage ($r = -0.87$; $P < 0.01$). This strong correlation between stress symptoms and yield, however, has not always been observed in preceding years; so for 1995 we are planning some indepth studies on the micro-variability of iron toxicity and the reproducibility of plant responses to this stress.

On the basis of the results of the planned study, and those of the 1994 study, we will select a new set of check varieties that are more representative of the desired high-yielding plant type for the irrigated lowland, and we will develop an improved screening method for better reproducibility of screening results. These studies will also take into account our observations from independent studies that iron toxicity is strongly influenced by the availability of a range of nutrients, and therefore might show different varietal response patterns under different inputs. At the same time, the most promising varieties will be made available to national breeders in 1995 for broader regional testing under iron-toxic conditions.

M&M: All plots (12 m^2 at M'bé; 24 m^2 at Korhogo) received a basal application of 20-36-36 kg ha^{-1} of NPK. Both experiments had a randomized complete block design with four replications.

PROJECT 4: INTEGRATED PEST MANAGEMENT METHODS FOR RICE IN WEST AFRICA

The incidence of rice pests and diseases depends on an intricate interaction among the crop, the biological and physical environment, and the farmer's management interventions. The transition from extensive production systems, which still dominate rice production in the subhumid and humid tropics in West Africa, towards intensified systems, is inevitable in the face of demographic growth and land shortage. Intensification, however, generally reduces biodiversity and is likely to increase the pest and disease pressure. An integiated approach combining productivity objectives with environmental resilience is imperative, particularly for environments in which farmers traditionally rely on natural biological control mechanisms, and they have neither the experience nor the means to invest in interventions that provide no immediate economic returns.

WARDA's approach to pest and disease management is strictly interdisciplinary. It addresses production environments as agroecological systems. For example, we examine weeds not only as competitors for resources, but also as alternative hosts for parasitic nematodes, hosts for diseases such as rice yellow mottle virus (RYMV), hosts for insect pests like the African rice gall midge (ARGM), or as habitats for useful predators. The goal of WARDA's IPM project is to integrate cultivar selection and management interventions in a way that sustains improved economic returns and maximizes favorable ecological trade-offs.

During 1994, our IPM research focused on six main themes. First we continued to study the genetic diversity and environment dependency of rice disease resistance, particularly to blast and RYMV. Second, our study of the genetic diversity and spatial distribution of the pathogens continued to be a major research focus and will in the near future be complemented by molecular genetic studies. The third research focus in 1994 was on the interactions among weeds, arthropods, and pathogens, with the objective to evaluate the intrinsic biological resilience of extensive and intensified rice agroecosystems. Beyond the diagnostic objective, some of these studies explicitly aim at the future development of interventions that would strengthen biocontrol mechanisms. For example, an ongoing collaborative project with NRI on the ecology of ARGM, a major rice pest in West African lowlands, will now focus on parasitoids that may help control ARGM.

The fifth IPM research focus during 1994 was the analysis of seasonal and cultural effects on pest and disease incidence at WARDA's research farm at M'bé along continuum toposequences, including the irrigated lowland. Sixth, we studied the weed competitiveness of rice as affected by position on the continuum toposequence, management factors, and rice genotype. The six IPM foci were complemented with surveys of farmers' perceptions of biotic constraints and the pest-control methods known to them.

Results generated during 1994 gave crucial guidance to WARDA's cropping systems research and breeding activities. We found that across rice ecosystems in the humid zone, and particularly in the upland ecosystem, naturally existing predators and parasitoids keep pest and disease pressure at a relatively low level. An important objective of future technology development research must therefore be to keep the existing natural mechanisms intact. IPM research is particularly urgent for the peri-urban lowland rice-based cropping systems, which are rapidly expanding and intensifying. From 1995 onwards, a multidisciplinary research thrust, including IPM, will address this crucial environment.

Control of pests, diseases, and their vectors is least costly to the environment if it is achieved through varietal resistance. In 1995 we will intensify our efforts to breed for weed competitiveness, RYMV and blast resistance, and resource-use efficiency. Particular emphasis will be on RYMV epidemiology and varietal resistance, because no technologies, either cultural or varietal, are currently available to lowland rice farmers for control of this dangerous disease.

PEST ECOLOGY

Phenological and seasonal occurrence of rice insects and diseases at M'bé

E.A. Heinrichs and A.A. Sy

Effectively evaluating rice germplasm for resistance to insects and diseases in the field requires knowing the time of year and the growth stage of the crop at which insect pest and disease pressures are greatest. To obtain this information for pests on the M'bé farm we have followed a rice garden approach, with monthly plantings of the rice variety Bouaké 189 under lowland irrigated conditions. The rice garden was established in May 1993 and will continue for several years. Regular sampling for insect pests, natural enemies, stem borer damage, and rice yellow mottle virus (RYMV) infection provides information on both the seasonal and phenological occurrence of biotic constraints.

Grain yields varied significantly as a function of planting date (Figure 15). Highest yields were obtained for the September and December through February planting dates. Leaf feeding damage by the beetle *Trichispa sericea* and the incidence of RYMV-infected plants were both severe for the July and August planting dates. *T. sericea* has been reported to transmit RYMV and, under the experimental conditions, was probably the main vector. Deadhearts caused by stem borers were most frequent for the May (60%) and least frequent in the August to October (about 10%) planting dates. Diopsids, *Diopsis macrophthalma* and *D. apicalis*, were distinctly most abundant in the December to March plantings;

The phenological and seasonal occurrence of rice insects and rice yellow mottle virus are monitored through monthly plantings of rice variety Bouake 189 in a lowland irrigated "rice garden". Information generated is used to time plantings of experiments in respect to pest populations. Nearly all stages of cultivation can be seen here—from fallow to recent harvest.

leafhoppers, *Cofana spectra* and *C. unimaculata*, in the November planting; *Locris* spp. in the September to December plantings; and the grain-sucking bug, *Aspavia armigera*, in December and April plantings. Predaceous spiders were abundant throughout the year, but populations were lowest in the December to February plantings. Most of the insect species and spiders also showed distinct peaks of abundance according to crop growth stage.

The first year of this study has indicated that pest species abundance varies significantly within a year and within a crop season. If continued studies show the trends to be consistent from year to year, the data will be used as a guide for selecting planting dates and crop growth stages that give maximum pest pressure in the field-screening of rice cultivars for pest resistance.

M&M: Seedlings planted at a 25cm x 25cm spacing. Fertilizer applied as NPK (10-18-10) at 150 kg ha at transplanting, and urea as 75 kg ha 30 and 60 days after transplanting. Plots hand weeded. No insecticide applied. Sweep-net sampling for insect pests and natural enemies and estimations of percentage of stem-borer-caused deadhearts made at two-week intervals throughout crop growth. Stem dissections to determine the percentage of stem-borer infestation and stem-borer species composition done at 30, 50, and 70 DAT. RYMV readings taken at 60 DAT. Yields were measured at harvest.

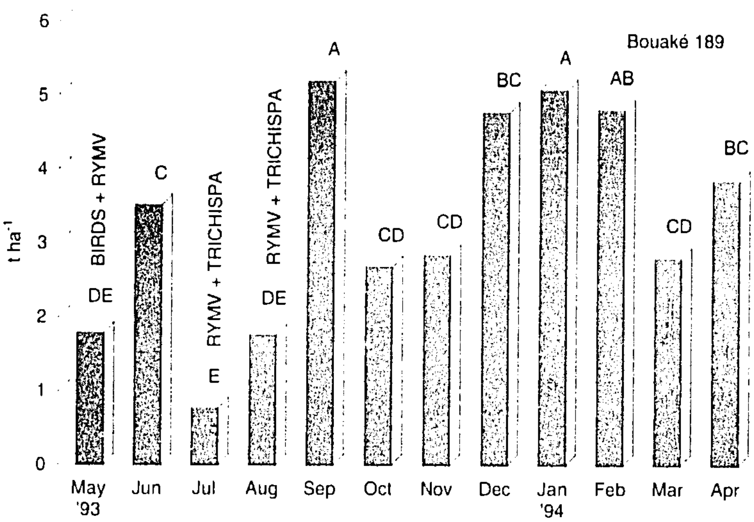


FIGURE 15: Grain yields of the rice variety Bouaké 189 under lowland irrigated conditions at M'bé, as affected by month of transplanting, May 1993 to April 1994. Bars with a common letter are not significantly different at the 0.05 level by Duncan's multiple range test.

Year-round monitoring of African rice gall midge in Nigerian outbreak areas

C. Williams (IIBC), E.A. Heinrichs, K. Harris (IIBC), O. Okhidievbie

Efforts to develop IPM systems to control the African rice gall midge (ARGM) (*Orseolia oryzivora*) have been intensified following serious outbreaks in Nigeria and Burkina Faso, and increasing infestation throughout the region. In 1993 a collaborative WARDA/CABI project, based at IITA Ibadan, was established to address this objective.

During 1994 we monitored ARGM populations in farmers' fields in central and southeastern Nigeria, in collaboration with the National Cereal Research Institute of Nigeria (NCRI) and extension staff, to obtain a better understanding of ARGM ecology and information crucial to the development of IPM options. Objectives were: to determine host plants and habitats important for the dry-season survival and early wet-season build-up of ARGM; to assess the importance of parasites in controlling ARGM; and to identify environmental determinants of high infestation. Twelve sites, grouped in three localities—the Guinea savanna, humid forest, and forest/savanna transition zones—were sampled from February to December 1994.

Gall midge damage in a Nigerian rice field. The damage is evident as light green slender galls, which form due to the presence of a gall midge larva.

We found no evidence that ARGM could use any grasses other than *Oryza* species as alternative hosts. Although galls were common on the weed *Paspalum scrobiculatum*, they were of a different, as yet undescribed, *Orseolia* species. Screenhouse tests on ARGM host range support these findings. The presence of the *Orseolia* on *Paspalum* may be beneficial, because it appears to be an alternative host for *Platygaster diplosisae*, the main parasite of ARGM.

Host plant species important for the dry-season survival of ARGM varied according to locality and cropping pattern. In the forest zone, ARGM survived on *O. sativa* ratoons, but in the savanna zone, wild perennial rice (*Oryza longistaminata*) was the key dry-season host, with *O. sativa* ratoons and volunteers providing bridges between it and the rice crop. At the only double-cropped site, in the forest zone, ARGM and its parasites persisted at low levels on the dry-season rice crop.

Our results confirmed that the key habitat for ARGM dry-season survival was rice fields left fallow through the dry season. Dry-season cropping with cassava appeared to reduce survival. *Oryza* species were rare, and ARGM galls were generally absent on old fallow fields (not cropped with rice in the last wet season), permanent ditches and bunds, and adjacent upland areas.

Late and staggered plantings were associated with high infestation, particularly at the forest/savanna transition locality. Here, low ARGM populations early in the wet season did not preclude heavy subsequent infestations: very low gall densities up to July were commonly followed by an explosive increase, associated with low parasitism levels. Results from the irrigated site show that double-cropping does not necessarily result in higher infestation, probably due to carry-over of parasites from dry- to wet-season rice crops.

Results of this monitoring suggest several possibilities for improving cultural and biological controls, and they will aid in predicting the consequences of changing agronomic practices. Potential control measures include earlier and more synchronized planting, control of wild rices that serve as alternative hosts for ARGM, and the use of ARGM parasites. These options, in combination with ongoing breeding for ARGM-resistant rices, will be pursued in 1995.

M&M: Sampling in Feb., May, Jul., Oct., Dec. Quadrats (25 cm x 25 cm) at 10-20 pace intervals along parallel transects were sampled to estimate density of galls on all Gramineae species and all main habitats, and abundance of Gramineae species. Additional quadrats were

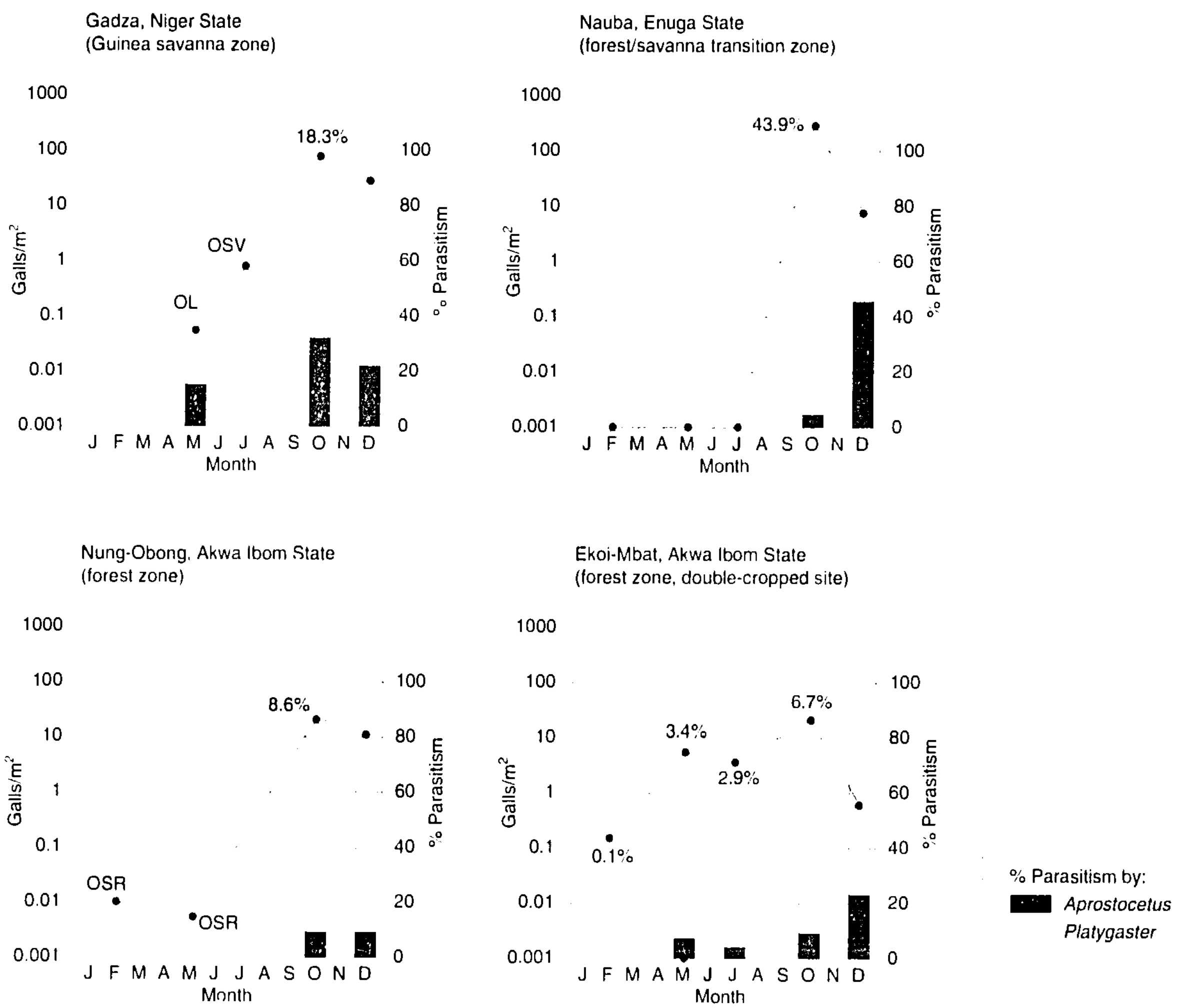


FIGURE 16: Seasonal changes in ARGM population densities and parasitism by *Aprostocetus procerae* and *Platygaster diplosisae* at four contrasting Nigerian sites. Gall densities are site averages, including all main habitats. Heavy lines under x-axes indicate periods when rice crops were available. Percentages show average tiller infestation levels for sampled rice crops. Host plants, other than rice crops, on which galls were found, are indicated: OL = *Oryza longistaminata*, OSR = *O. sativa* ratoons, OSV = *O. sativa* volunteers.

searched for likely alternative hosts. Galls were dissected to assess percent parasitism. *Orseolia* spp. and parasites were identified by K. Harris and CABI IIE taxonomists. During the cropping season, percentages of tiller infestation on rice fields were recorded, along with field parameters possibly influencing infestation.

Stem borer species composition in rice-maize cropping systems in Côte d'Ivoire

E.A. Heinrichs and F. Schulthess (IITA)

Rice and maize are often grown as a mixed crop in the rainforest zone of Côte d'Ivoire, with rice being the predominant component, making up more than 90% of the biomass. Stem borers are known to be important pests of both rice and maize, but little is known of the interactions between stem borer species in rice-maize cropping systems.

A mixed crop of rice and maize in Côte d'Ivoire.

In 1994 we conducted two surveys in collaboration with IITA to determine the species composition of the stem borer complexes and the abundance of stem borer species in rice and maize in rice-maize mixed cropping and in maize as a sole crop. The first survey was conducted June 29 to July 27 in the wet season, and the second survey from November 26 to December 3 in the dry season. The surveys were conducted on farmers' fields in the areas around Yamoussoukro, Bouafle, Gagnoa, Deuekue, Daloa, Man, and Danane in Côte d'Ivoire. In the first survey 39 rice/maize fields and 39 maize monocrop fields, and in the second survey, 13 rice/maize and 65 maize monocrop fields were sampled. In each field, 10 maize and 10 rice plants were dissected and stem borer species determined.

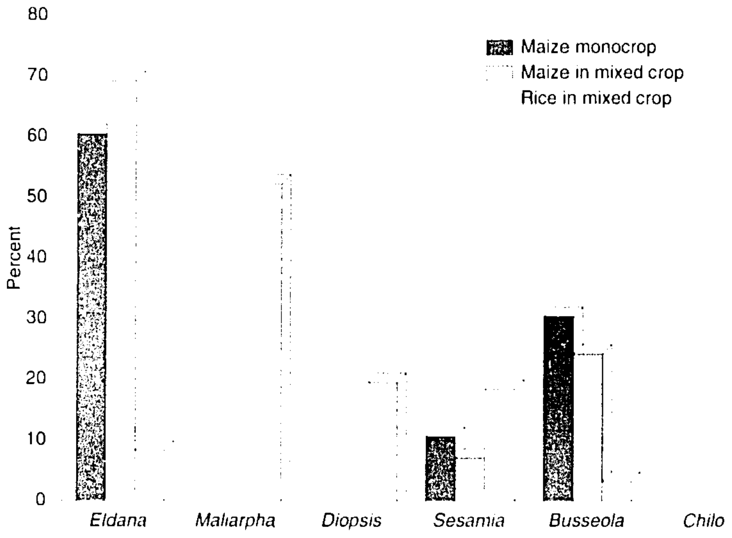


FIGURE 17: Percentage of species (*Eldana saccharina, Maliarpha separatella, Diopsis* spp., *Sesamia calamistis, Busseola fusca,* and *Chilo* spp.) composition of stem borers dissected from stems of rice and maize plants grown in rice-maize mixed cropping, and in maize plants when grown as a monocrop. The survey was conducted in farmers' fields in the rainforest region of Côte d'Ivoire, November 25 to December 3, 1994.

Stem borer populations were generally lower in the wet season. The borer species restricted to rice were *Diopsis* spp. and *Maliarpha separatella* , whereas *Busseola fusca, Chilo* spp., *Eldana saccharina,* and *Sesamia calamistis* occurred on both rice and maize. No *M. separatella* were collected in rice in the wet-season survey, but it was the predominant species (52%) in the dry-season survey, followed by *Diopsis* spp. (19%), *S. calamistis* (18%), *E. saccharina* (8%), and *B. fusca* (3%) (Figure 17). Although we observed no differences in the relative abundance of borer species in maize when grown with rice or as a sole crop, the percentage of maize stems attacked by borers was significantly less in the rice-maize system than in the monocrop maize system. Stepwise linear multiple regressions yielded significantly negative relationships ($P < 0.05$)

between the incidence of stem borer infestation in maize and the abundance of wild plant hosts and/or rice.

Our results indicate that rice may act as trap plants, thereby decreasing the amount of stem borer attack in maize. In 1995 we will conduct experiments at M'bé to verify the present results and to determine the degree of stem borer attack in rice as affected by different densities of intercropped maize populations.

Response of parasitic nematodes to mineral fertilization in upland rice

D. Coyne (NRI) and K. Sahrawat

Rice root infestation with nematodes depends on both the rice variety and the environment, including soil fertility and fertilizer application. In 1994 we studied the effect of long-term differential N, P, K, Ca, Mg, and Zn treatments on root nematode frequency in the locally cultivated nematode-susceptible variety IDSA6. The experiment was a long-term upland soil nutrient deficiency field trial at M'bé, Côte d'Ivoire, in its sixth consecutive year.

Four species of parasitic nematodes were naturally present in the trial: *Meloidogyne incognita*, *Pratylenchus zeae*, *Helicotylenchus psuedorobustus*, and *Criconemella tescorum*. The first two species are known pests of upland rice, but the ecology of the last two is less well understood. All nematodes were found in high densities (Table 9) which, at least for *P. zeae* and *M. incognita*, would translate into significant economic losses.

TABLE 9: Numbers of nematodes recovered from plots treated with different nutrient applications

Treatment +	Nematode species ++				
	M. incognita	*P. zeae*	*H. pseudo-robustus*	*C. tescorum*	Total
Zero-check	4.02	3.46	2.10	1.39	10.96 ns
compl. fertilizer	4.15	3.41	1.65	1.48	10.69-
N	4.27	3.47	1.90	1.50	11.14 ns
P	3.63	3.20	1.18	0.82	8.82*
K	3.56	2.95	1.86	1.19	9.56 ns
Ca	4.16	3.48	1.60	1.48	10.71 ns
Mg	4.13	3.03	1.84	1.05	10.04 ns
Zn	3.82	2.56	1.35	1.16	8.88*
LSD (0.05)	0.98	0.93	0.77	0.82	1.66
CV (%)	17	20	31	44	23

+ = zero check = no fertilizer
++ = transformed mean of 4 replications; nematode numbers recovered from 100 ml soil + 2g roots (fresh weight)
* = significantly ($P < 0.05$) different from completely fertilized control
ns = not significantly different from completely fertilized control

No differences in total nematode infestation (all four species) were observed between the treatments fertilized with either none of or the complete range of elements. Infestation was significantly ($P < 0.05$) lower, however, if either P or Zn was withheld. These differences were only evident for the combined populations of the four nematode species, whereas for any given species, no treatment effects were found.

Our results permit two preliminary conclusions. First, soil nutrition may affect the nematode infestation of upland rice roots. However, such effects seem not to be related to the overall fertilization level (full range vs. no elements applied). Instead, an imbalanced fertilizer application (deficiency in P or Zn) may lead to reduced nematode populations. Second, increased nematode infestation might neutralize the potential yield increases brought about by P or Zn application, thereby masking actual deficiencies in P and Zn.

In 1995 we will study in more detail the response of rice root nematode infestation to soil properties and fertilization, particularly in the highly acid and P-deficient upland soils that characterize many upland rice environments in West Africa.

M&M: The long-term nutrient deficiency trial at M'bé/upland follows an RCB design with 4 replications and 8 treatments, including a non-fertilized control and a fully fertilized control (100 kg ha-1 N, 100 P, 100 K, 50 Mg, 10 Zn). For the remaining 6 treatments, one of the elements was omitted (e.g., N, P, etc.).

BIOLOGICAL PEST CONTROL

White leafhopper parasitism in Côte d'Ivoire

E.A. Heinrichs

The dominant low-input rice production systems in West Africa rarely use insecticides. They depend highly on natural mechanisms for the control of insect pests, such as insect pathogens, predators, and parasites. In a 1993 study we found internal strepsipteran parasites of the genus *Halictophagus* to be abundant on white leafhopper species at WARDA's experimental farm at M'bé. Specimens of *Cofana spectra* and *C. unimaculata* collected from lowland rice fields showed 21% to 31% and 8% to 19% parasitism, respectively. This study was expanded to seven key locations in Côte d'Ivoire in 1994, including M'bé, in order to determine the importance of strepsipteran parasitism over a wider subregion in the main wet season. Leafhoppers were collected from sites in the rainforest, forest savanna, and savanna agroecological zones; and from upland, hydromorphic, and lowland ecosystems.

Strepsipteran parasitism over the seven sites was generally higher for *C. spectra*, with an average of 21% (range of 8% to 29%), and only 10% (range of 4% to 21%) for *C. unimaculata*. Parasitism of both species was highest in Korhogo and M'bé, which are both located in the savanna zone (Figure 18).

Our results indicate that the level of strepsipteran parasitism of the two *Cofana* species on farmers' fields in diverse regions of Côte d'Ivoire is similar to that on the WARDA M'bé research farm. These parasites, which provide a high level of natural control, must be maintained as cropping systems and must be intensified. More research is required and will be conducted by WARDA to determine the effects of crop intensification on pest parasitism, and to determine possible alternative cultural practices that might help sustain natural control mechanisms for insect pests.

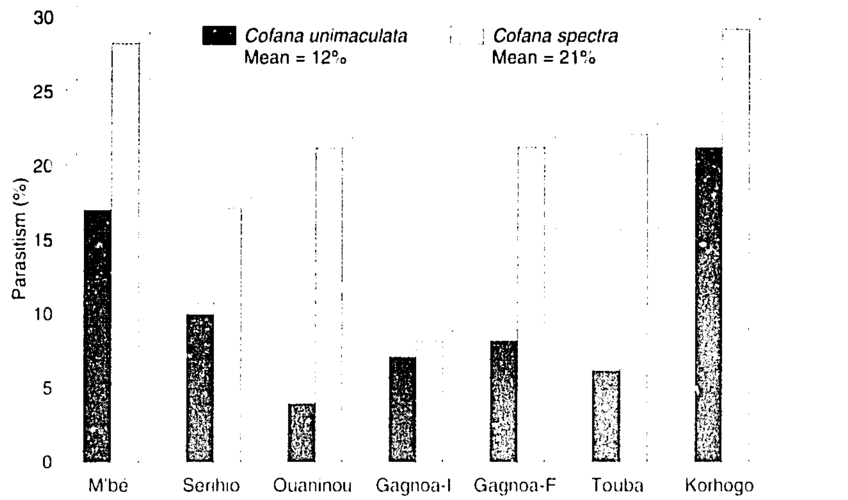


FIGURE 18: Percentage of *Cofana unimacualata* and *C. spectra* parasitized by the strepsipteran *Halictophagus* sp. in a 1994 wet-season survey conducted at several locations in the rainforest and forest-savanna regions of Côte d'Ivoire.

M'bé = WARDA lowland fields; Serihio (near Gagnoa) = farmers' upland, hydromorphic, and lowland fields; Ouaninou (near Touba) = farmers' upland fields; Gagnoa-I = lowland fields at the IDESSA Research Station; Gagnoa-F = farmers' lowland fields; Touba = farmers' lowland fields; and Korhogo = farmers' lowland fields.

Note: Adults of white leafhoppers were collected with sweep nets during the wet season. For the seven sites referred to in Figure 18 sweeping was done at M'bé on 12 days at 3- to 4-day intervals during the reproductive stage of rice. Samples were taken on six dates at Serihio and Ouaninou, and on one date at other locations. Insects were placed in alcohol and returned to the laboratory for study.

The influence of weeds on the natural control of insect pests

J. Afun, A. Russell-Smith (NRI), D. Johnson (NRI), and E. Heinrichs

Farmers in traditional upland rice systems rarely maintain a weed-free crop throughout the season. Although weeds compete with the crop, they also provide habitats for predatory arthropods which regulate insect pest populations.

Weeding of rice field planted after a short fallow period. Rice plants damaged due to competition with weeds are evident in the weeded area in the foreground.

In 1994, we conducted a range of experimental and diagnostic activities to elucidate the balance between beneficial and detrimental effects of weed populations, and to identify weed and weed residue management practices that would increase the abundance of predators.

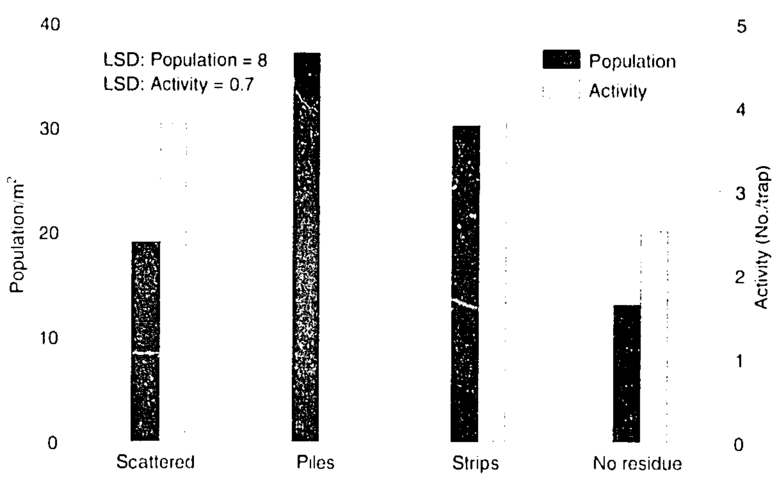
To determine associations among weeds, insect pests, and predators, we conducted surveys in farmers' fields in the forest and savanna zones of Côte d'Ivoire. We also conducted experiments at M'bé on the effects of seven different weeding regimes and four weed residue management practices on predators and pests.

Our field surveys showed that broad-leaf weeds were predominant in the forest zone, particularly *Chromolaena odorata*, whereas grasses such as *Imperata cylindrica*, *Pennisetum polystachion*, and *Hackelochloa granularis* dominated in the savanna zone. Spiders and ants were generally the most abundant predators, as determined by sweep-net and quadrat sampling. In the forest zone, spider and ant activities, as determined by passive (pitfall) traps, were positively correlated with the proportion of grass weeds in the crop. In the savanna zone, spider activity varied between fields but was not correlated with weed/crop biomass ratio.

In the weeding regime study, spider populations were significantly higher in unweeded plots compared to weeded plots. Their activity was higher in manually weeded plots than in chemically weeded plots, and activity was higher if manual weeding took place at midseason (28 to 63 days after emergence), as compared to early or late weeding. Manual weeding at midseason did not reduce yield relative to the

FIGURE 19: Effect of weed residue management on spider populations and activity in upland rice. M'bé, wet season, 1994.

Scattered = residue randomly distributed; Piles = 1 pile/10 m^2; Strips = 1 strip every 5 rows of rice; and No residue = all trash removed from plot. Spider populations are based on ten 0.25 m^2 quadrat counts per treatment at 50, 63, and 86 DAE. Spider activity is based on 10 pitfall traps per treatment at 46, 67, 88, and 120 DAE.



herbicide-treated plots, but it maintained a much higher population of spiders, which are useful predators. In the weed residue management study, spider activity was higher when residue was placed in strips or scattered in the plot than when it was piled or removed from the plot. The lowest populations and the least activity were recorded on residue-free plots (Figure 19). Insect pest populations and damage, however, were not affected by residue placement, and this finding needs to be verified or explained in subsequent studies. In contrast to spiders, ant populations were not affected by weeding regime or residue management.

The observed influence of weeds and weed residues on natural enemies of insect pests suggests that the weed/predator complex helps to maintain a natural balance in the population of insect pests. There seems to be scope, however, for controlling weeds while sustaining useful predator populations. In 1995 we will confirm these results and relate them to the crop damage actually caused by insect pests. Based on this, we will then explore technical options for a more integrated control of both weeds and insect pests in farmers' fields.

Note: Treatments: not weeded, weeded 0 to 21 days after emergence (DAE), 14 to 35 DAE, 28 to 49 DAE, 42 to 63 DAE, 0 to 100 DAE; herbicide treatment—Ronstar applied at planting and Garil at 25 DAE. Design—RCB. Wet season, June - November, 1994. Plot size, 7 m x 5 m.

VARIETAL RESISTANCE TO BIOTIC STRESSES

Determining traits that enhance weed competitiveness in upland rice
M.P. Jones, D. Johnson, B. Fofana, and T. Koupeur

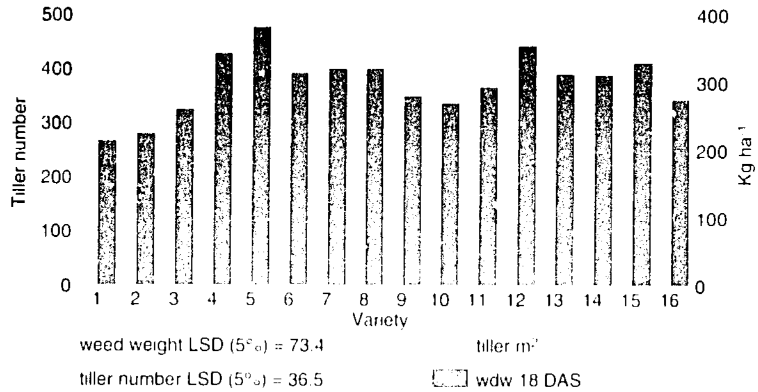
Weed infestation is a major cause of low rice yields in upland and hydromorphic ecosystems in West Africa. Weeding is generally manual, but in many cases effective weed control is impossible due to shortage of, or competing demands for, labor. One way of reducing costly weed control inputs (manual weeding or use of herbicides) is to use weed-competitive cultivars. Two experiments were conducted in 1994 to identify varieties that can compete with or tolerate weeds.

In the first experiment, sixteen promising genotypes selected in 1993 for their weed competitiveness were evaluated under high-, medium-, and low-input management at WARDA headquarters.

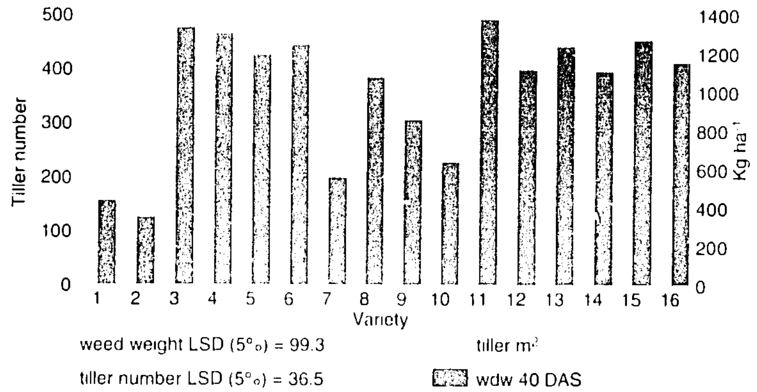
O. sativa *x* O. glaberrima *lines about 18 days after sowing. Rapid vegetative growth and early tiller development are traits that enhance competition with weeds.*

Two *O. glaberrima* varieties—CG 14 and CG 20—gave the highest number of tillers and leaf area under all levels of management. Rapid vegetative growth, which was the main competitive advantage in these cultivars, helped keep weed biomass very low at 40 days after sowing (Figure 20). The comparatively low-tillering but tall-statured *O. sativa* genotypes WAB 96-1-1 and SP4 also suppressed weed growth. Neither of the two groups had high yields, however. This was the case for the *O. glaberrima* cultivars because of their inherently low spikelet number per panicle and for the tall *O. sativa* cultivars because of low panicle number. A third group, represented by WAB 181-18, WAB 56-50, and WAB 56-125, were high tillering, had high leaf area and intermediate stature. These materials were selected for detailed characterization in 1995 because of their tolerance to weeds during reproductive and ripening stages, resulting in superior yields under weed competition.

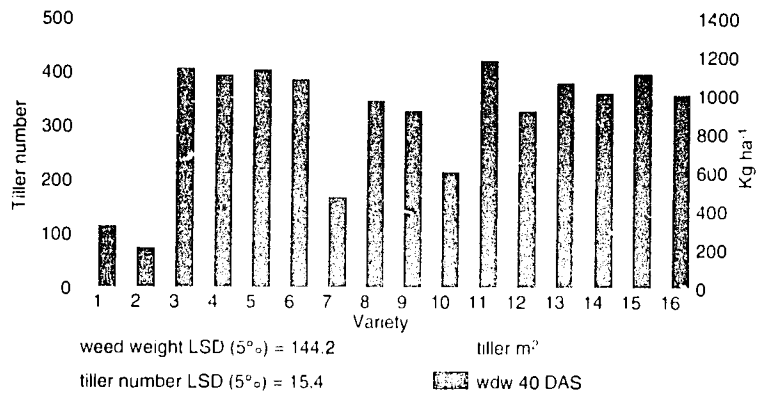
FIGURE 20 A-C: Relationship between tiller number and weed dry weight under low and medium input.



A) Tiller number and weed dry weight 18 DAS under low input.



B) Tiller number and weed dry weight 40 DAS under low input.



C) Tiller number and weed dry weight 40 DAS under medium input.

Variety	Number
CG20	1
CG14	2
WAB 56-50	3
WAB 181-18	4
WAB 56-104	5
WAB 56-125	6
WAB 96-1-1	7
IRAT 144	8
WABC 165	9
SP 4	10
WAB 99-1-1	11
IDSA 10	12
ITA 257	13
IAC 164	14
IRAT 112	15
CNA 4136	16

In a second experiment, twelve *O. sativa* and *O. glaberrima* lines covering a wide range of different plant types—height, tillering capacity, and leaf canopy architecture—were grown under differing levels of weed control. The objective was to identify traits associated with competitiveness with weeds. Interactions between variety and weeding regime were highly significant ($P < 0.01$). Regression analysis across varieties and replicates showed that grain yield on plots with poor weed control, expressed as a fraction of yield on plots with good weed control, was negatively correlated with weed weight at rice maturity ($r = -0.62$, $n = 36$) and, likewise, positively correlated with rice root length at 49 DAS (0.79), tiller number (0.75) and leaf area (0.73) at 36 DAS. These results are further evidence of the association between crop development during the vegetative phase and competitiveness with weeds. As in the first experiment, the most weed-competitive materials were *O. glaberrima* cultivars.

During 1995 we will conduct more-detailed analyses of the component traits that contribute to the weed competitiveness of rice genotypes. We will also seek to introgress the higer-yielding *O. sativa* potential into *O. glaberrima* genotypes with superior weed competitiveness. Preliminary results are encouraging, and stable intermediate progeny will be ready for evaluation in 1995.

M&M: The first trial had a split-plot design with three replications and management levels as the main plot and varieties as subplots. The low-input treatment included one cycle of manual weeding and the application of 40-0-0 hg ka^{-1} NPK, the medium-input treatment two cycles of manual weeding and 60-20-0 NPK, and the high-input treatment one chemical post-emergence weeding followed by continuous clean weeding and 80-36-36 NPK fertilizer inputs.

The second experiment had a factorial RCB design with 12 varieties, two levels of manual weed control (weeding at 10-day intervals or only at 30 days after emergence), three replications and plot size of 4m x 2.5m. Fertilizer inputs were 33-46-0 kg ha^{-1} NPK.

Field screening for rice resistance to Striga *spp. in Côte d'Ivoire. Three rows of a susceptible variety (center) are bordered on each side by moderately resistant varieties.*

Rice cultivars resist the parasitic weed, *Striga*.

D.E. Johnson (NRI), M.P. Jones, R. Diallo, and C.R. Riches (NRI).

Upland rice can be severely damaged by several species of the root parasite *Striga*, weeds commonly associated with sorghum, maize, and millet. As a rice parasite, *Striga* occurs mainly in the savanna environments, particularly on poorer soils, where severe infestation is localized rather than widespread. Populations build up rapidly through high seed production, and seeds remain viable in the soil for many years. While four species of *Striga* have been noted on rice in the region, only two, *S. aspera* and *S. hermonthica*, are important, with *S. hermonthica* being more common.

In an effort to identify sources of resistance, we screened a wide range of rice germplasm, including *O. sativa* and *O. glaberrima*, in glasshouse trials at Long Ashton Research Station, UK, using *Striga* seed collected in Côte d'Ivoire and elsewhere in Africa. In 1994 we evaluated in the field those varieties that had shown good resistance in the glasshouse experiments. Two field sites in northern Côte d'Ivoire were selected because of their high natural infestation with *Striga*: Kouto (*S. aspera*; poor hydromorphic soil) and Korhogo (*S. hermonthica*; poor upland soil).

All *O. glaberrima* lines tested showed good resistance to *S. aspera*, but of these only M27 and T2 were resistant to *S. hermonthica*. The *O. sativa* lines IR47255-B-B-5-4 and IR49255-B-B-5-2, previously found to be resistant to *S. hermonthica* in Kenya by ICIPE, were resistant to both species in our experiments. The susceptible check IAC 165 was devastated.

Our results suggest that genetic sources of rice resistance to *Striga* exist. If they were incorporated into improved varieties, they could significantly reduce losses in infested areas. Field screening will continue in 1995 in order to enlarge the sources for resistance.

M&M: RCB design: 5 *O. glaberrima* and 4 *O. sativa* test varieties, check variety (IAC 165) adjacent to each test plot. Eight replications per site, plot size 5m x 0.75 m. No fertilizer applied. Wet season 1994.

Accelerated screening to detect sources of leaf blast resistance

A.A. Sy and K. Akator

Blast is believed to be the most significant rice disease in West Africa, with yield losses particularly severe in rainfed ecosystems. A consensus has developed among WARDA and its national and international partners to emphasize genetic resistance in blast-related research, and to pursue this goal in an integrated approach. This approach includes the accelerated search for sources of durable resistance, characterization of the genetic diversity and spatial distribution of the pathogen, and the systematic testing of resistant germplasm at hotspot sites across the region.

During 1994, we tested a screening system for leaf blast, designed to accelerate the identification and characterization of rice germplasm with different types of resistance. Two nurseries totalling 435 entries were planted in two staggered (asynchronous) but temporally overlapping trials in June and September at M'bé. Except for the checks, the entries in the two nurseries were different. The experiment design was similar to the IRRI standard model, with the difference that instead of one row, four rows each of the 435 entries were planted. For every 50 entries, five susceptible checks (CO 39, Maratelli, OB 677, OS 6, B 40) and five resistant checks (CG20, TOG 6387, IR36, TOG 5810, WAB 56-50), which had previously been characterized for their differential profiles, were planted at random. The management practices followed WARDA's internal standard, and the evaluation scale was based on IRRI's standard.

In the first trial planted in September, 63% of the entries rated highly resistant (score 0 to 1), whereas in the second trial planted in September, only one percent of the entries rated resistant. Sequential observation showed that the disease pressure increased throughout the wet season, resulting in a very strong pressure for the late planting date of September. In comparison, farmers usually plant in June, the beginning of the main wet season. To illustrate this temporal gradient, the most resistant sativa check (IR 36) had a severity score of 0 for the early trial but 5.5 for the late trial. Conversely, the most susceptible Maratelli had a score of 1.5 during the early trial and 8.6 during the late trial. Among the most resistant entries in the late trial were TOX 3095-35-2-3-3 and TOX 3162-1-1-1-3-1-1-1 (score 0 to 1), and WAB 488-121-1, TOX 85C-C5-B-35, TOX 3084-136-1-3-1-2, TOX 3108-17-2-1-2-2, and WAB 488-170-1 (score 2 to 3).

The most resistant entries (0 to 3 severity scores) were pooled to form a confirmation nursery, which will be planted during the late wet season in 1995. The best varieties identified in this confirmation trial will be proposed to the INGER-Africa coordinator for nomination in the Africa blast-resistance screening nursery, in order to assess their blast tolerance across a broad spectrum of environments and to make them broadly available to breeders.

African rice blast screening nursery

A.A. Sy, Krishna Alluri (IITA), and K. Akator

The objective of this continental nursery is to evaluate the stability across diverse environments of highly blast-resistant materials nominated by the countries and institutions that participate in the INGER-Africa network. This arrangement enables a rapid and extensive exchange of germplasm within Africa in the context of a precise breeding objective. WARDA, as a member of this network, provides M'bé as one of the key sites where the nursery is grown.

During the 1994 wet season we planted an augmented version of the continental nursery at M'bé, including 160 entries provided by INGER-Africa and 40 entries added from WARDA's blast resistance selection program. The trial followed the experimental design, management practices, and evaluation methods recommended by INGER. The entries were evaluated at 30, 37, 44, 51, and 58 days after sowing (DAS) for leaf blast, and at 116 DAS for the incidence and severity of neck blast. Panicle blast was evaluated at the 50% flowering stage, using the IRRI scale.

At 58 DAS, 33% of the entries showed a good level of resistance (severity score 0 to 1) to leaf blast. Two-thirds of the entries were not at all affected by panicle blast (score 0). Consequently, there was a strong pressure for leaf blast, but the pressure for panicle blast was low, with neck blast being intermediate. Among the entries showing no blast symptoms of any type were TOX 3093-10-2-3-2, TOX 3118-12-1-3-1, TOX 981-10-3-2, TOX 3217-69-3-1, and TOX 3211-14-1-2-1-2. The entries IMBO, TOX 3098-12-1-11, TOX 3145-TOC-15-2-1, and TOX 3248-76-3-1-2 did show blast symptoms, but these did not exceed score one for any of the three types of blast disease. Twenty-nine percent of the entries were rated resistant, rating a score of zero for neck blast and a score of one for leaf blast.

In 1995 we will conduct a region-wide temporal and spatial analysis of the results so far generated by the African blast nursery, in collaboration with INGER-Africa and the IPM Task Force. On the basis of regional distribution of blast strains and the general pressure of the disease, recommendations will be formulated for the selective diffusion of resistant materials.

Selecting representative sites for screening blast-resistant cultivars

A.A. Sy[1], *K. Alluri*[2], *S.N. Fomba*[3], *E. Imolehin*[4], *Y. Sere*[5], *J. Tchatchoua*[6]

Rice blast disease is characterized by substantial genetic diversity of the pathogen, a fungus, and its manifestation is markedly influenced by the environment (e.g., humidity and temperature) and cultural conditions (e.g., fertilizer inputs). Consequently, the disease, although cutting across all rice ecosystems, is extremely variable in space and time. The development of blast-resistant rice cultivars for West Africa must take this diversity into account.

WARDA scientists, INGER-Africa, and their NARS partners have developed a network of key sites, which permits exposing blast-resistant materials to a range of diverse environments in which blast disease pressure is high. For efficiency, we keep the number of key sites as low as possible, but as high as necessary to cover the diversity of environments. The final selection of sites must also take into account possible shifts in disease pressure over time.

During the 1992, 1993, and 1994 wet seasons, we analyzed the incidence and severity of blast infection of advanced varietal selections with diverse agronomic and resistance properties at six blast-prone sites in West Africa. The experiment had four replications and was conducted at Ibadan and Onne (Nigeria), Man and M'bé (Côte d'Ivoire), Farako-bâ (Burkina Faso), and Rokupr (Sierra Leone). A common set of 23 varieties was maintained across sites and years. In addition, a local susceptible check was included at each specific location. This enabled year-to-year analyses of disease pressure. Means were compared with Dunnett's test.

A two-way analysis of variance of the 1994 data established significant differences ($P < 0.01$) among the environments (intrinsic disease pressure) and among the genotypes (intrinsic resistance potential of hosts), and revealed significant genotype x environment interactions. WARDA's recently developed improved upland tropical japonica variety WAB56-50 showed the best resistance across sites (Table 10), confirming results observed in 1993. Among the irrigated lowland materials, SIPI692033, an improved indica variety, showed superior resistance to blast.

Ranking of sites according to environment indexes (EI) based on severity of blast disease symptoms revealed significant shifts in disease pressure during the past three years (high EI indicated high pressure):

Rank	1992	1993	1994*
1	Farako-Bâ (-8.6)	Onne (-30.8)	Ibadan (-12.9)
2	Onne (-1.0)	Ibadan (-13.9)	Man (-11.3)
3	Man (-1.4)	Farako-Bâ (-0.7)	Onne (-6.1)
4	Ibadan (-2.0)	Man (-15.2)	M'bé (-8.6)
5	M'bé (-4.2)	M'bé (-27.8)	Farako-Bâ (-20.2)

*The Rokupr site had an EI of -1.4 in 1994. Data for 1992/93 are not available.

(1) WARDA/ADRAO, Bouaké, Côte d'Ivoire
(2) INGER-Africa, Ibadan, Nigeria
(3) RRS, Rokupr, Sierra Leone
(4) NCRI, Badeggi, Nigeria
(5) INERA, Bobo Dioulasso, Burkina Faso
(6) IRA, Dschang, Cameroon

TABLE 10: The most blast-resistant entries, as observed at six different sites and across sites in West Africa (Dunnett 5% level of confidence).

Sites	Entries
Ibadan	WAB 56-50
Man	Faro 29, Faro 37
Onne	SIPI 692033, Faro 29
Farako-bâ	Faro 37, WABC 165, WAB(99-14; 96-13-1; 56-50; 56-39; 56-125; 56-104; 181-11), Faro 29, IDSA 13, ITA 257, Moroberekan, SIPI 692033; IRAT 112
M'bé	WAB 56-50, ITA 257, WAB 56-104, WAB 56-125, Faro 37
Rokupr	WAB 56-50, ITA 257, WAB (56-59; 56-125; 181-11; 99-14; 56-104), IRAT 112, IDSA 13, FKR 33, FKR 27
Multisites	WAB 56-50

The disease pressure was generally low at M'bé, consistently high at Onne, and extremely variable in Farako-Bâ. This observation shows that it may be necessary to maintain all six sites for a thorough analysis of genotype x environment interactions. During 1995 we will conduct indepth statistical analyses across years in order to identify the optimal sets of sites for different objectives, such as initial screening of new entries, characterization of the adaptability to diverse environments of advanced selections, and the characterization of the spatial and temporal variability of blast disease in the region.

M&M: All trials had 4 replications and were conducted under upland conditions. Fertilizer application was 74 kg N ha^{-1} as urea (triple split), 50 kg P ha^{-1} as superphosphate, and 50 kg N ha^{-1} as KCl.

Rice yield loss caused by early and late inoculation with RYMV

A.A. Sy and K. Akator

Rice yellow mottle virus (RYMV) was first detected in East Africa about 30 years ago and has since spread across rice environments in sub-Saharan Africa. The virus preferentially attacks rainfed and irrigated lowland rice, but little is known of its epidemiology. Surveys conducted by WARDA in collaboration with NARS from 1992 through 1994 indicated that the number of infested sites and the yield losses at such sites are rapidly increasing. The disease cuts across agroecological zones and, in 1994, has caused an estimated 50% yield loss in the Office du Niger irrigation schemes (Sahel zone) and 68% yield loss at the Selingue scheme (Sudan savanna zone) in Mali. All popular lowland rice cultivars in West Africa are susceptible to the disease, including BG90-2 grown throughout Mali, Jaya in Senegal and Mauritania, and Bouaké 189 in Côte d'Ivoire. Resistant cultivars, which to date are restricted to the tropical japonica type, are only available for the upland ecosystem, where RYMV pressure is low. In contrast to some other virus diseases, RYMV can be transmitted by a wide but not completely known range of vectors, and the mere contact of a leaf with a RYMV suspension can cause infection.

WARDA is addressing the RYMV challenge at three levels. First, we have intensified the search for sources of resistance and are conducting conventional and wide crosses to generate resistant cultivars. Second, we are exploring collaborative options to create and transfer synthetic transgenic resistance. Third, we are studying the epidemiology of the disease in order to develop IPM strategies that may in the future include both genetic resistance and vector control. The present epidemiological study sought to quantify for the resistant upland check Moroberekan and the susceptible lowland check Bouaké 189 the yield losses and components as a function of the phenological stage of infection, based on artificial inoculation at M'bé (savanna zone) and Gagnoa (forest zone) under irrigated conditions. Plants were inoculated at seven days (early treatment, seedling stage) or 41 days after transplanting (late treatment, panicle initiation stage).

At Gagnoa, average yields of the non-infected controls were 4300 kg ha^{-1} for Bouaké 189, and 2060 kg ha^{-1} for Moroberekan. At M'bé, control yields were 2800 kg ha^{-1} for Bouaké 189 and 2020 kg ha^{-1} for Moroberekan. Infection resulted in severe leaf chlorosis, poor panicle exsertion, spikelet sterility, and reduced 1000-grain weight in Bouaké 189 at both sites (Table 11). Plant height at maturity was

Screening for resistance to rice yellow mottle virus at Gagnoa, a hot-spot in central Côte d'Ivoire. This is the only known rice virus disease in Africa. It can cause total crop loss.

reduced by about 40% after early inoculation, but by less than 10% after late inoculation. Moroberekan showed the same symptoms but with much less severity, indicating that it contracted the disease but resisted it. The resulting yield reductions were non-significant for Moroberekan. In Bouaké 189, yield reductions were generally over 50% for the early inoculation and more than 90% for the late, indicating that infection at the panicle initiation stage depressed yield more than the early inoculation did.

The main conclusion from this study is that infection of a susceptible variety with RYMV is likely to cause severe yield loss, regardless of the time of infection, with the greatest loss occuring with late infection. Consequently, infection must either be prevented throughout crop development (e.g., by controlling vectors and/or alternative hosts), or resistant cultivars must be found. In 1995 we will characterize the cultural determinants of varietal tolerance to RYMV, determine current economic losses for different production systems, environments, and climatic zones, and initiate a comprehensive study on alternative hosts and the role of soil, air, and seed-borne vectors. We will use this information to develop strategies for the integrated management of the disease.

M&M: RCB design with 4 replications, yield taken from a 6.24 sqm area per plot; irrigated lowland culture conditions based on transplanting.

African rice yellow mottle virus evaluation and screening set

A.A. Sy, Krishna Alluri (IITA), and K. Akator

Rice yellow mottle virus (RYMV), so far the only known virus disease affecting rice in Africa, causes severe economic damage to lowland rice production throughout sub-Saharan Africa, including Madagascar. Within West Africa, RYMV is present in Burkina Faso, Côte d'Ivoire, Ghana, Guinea, Liberia, Mali, Niger, Nigeria, Senegal, and Sierra Leone. No resistant lowland-adapted cultivars are so far available to farmers, and breeders know of no established donor materials for resistance within the indica group of *O. sativa*, which is generally preferred by consumers and producers of lowland rice. Rice germplasm carrying reliable resistance to RYMV is frequent in the *O. sativa* japonica group and in the African indigenous rice species *O. glaberrima*, but sterility barriers make it difficult to transfer to indica rices.

Although WARDA has given high priority to the development of lowland indica varieties through wide crosses, the rapid spread of the disease demands that existing germplasm with some degree of resistance be identified immediately and made widely available to NARS. The objective of the present activity is to identify, in collaboration with INGER and NARS, sources of genetic resistance to RYMV within the region, and to test them in a broad range of environments in sub-Saharan Africa. The underlying mechanism of this long-term activity is that INGER composes annual nurseries consisting of promising materials nominated by NARS and WARDA, and subjects these nurseries to both natural and artificial

TABLE 11: **Effect of rice yellow mottle virus on the vegetative and reproductive organs of resistant Moroberekan and susceptible Bouaké 189 rice (Gagnoa, M'bé, 1994).**

Site	Variety	Inoculation (DAT, days after trans-planting)	Leaf chlorosis score (66 DAT)	Percent reduction in plant height (66 DAT)	Panicle exsertion score	Percent unfilled grains	Percent yield reduction	1000 grain weight (g)	Grain weight reduc-tion (%)
Gagnoa	Bouaké 189	none	1	-	1	-	-	26.7	-
		7	7.3	42	7	69.1	81.2	21.8	15.3
		42	6.9	8	9	96.2	92.6	19.3	18.9
	Moroberekan	none	1	-	1	-	-	27	-
		7	1.1	8	1	3.3	4.6	26.6	2.3
		42	1	-1.2	3	0.5	3.9	26.7	2.7
M'bé	Bouaké 189	none	1	-	1	-	-	24	
		7	6.7	41.5	5	80.1	57.2	20.7	18.2
		42	7	3	9	100	95.3	17.7	27.7
	Moroberekan	none	1	-	1		-	25.7	-
		7	1.3	9	1	3.5	5.5	25.6	1.5
		42	1.1	3	3	2.4	5.2	25	1

inoculation with RYMV across different environments. WARDA's trial in Gagnoa, in Côte d'Ivoire follows the common design but is augmented by additional entries.

During the wet season 1994 we tested 131 entries, including 100 lines from INGER and 31 supplementary entries from WARDA. Forty materials were adapted to the irrigated lowland (mostly indica types) and 50 to upland ecosystems (generally japonica and *O. glaberrima* types). Ten check entries represented materials with known, extremely high or low, resistance to RYMV. The tropical japonica upland variety Moroberekan served as the resistant check, the indica lowland variety BG90-2 as the susceptible check, and the susceptible indica lowland variety Bouaké 189 as the local check. Disease symptoms were scored at 14-day intervals during the vegetative and reproductive growth stages.

Throughout the trial, the number of entries severely affected by RYMV increased, with the increase much more rapid under artificial than under natural infection (Figure 21). Under natural disease pressure, 57 entries (43.5%) showed an average severity score of one (highly resistant) during the reproductive stage (69 days after transplanting), against only 29 entries (22.1%) for the inoculated population. The 29 entries resistant under artificial inoculation included 27 entries adapted to the upland and were generally of the japonica or traditional *O. glaberrima* types (TOG 5672, TOG 81, Moroberekan, Lac 23, Faro 300, IDSA 10, IDSA 16, IRAT 156, IRAT 161, IRAT 208, IRAT 284, IRAT 314, ITA 257, ITA 305, TOX 1010-6-9-3-201, Wabis 18, WAB 99-1-1, IR47686-15-1-1, and Bogudi). Only two resistant entries were adapted to irrigated lowland conditions, Maratelli (a temperate japonica from Italy) and Fofifa 62 (not classified).

The disappointing absence of lowland indica types in the RYMV-resistant selections warrants an intensified search within the indica group. WARDA, NARS, and INGER are aware of this problem, and large numbers of indica lines are now undergoing initial evaluation for RYMV resistance.

Resistant selections will then be tested regionwide for further characterization.

In 1995 a new regional nursery will be composed, and all results from the 1994 regionwide trial will be pooled and analyzed. Results indicate that some of the *O. glaberrima* entries show no disease symptoms at all, even under artificial inoculation and across environments, and can be rated immune. Some indica lowland rices with moderate resistance were also identified in other more preliminary trials. If the 1995 results confirm this observation, prospects for obtaining RYMV-resistant lowland rice rapidly through conventional breeding will greatly increase. At the same time, however, we will continue to utilize the superior sources of resistance in japonica and *O. glaberrima* rices to achieve high and durable levels of resistance.

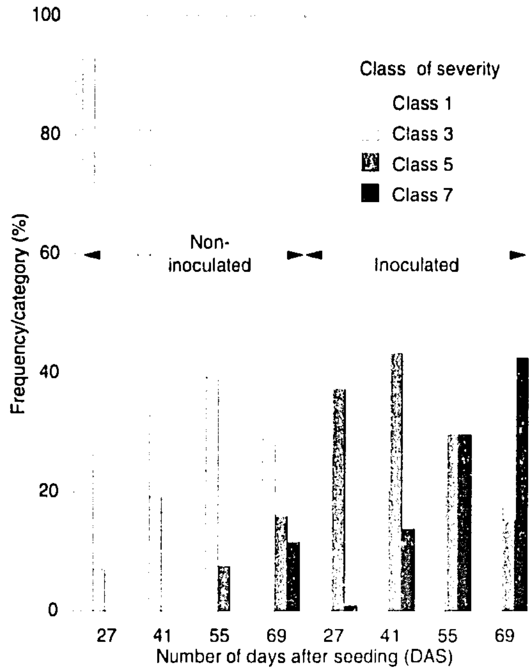


FIGURE 21: Modified African screening nursery for the selection of cultivars resistant to RYMV: distribution of entries according to their level of resistance/susceptibility.

A Task Force multidisciplinary team on a monitoring tour to Guinea in 1994. The farmer who owns this upland field is in the white suit.

COOPERATIVE RESEARCH THROUGH TASK FORCES

From 1989 through 1992, two research working groups composed of national scientists guided WARDA management in developing new ways to enhance collaboration between WARDA and NARS. The working groups developed the concept of research "Task Forces". From the establishment of the first Task Force in 1991 until the present, they have been the central component of WARDA's collaboration with its constituent NARS. The Task Forces are composed of rice scientists in the 17 WARDA member countries who are working on closely related problems. Eight Task Forces were active in 1994:

- Mangrove Swamp Rice Improvement
- Sahel Irrigated Rice
- Upland Rice Breeding
- Lowland Rice Breeding
- Integrated Pest Management
- Cropping Systems
- Problem Soils
- Rice Economics

The Task Forces are self-managing, with steering committees composed of, and chaired by, national scientists. Each Task Force has developed a regional master plan and, following consultation, specific tasks have been allocated to various national programs and to WARDA, based on their institutional comparative advantage.

Accomplishments of the Task Force concept have been significant in a brief span of time. National scientists are now aware of relevant research being conducted by colleagues in other national programs and have immediate access to their results. In 1994, 107 collaborative research projects were developed and conducted by African scientists in 16 countries. More than 600 rice varieties or breeding lines have been exchanged, of which 17 have been released or are about to be released.

Task Force studies in pest management have led to identifying the areas in which the very destructive rice gall midge is a serious problem and have begun to unravel its complex ecology. Seventeen cultivars with various levels of resistance to gall midge have been identified and evaluated. The two most promising of these are being retested for possible use in national breeding programs. In disease control, five varieties highly resistant to blast disease have been identified.

In 1994 five Task Force monitoring tours were carried out. Thirty-five national scientists and 12 WARDA scientists visited Cameroon, Guinea, Sierra Leone, Mauritania, Senegal, Mali, and Guinea Bissau to observe farmers' problems, to evaluate the performance of improved technologies, and to assess the research capacities of the national programs.

Through the Task Forces, three visiting scientist fellowships were awarded to African scientists in 1994. Two came from Togo and one from Ghana. All three sharpened their skills in genetics and plant breeding.

Task Force funds were also used to strengthen the capacity of the Rice Research Station in Rokupr, Sierra Leone. With the closure of WARDA's mangrove swamp rice research program in 1993, this station now plays the lead role in generating new technologies for this environment.

Financial support for the Task Forces in 1994 came from the African Development Bank, the European Economic Community, the International Development Research Centre of Canada, and the U.S. Agency for International Development.

PROJECT 5: GERMPLASM IMPROVEMENT FOR THE UPLAND-LOWLAND SWAMP CONTINUUM

Improved rice germplasm is a central element in the development of sustainable rice-based cropping systems. Ideally, productive varieties resistant to key environmental stresses should reduce dependence upon purchased inputs as well as the resources removed from the system by the crop. To move towards this goal, WARDA's breeding activities for the continuum prioritize yield stability on the basis of broad and durable resistance to stresses. This principle is applied to extensive production systems, in which farmers have limited scope for controlling stresses, as well as to intensified systems, in which certain biotic constraints are likely to increase because of disturbed ecological equilibria.

Distinct rice ecosystems in inland valleys require different morphological plant types, physiological adaptations, and resistances to pests and diseases. WARDA's varietal improvement program for the continuum is separately targeting the lowland and upland ecosystems and, within these, different levels of management and environmental adversity. Separate but interactive breeding itineraries are followed for irrigated, favorable and unfavorable lowlands; and for high-, medium-, and low-input production systems in the upland. WARDA breeders conduct specific breeding activities in collaboration with the respective in-house disciplinary experts, for key biotic stresses, such as blast in all ecosystems, and for rice yellow mottle virus (RYMV) and African rice gall midge (ARGM) in the lowlands. Specific breeding activities also target key abiotic stresses like drought (upland and lowland), weed competition (upland), acid ultisols (upland), and iron-toxic soils (lowland). Resistances to some other stresses with local or minor importance, as well as grain-quality-related objectives, are pursued through secondary varietal screening in the context of the main breeding itineraries.

The different breeding activities are interconnected through collaboration with the in-house crop and resource management projects, namely the cropping systems, soil fertility, and integrated pest management projects, all of which cut across ecosystems within the continuum. The characterization project provides crucial guidance in setting breeding objectives.

WARDA's continuum varietal improvement activities are integrated into national research systems through the Upland and Lowland Rice Breeding Task Forces and INGER-Africa. Breeding objectives are discussed and adjusted during the annual Task Force meetings and monitoring tours. Advanced varietal selections from NARS and WARDA are systematically tested in nurseries at key sites across the region. This high level of regional integration provides WARDA's breeders access to different target environments, and gives national breeders immediate access to the latest breeding products available in the region.

Rice breeding in West Africa can build on rich indigenous genetic resources, while at the same time exploiting the germplasm introduced from other continents, directly or through INGER. A major problem, however, is that some of the most valuable adaptive traits are restricted to specific genetic groups within *O. sativa* (japonica or indica) or to other species within the genus. For example, resistance to RYMV is apparently restricted to the japonica group within *O. sativa*, and full immunity to the virus has so far been found only in the African rice, *O. glaberrima*. Some *O. glaberrima* cultivars also show superior weed competitiveness and resistance to a large number of other important stresses. But the genetic distance between these groups reduces the transferability of those traits, particularly to the indica group, which is widely preferred by lowland rice farmers because of its yield potential, and by consumers because of its grain type.

WARDA has initiated a major research focus on wide crosses among sativa and glaberrima rices. During 1994, WARDA breeders achieved a breakthrough in the improvement of upland rice by successfully combining desirable traits from both species and stabilizing interspecific progeny. For the lowland ecosystem, similar efforts are also under way. During 1995, WARDA's internal expertise in anther culture and other tools needed in wide hybridization will be complemented by collaborative projects with outside molecular biologists in order to map interspecific gene transfer and explore the potential of transgenes. Our vision for the medium term is to improve *O. sativa* with traits from *O. glaberrima*, and to explore the development of a new category of broadly stress-resistant *O. glaberrima*-based rice types that derive their input responsiveness from key traits of *O. sativa*.

UPLAND AND HYDROMORPHIC ECOSYSTEMS

Targeting upland rice varieties for high-input and low-input systems

M. Jones, B.N. Singh, and T. Koupeur

More than 80% of rice farmers cultivating the upland and lowland ecosystems in West Africa use traditional low-input cultivation systems. Despite significant intensification of rice production in the more densely populated areas (which are frequently but not always associated with higher inputs), low-input farmers are expected to contribute most of the regional rice production in the foreseeable future. WARDA's breeding objectives recognize the demand for rice germplasm adapted to low management and low fertilizer inputs, while at the same time ensuring input responsiveness as an incentive to farmers for greater input use so as to avoid mining depletable resources.

Progeny of a promising O. sativa x O. glaberrima cross with 100% fertility at the F_6 generation. The breeders are admiring the grain characteristics of this line—long, slender, translucent. Tillering is also high.

WARDA's breeding program for upland rice is based on two separate but interactive selection itineraries, one under low levels and the other under high levels of management and inputs. The management levels differ in fertilizer inputs, weeding regime, and soil preparation. During the early stages of selection, subsets of segregating or newly fixed lines are systematically shifted back and forth in subsequent generations between the two itineraries in order to select for materials that perform well under all input levels. All materials that advance to the observational yield trials (OYT) and replicated yield trials (RYT) are tested under high-input conditions at Man (high rainfall, acid ultisols, high blast disease pressure) and at Korhogo (drought prone, blast) in Côte d'Ivoire. In addition, we test all materials in trials with low and high inputs at M'bé. Elite selections that further advance to the advanced yield trial (AYT) level are grown simultaneously at M'bé in replicated experiments with low-, medium-, and high-input treatments in order to characterize response to management and inputs. Out of this group we nominate entries for regional multilocation trials managed by the Upland Rice Breeding Task Force, where they are compared with materials nominated by national breeders. WARDA also provides NARS breeders, upon request, materials from any earlier stage of varietal selection.

During 1994, 558 entries were screened in OYT and RYT under high-input management at M'bé, Man, and Korhogo. Yields at Man were reduced by soil acidity and leaf and neck blast, and by drought stress and leaf and neck blast at Korhogo. The highest-yielding entries across locations in the RYT were WAB 368-B-3-H1-HB, WAB 272-B-B-1-H1, WAB 365-B-2-H1-HB, and WAB 272-B-B-1-H1. In the OYT, WAB 488-100-1, WAB 506-126-1, WAB 488-144-2, and WAB 488-125-1 had the highest mean

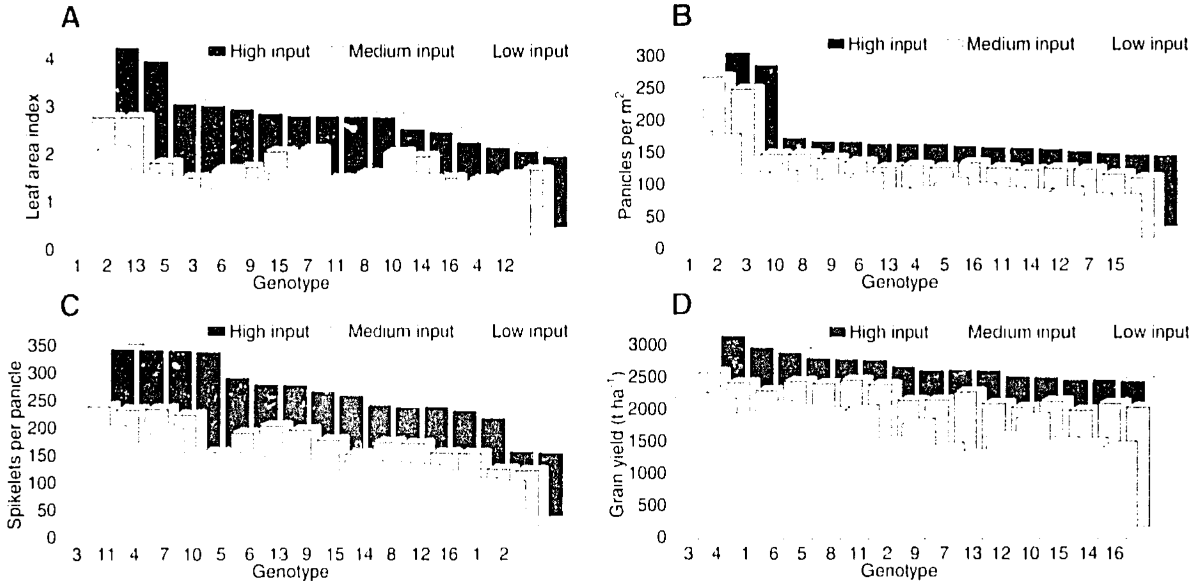


FIGURE 22: Response of two *O. glaberrima* and 14 *O. sativa* upland rice genotypes to input levels. Figure 21a, leaf area index at 60 days after sowing (DAS); Figure 21b, panicle number per m^2; Figure 21c, spikelet number per panicle; and Figure 21d, grain yield (t ha^{-1}). M'bé, Côte d'Ivoire, 1994 wet season.

Varietal codes:

O. glaberrima:	CG20 (1), CG14 (2);
O. sativa:	WAB 50-56 (3), WAB 181-18 (4), WAB 56-104 (5), WAB 56-125 (6), WAB 96-1-1 (7), IRAT 144 (8), WABC 165 (9), SP4 (10), WAB 99-1-1 (11), IDSA 10 (12), ITA 257 (13), IAC 164 (14), IRAT 112 (15), CNA 4136 (16)

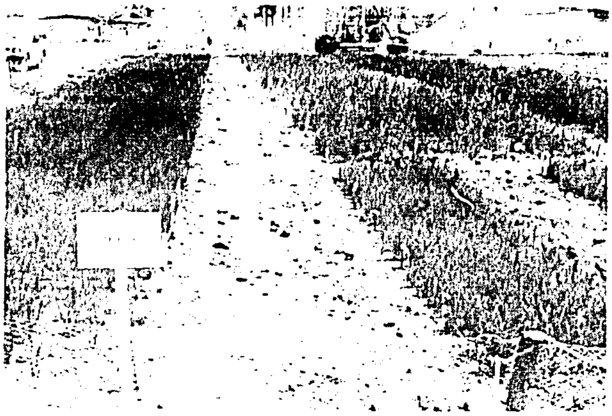
grain yields. Also in 1994, we evaluated 154 entries in a low-input OYT at M'bé. The best yielders were WAB 375-B-7-L1-B, WAB 377-B-17-L2-B, WAB 377-B-5-L2-LB, and WAB 165. WARDA's elite selections WAB 56-50 and WAB 181-18, which also perform well under high-input conditions, continued to rank among the top entries.

Sixteen advanced entries were evaluated in replicated yield trials at M'bé under high-, medium-, and low-input conditions at M'bé. The entries included two *O. glaberrima* cultivars, CG14 and CG20; the traditional *O. sativa* cultivar SP4; and 13 improved lines (Figure 22).

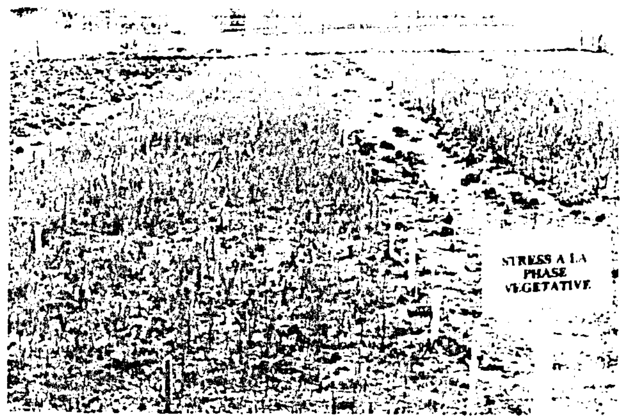
The *O. glaberrima* entries gave the highest leaf area index and panicle number, but the lowest spikelet number per panicle among the entries. Their yields were intermediate, ranging from 1.5 to 2 t ha^{-1}. The improved *O. sativa* varieties WAB 56-50 and WAB 181-18, developed at WARDA, were the top yielders, with grain yields ranging from 2.2 to 2.8 t ha^{-1}.

O. glaberrima cultivars responded to improved inputs by increasing their panicle numbers, whereas the spikelet number per panicle was constant. The leaf area of these types also responded strongly to inputs. By contrast, the yield response to inputs of improved *O. sativa* materials, such as WAB 56-50, came mainly from the spikelet number per panicle. In 1995 we will for the first time characterize the yield responses to inputs of stable interspecific progeny that combine the panicle type of *O. sativa* with the growth vigor and tillering ability of *O. glaberrima* cultivars.

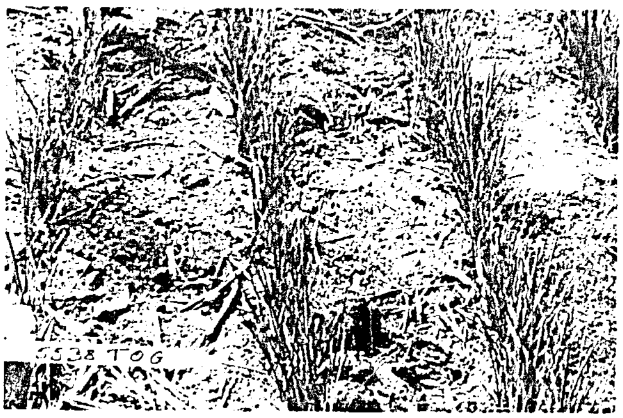
M&M: The different input/management levels are as follows. Low: 40 kg N ha^{-1} applied as 2 splits after manual weeding at two dates; soil preparation by hoe. Medium: 60 kg N ha^{-1} as 2 splits after manual weeding at two dates; 15 kg P ha^{-1} basal application as triple superphosphate; harrowing by tractor. High: 20-36-36 kg N-P-K ha^{-1} basal application and two additional split applications, each of 40 kg N ha^{-1}; chemical weeding with Ronstar pre-



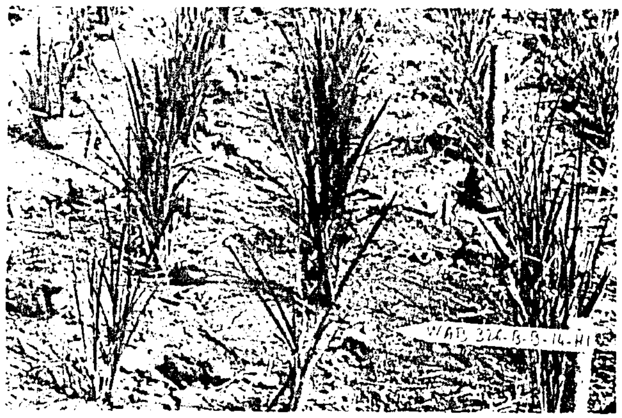
This control plot at 55 days after seeding has received continuous watering



Plots at 55 days after seeding, but they have received no water for the last 40 days



TOG 5538, a drought-resistant O. glaberrima cultivar after 41 days of water stress. It has continued to produce tillers and has grown slightly taller.



WAB 326-B-B-14-H1, a drought-resistant O. sativa variety. Under water stress it grows taller but produces few tillers

emergence herbicide and manual clean weeding throughout the season; harrowing by tractor. All variety plots have a yield area of 10 m^2 and are replicated three times.

Improving drought tolerance in upland rice

M.P. Jones and K. Aluko

Highly variable rainfall in the forest and savanna zones of West Africa can introduce water stress to upland rice at any stage of crop development. WARDA's varietal screening and characterization program for drought tolerance makes use of the natural distribution of rainfall in the wet season at two sites in Côte d'Ivoire (M'bé and Korhogo); and differential sprinkler irrigation in the dry season (M'bé only). Entries selected from initial screenings undergo drought screening in the dry season with stage-specific drought treatments (withholding irrigation at either the vegetative stage or reproductive stage, compared to continuous irrigation). Selections from this trial are then further characterized in wet-season observational (non-replicated) or replicated, exclusively rainfed, yield trials.

In the 1994 dry season we evaluated 76 *O. sativa* and 48 *O. glaberrima* lines and varieties, selected in 1993 for their drought resistance, for development-stage-specific drought responses under controlled conditions. We observed considerable variation for seedling vigor, tillering, leaf tip burn, and leaf rolling and unrolling ability among the accessions. During vegetative stage drought (15 to 56 days after emergence [DAE], with observations taken at 35 DAE and expressed relative to well-watered controls), *O. glaberrima* materials generally had a reduction in seedling vigor (20 %), seedling height (28%) and tiller number (18%), as compared to *O. sativa* materials (40, 45, and 50% respectively; means across accessions). Visual drought scores were correlated with leaf tip burn during the vegetative stage ($r = -0.74$; $P < 0.01$).

During the reproductive stage, 10% of the *O. glaberrima* and 2% of the *O. sativa* materials were visually rated as resistant after three weeks of drought stress (45 to 66 DAE). The visual drought score was positively correlated with the tillering score ($r = 0.57$; $P < 0.01$), and negatively correlated with leaf tip burn score ($r = -0.74$; $P < 0.01$), observed before the onset of drought. Consequently, plants with high tiller numbers and low tip burn better resisted a subsequent drought. Among the entries showing good drought tolerance at both vegetative and reproductive stages were WAB 160-24-HB, WAB 181-43, WAB 326-B-B-14-H, and IR 47686-B1-1-1 (improved *O. sativa*); and TOG 5458, TOG 5486, and TOG 5983 (*O. glaberrima*).

Advanced materials selected for drought tolerance in 1993 were tested in rainfed yield trials during the 1994 wet season. Drought was severe at Korhogo during the crop's late vegetative and grain-ripening stages, resulting in grain yields between 145 and 2130 kg ha^{-1}. Many new lines out-performed the local drought-tolerant check, Moroberekan, and the improved check, WAB 56-50. The best lines with more than 2000 kg ha^{-1} grain yield were WAB 376-B-15-H5, WAB 95-B-B-B-B-H2, WAB 95-B-b-B-B-12-H2, and WAB 99-47. Drought was milder at M'bé, and grain yields ranged from 300 to 3180 kg ha^{-1}. The top four yielders at M'bé that gave yields in excess of 2500 kg ha^{-1} were different from those at Korhogo, namely IR 47686-13-2-2, WAB 340-B-B-4-171, WAB 365-B-2-H1-HB, and WAB 340-B-B-1-H2. Since all accessions had short duration, the range of performance under drought was not attributable to temporal escape, but rather to tolerance.

In 1995 we will continue to search for new sources of tolerance. In addition, we will attempt to utilize the superior drought tolerance of *O. glaberrima* by introgressing genes to high-yielding *O. sativa* materials through our wide-crossing program.

Varietal tolerance to upland soil acidity

M.P. Jones, K.L. Sahrawat, K. Aluko, and S. Mandé

More than 70% of the area under upland rice cultivation in West Africa is in the humid forest zone, where annual rainfall is 200 cm or more. Upland rice in this zone is often grown on acid oxisols, which are extremely low in P and frequently incur Al and Mn toxicity. In 1992, WARDA initiated an upland rice breeding program with the objective to develop agronomically improved varieties with high grain yield and yield response to P inputs on acid upland soils.

During the 1994 wet season we screened 200 cultivars on an acidic (pH 4.3) and P-deficient soil (ca. 3 mg P kg^{-1}) at Man in western Côte d'Ivoire for their general adaptation and response to P fertilization. P fertilization failed to increase grain yield ($P < 0.001$) in only 15 varieties. Mean yields in the unfertilized plots ranged from 0 to 3.2 t ha^{-1}, while those in the fertilized plots were between 0.6 and 5.4 t ha^{-1}. Four varieties with mean yields higher than 3.0 t ha^{-1} in unamended soils were TOX 3380-8-2-2-3, NDRP7, DR79-21, and WAB 56-50. In the fertilized plots, the highest-yielding varieties were IDSA 64 (4.5), IR4770-1-6-3-1 (5.3), and DR79-21 (5.4 t ha^{-1}). Eight accessions did not grow or yield at all under non-fertilized conditions, but they yielded between one and three t ha^{-1} when P was applied, indicating that P application dramatically improved the tolerance of these genotypes to acid oxisols.

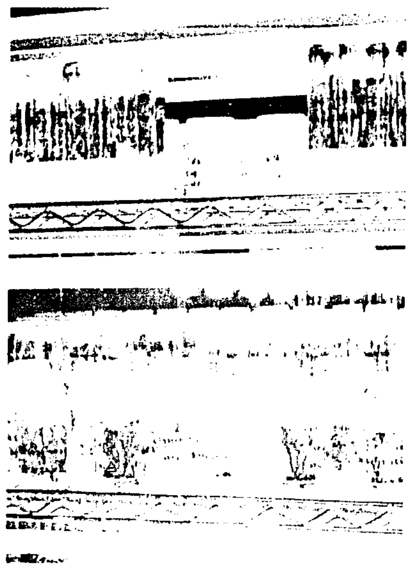
We evaluated another set of 127 lines in an observational yield trial at Man during the 1994 wet season, but without any P applied. Considerable variability was obtained in several important traits. For example, grain yields ranged from 0 to 3.9 t ha^{-1}, duration varied from 105 to 139 days, culm length ranged from 70 to 128 cm, and acidity scores from 1 to 7 (with 1 = highly tolerant and 9 = highly susceptible or dying plants). The correlation between grain yield and duration ($r = 0.243$, $P < 0.001$) was significant but weak, indicating that a number of short-duration materials achieved high yields. Grain yield had a much higher correlation with the acidity tolerance score ($r = -0.538$, $P < 0.001$), indicating that the acidity stress was the main determinant of yield, despite substantial varietal diversity in morphology and duration. Several short-duration accessions with superior tolerance to acid oxisols and high yield potential were selected for more detailed characterization in 1995.

M&M: Both experiments were conducted near Man, WARDA's key acid oxisol site. The first trial had a split-plot design with two replications, with P as the main plot (0 and 40 kg P ha^{-1}) and varieties as subplots. The second trial had an unreplicated augmented design with recurrent plots for the susceptible check IDSA6 and the tolerant check WABC165. No fertilizer was applied.

Using anther culture to generate fertile doubled-haploid interspecific progeny

M.P. Jones, S. Mandé, A. Dalebа, and H. Sehi

The culture of tissue derived from anthers, from which new plants can be regenerated (anther culture), provides the means for rapid genetic fixation of progeny from crosses. In the context of wide crosses (e.g., interspecific crosses between *O. sativa* and *O. glaberrima*), or within *O. sativa*, between indica and japonica types, anther culture can provide fertile doubled-haploid progeny with fixed introgressions that might otherwise disappear in the course of an extended series of backcrosses. WARDA is using anther culture and embryo rescue techniques to accelerate and render more efficient its *O. sativa* x *O. glaberrima* hybridization program. Beginning in 1994, WARDA's anther culture program received a three-year commitment of financial support from the Rockefeller Foundation. The program was expanded to classify representative japonica, indica, and *O. glaberrima* genotypes, as well as their F_1 and F_2 progeny for suitability to anther culture.

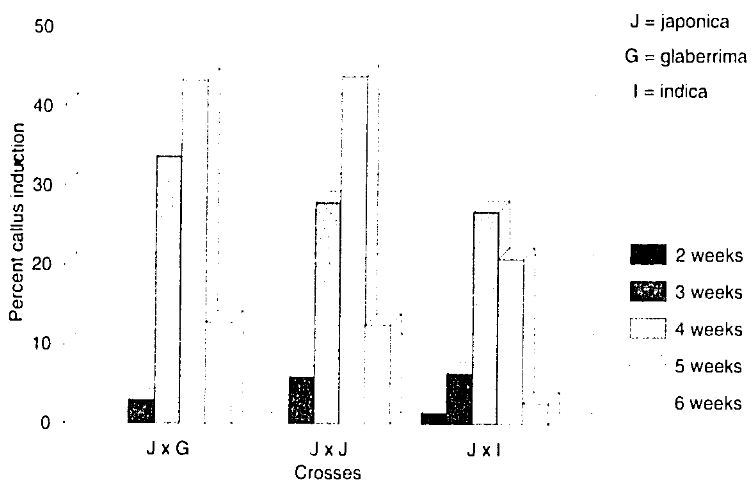


Anther cultures showing a high rate of regeneration from O. oryza *japonica x* O. glaberrima *and japonica x indica crosses following a regeneration subculture.*

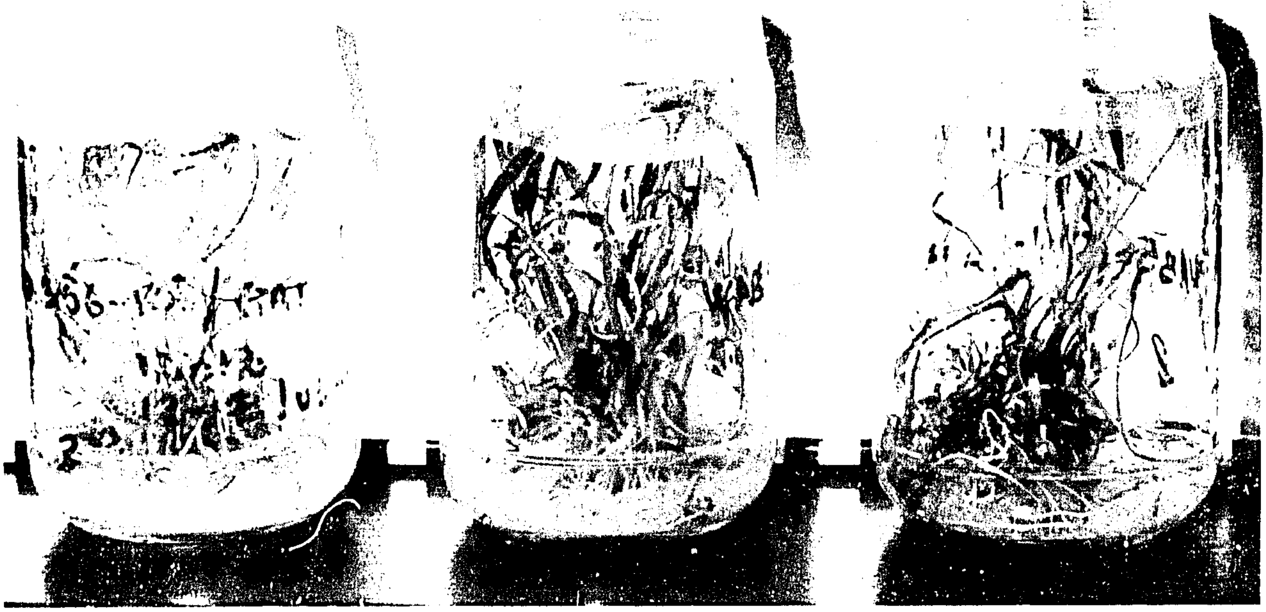
Mature H_1 anther-derived progeny of O. sativa *and* O. glaberrima *crosses. The doubled-haploid lines are 100% fertile.*

During 1994, we submitted to anther culture 10 parental lines and the progeny of 55 japonica x japonica, japonica x indica and *O. sativa* x *O. glaberrima* crosses. Response to callus induction and green plantlet regeneration depended on the genetic origin of the crosses, with japonica x *O. glaberrima* hybrids responding best, followed by pure japonica varieties and intra-japonica hybrids; japonica x indica hybrids; pure indica and intra-indica hybrids; and, pure *O. glaberrima* and intra-*glaberrima* hybrids responding least (Figure 23). Callus production generally peaked at four to five weeks after induction, and tissue produced during this period gave the highest probability of yielding green plantlets.

FIGURE. 23 Induction of anther-derived rice calli as a function of parent material and duration of in-vitro incubation.



Among the regenerated plants, we found a 5:4:1 ratio for haploids, doubled haploids, and polyploids, regardless of the genetic origin of the crosses. The spontaneous doubled haploid lines frequently displayed partial fertility, particularly when derived from crosses of *O. sativa* x *O. glaberrima*



Close-up view of regenerated plantlets. Note the high proportion of green plantlets and fewer albinos.

crosses, and to a lesser extent when derived from japonica x indica crosses. High sterility levels might have been caused by aneuploidy of the regenerated plants or fixation of sterility genes.

In 1995, more than 500 progenies of spontaneous doubled haploid fertile lines of *O. sativa* x *O. glaberrima* and 500 japonica x indica lines will be evaluated in the field in order to study their fertility, genetic stability, and agronomic traits. On the basis of the seed recovered from these trials, we will conduct specific screening trials for resistance to the major biotic and abiotic stresses in the region.

M&M: For anther culture, main stem boots of plants were collected when the auricle distance of the flag leaf to the next leaf is about 4 to 8 cm exserted. Panicles were disinfected and cold pretreated at 8° C for 10-20 days depending on the varietal type. Anthers were incubated in the dark at 25 ± 1° C in modified N6 medium, and calli obtained were regenerated in Murashige and Skoog (MS) medium with 16 hours photoperiod at 25° C. Plantlet regeneration was induced with the base MS salts and 3 ppm thiamine-HCl, 1 ppm IAA, 4 ppm GA3, and 2% sucrose increased green plantlet regeneration.

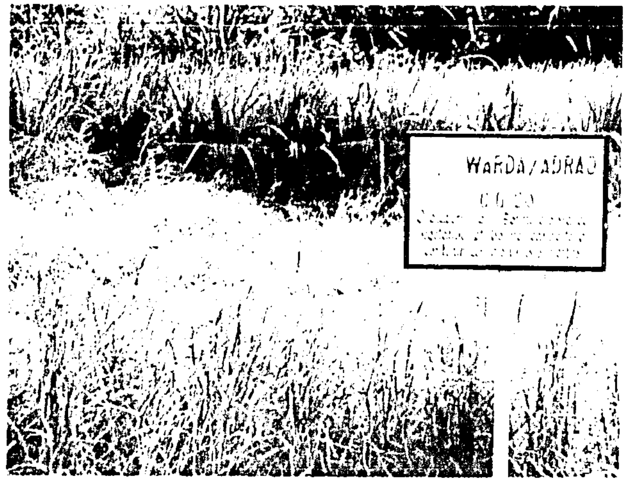
Interspecific *O. sativa* x *O. glaberrima* crosses yield stable and blast-resistant progeny

M.P. Jones, S. Mandé, K. Aluko, D. Hilaire, and K.E. Brou

Oryza glaberrima, a cultivated rice species indigenous to Africa, has been almost completely displaced by *O. sativa*, or Asian rice, which generally gives higher yields. A substantial sterility barrier between the two species has in the past prevented utilization of the many useful adaptations of *O. glaberrima* genotypes. These include superior resistance or tolerance to drought, weed competition, iron toxicity, blast disease, rice yellow mottle virus (RYMV), and African rice gall midge.

In 1992, WARDA initiated a wide hybridization program aided by anther culture and embryo rescue techniques in order to introgress useful traits from *O. glaberrima* into improved *O. sativa* japonica genotypes. This program yielded segregating intermediates in 1993 and the first genetically stable and fully fertile interspecific hybrids in 1994. On the basis of seven successful crosses using weed-competitive and blast-resistant and drought-tolerant parents, 1300 F_3 to F_6 populations were produced and evaluated for seedling vigor, plant height, tiller number, leaf width and color, presence of awn, epiculus color, and more.

Although true intermediates between *O. glaberrima* and *O. sativa* were generally rare, their occurrence in some populations was as high as 30%. The intermediates had a



O. glaberrima *has many desirable qualities, including blast resistance and drought tolerance, but it lodges easily and has low number of spikelets per panicle.*

O. sativa *(left) and* O. glaberrima *x* O. sativa *progeny (right). Note the high tillering and fertile panicles of the hybrids.*

Interspecific F_5 bulk populations after two backcrossings. Note the wide variation in morphological traits.

ligule length of 15-25 mm, compared to about 6 mm in *O. glaberrima* and 45 mm in *O. sativa*. Various degrees of awning and shades of purple epiculus were observed in the intermediates. Most important, the intermediates combine the high yield potential of *O. sativa* (a result of high spikelet number caused by secondary branches on the panicle) with traits from *O. glaberrima* for rapid vegetative growth, high tillering, short duration, and superior grain quality. Many of the stable F_5 populations are also highly resistant to seedling blast.

Anther culture was used to generate 191 doubled haploid plants from genetically stable F_1 and F_2 populations and, in 30% of the cases, they had 92% to 100% fertility. By contrast, genetic stabilization by conventional methods, requiring several cycles of back-crossing and selfing, is impeded by sterility and leads to the likely elimination of desired introgressions.

In 1995 we will increase the range of interspecific crosses in order to further broaden the available rice gene pool and to develop introgressed materials for specific stress environments. The interspecific progeny will be characterized on the basis of isozyme patterns and molecular markers in order to better understand the mechanisms of introgressions. Finally, given the wealth of useful traits found in *O. glaberrima*, which include many morphological traits needed in improved cultivars, such as high tillering and erect stature, we will also work for varietal improvement within *O. glaberrima*, with only specific essential traits taken from *O. sativa*, such as secondary branching of panicles.

TABLE 12: **Numbers of nematodes recovered from 20 rice cultivars inoculated with root-knot nematodes.**

Entry	Varietal type	nematodes recovered+		mean % of check
CG20	*O. glaberrima*	0	*	0
CG14	*O. glaberrima*	0.70	*	1
CG17++	*O. glaberrima*	-	-	-
WAB181-18	improved *O. sativa*	0.40	*	3
WAB56-104	improved *O. sativa*	0.85	ns	7
WAB96-1-1	improved *O. sativa*	0.87	ns	8
WAB-56-50	improved *O. sativa*	0.90	ns	11
WAB56-125	improved *O. sativa*	0.92	ns	12
OS6	traditional *O. sativa*	0.61	*	4
WAB450-25-1-14	*O. glaberrima* x *O. sativa* (CG14 x WAB56-104)	0.47	*	12
WAB450-24-1-1	*O. glaberrima* x *O. sativa* (CG14 x WAB56-104)	0.52	*	1
WAB450-14-6-2	*O. glaberrima* x *O. sativa* (CG14 x WAB56-104)	0.53	*	1
WAB450-25-1-10	*O. glaberrima* x *O. sativa* (CG14 x WAB56-104)	0.56	*	1
WAB450-2-2-10	*O. glaberrima* x *O. sativa* (CG14 x WAB56-104)	0.62	*	4
WAB450-28-1-7	*O. glaberrima* x *O. sativa* (CG14 x WAB56-104)	0.63	*	7
WAB450-10-5-9	*O. glaberrima* x *O. sativa* (CG14 x WAB56-104)	0.65	*	7
WAB450-18-2-5	*O. glaberrima* x *O. sativa* (CG14 x WAB56-104)	0.75	ns	9
WAB450-11-1-16	*O. glaberrima* x *O. sativa* (CG14 x WAB56-104)	0.97	ns	32
WAB450-11-2-17	*O. glaberrima* x *O. sativa* (CG14 x WAB56-104)	1.10	ns	93
IDSA6 (check)	*O. sativa* improved	1.11	-	100
LSD (P=0.05)		0.41	-	
CV (%)		46.4	-	

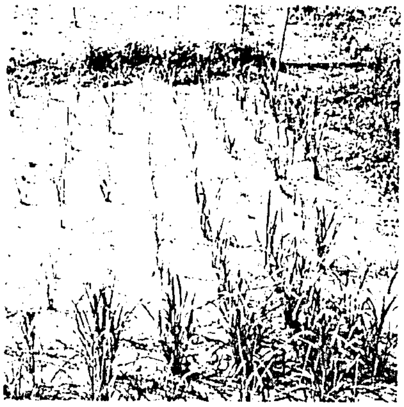
+ = numbers of nematodes per plant; log transformed mean of 4 replications
++ = missing plants
* = significantly ($P < 0.05$) different from check
ns = not significantly different from check

Rice plant (left) showing typical symptoms of yellowing and stunting following severe nematode infestation, compared with healthy nematode-free plant.

The African rice *Oryza glaberrima* provides nematode resistance for interspecific rice hybrids

D. Coyne (NRI), R. Plowright (IIP), and M. Jones.

Past field surveys have shown that root-knot nematodes (*Meloidogyne* spp.) are important restraints to rice production in West Africa, particularly in upland ecosystems. Nematode-resistant rice cultivars would be a low-cost means of nematode control, but improved cultivars currently grown have proved to be highly susceptible to these pests. Because resistance is



Stunted and patchy growth of rice plants as a result of plant-parasitic nematode damage in a trial at M'be, Côte d'Ivoire

known to occur in *O. glaberrima*, we undertook the present study to assess nematode resistance among the stable progeny of *O. sativa* x *O. glaberrima* crosses made at WARDA since 1992.

Seven *O. sativa* japonica-type upland rice cultivars, three *O. glaberrima* cultivars, and 10 stable progeny from a CG14 x WAB56-104 interspecific cross (Table 12) were screened under glasshouse conditions in the UK for resistance to *M. incognita* Race 2. IDSA6, an improved variety commonly cultivated in Côte d'Ivoire, was used as the susceptible check.

Among the *O. sativa* materials, only the traditional variety OS6 and WARDA's improved line WAB181-18 were resistant (showed significantly lower root infestation compared to check; Table 12). Among the three *O. glaberrima* materials, one was resistant, one was immune (no nematodes found in the root), and one failed to grow for unknown reasons. Among the interspecific progeny that resulted from a CG14 (resistant) x WAB56-104 (susceptible) cross, seven out of 10 were resistant, indicating that resistance to root-knot nematodes is a transferable trait.

Our results are encouraging in the development of new resistant cultivars. However, the possibility of a recurrence of susceptibility requires that progeny testing for nematode resistance should be continued throughout cultivar development. In 1995 we will validate the greenhouse observations in the field. The field trials will encompass broader ranges of nematode species and test varieties.

M&M: Single plants in pots were inoculated at 12 days after sowing with 200 hatched *M. incognita* juveniles in a RCB design with four replicates. Root nematode populations were assessed two months after inoculation.

IRRIGATED AND RAINFED LOWLAND ECOSYSTEMS

Breeding for irrigated lowlands
B.N. Singh

Most lowland rice production systems in West Africa are rainfed, based on a wet-season rice crop, followed by a different crop or fallow vegetation, using residual moisture. Irrigated rice is grown in large irrigation schemes, which frequently permit growing two rice crops per year, and in an increasing number of improved valley-based lowland systems. The main environmental constraints to high rice yields are biological, such as leaf and panicle blast, rice yellow mottle virus (RYMV), African rice gall midge (ARGM), and some pests and diseases of local significance. Iron toxicity is a severe problem at specific sites, particularly in the inland valleys.

CRET trials for irrigated lowlands being evaluated in Nigeria by a joint team from WARDA, the Nigerian NARS, and INGER.

WARDA's irrigated lowland rice breeding activity targets rice varieties with high yield potential, medium or short duration, slender grains with good quality, and stable resistance to the biotic and abiotic stresses mentioned. Because of the prevalence of blast disease, all new introductions and recombinants undergo initial blast screening. Resistant entries move on to onstation observational yield trials (OYT), regional OYT, and regional replicated yield trials (RYT) coordinated by the Lowland Rice Breeding Task Force. Selected lines from RYT in any given country are evaluated in elite varietal trials

TABLE 13: Top-ranking entries in the second regional irrigated lowland yield trial, short duration, 1994.

Location	Entry	Yield (t ha^{-1})
Ibadan, Nigeria	FAROX 308-1-2	5.53
	TOX 3049-13-1-2-3-1	5.29
	TOX 3090-135-1-3-2-2	5.13
	TOX 3058-28-1-1	4.87
	FARO 44[a]	4.26
	SE ±	0.27
	CV (%)	10.6
Rokupr, Sierra Leone	TOX 3090-135-1-3-2-2	4.12
	TOX 3049-13-11-2-3-1	4.09
	ITA 123	3.66
	Guinea Yaka[b]	3.43
	FARO 44[a]	2.48
	SE ±	0.77
	CV (%)	4.5
Midekhine, Chad	TOX 3440-16-1-2-2-1	6.78
	TOX 3090-135-1-3-2-2	6.73
	IR 64	6.68
	FARO 44[a]	5.58
	TOX 728-1[b]	5.06
	SE ±	—
	CV (%)	12.2
N'Diaye, Senegal	FARO 44[a]	6.26
	TOX 3058-28-1-1	5.34
	ITA 416	5.22
	TOX 3440-16-1-2-2-1	5.18
	TOX 3049-1-3-1-2-3-1	5.21
	SE ±	—
	CV (%)	—
Kaedi, Mauritania	TOX 3049-13-1-2-3-1	6.97
	ITA 416	6.83
	TOX 3090-135-1-3-2-2	6.17
	FAROX 303-6-7-2	6.13
	TN 1[b]	4.03
	SE ±	—
	CV (%)	16.4
Nyankpala, Ghana	TOX 3090-135-1-3-2-2	3.2
	TOX 3058-28-1-1	2.8
	TOX 3049-13-1-2-3-1	2.6
	IR 72	2.5
	GR 18	2.0
	SE ±	—
	CV (%)	—

[a] = Regional check [b] = Local check

(EVT) or coordinated rice evaluation trials (CRET), followed finally by trials in farmers' fields.

In the 1994 onstation OYT at Ibadan, we screened 300 fixed lines selected from pedigree nurseries in 1993. Entries were evaluated in an augmented design with five checks (IR72, ITA 306, IR46, Mahsuri, and FARO 15). Based on grain yield and plant type, 80 lines were selected for irrigated lowland conditions. Another 63 lines were shifted to rainfed lowland nurseries, based on morphological criteria. Regional OYT had 50 entries, and RYT had 12 entries in 1994. High ARGM and RYMV pressure at some of the regional sites enabled the elimination of highly susceptible entries. Only one line, TOX 3370-54-3-1-2, was moderately resistant to ARGM. Twenty-four lines showing better general performance than the local check ITA 306 were selected for further characterization during 1995.

A set of advanced short-duration selections was tested at six sites in six countries. FARO 44 (SIPI 692033) served as the regional check, complemented with site-specific local checks (Table 13). Two entries, TOX 3049-13-1-2-3-1 and TOX 3090-135-1-3-2-2, showed superior performance across diverse environments. TOX 3090-135-1-3-2-2 had high yields even at sites with severe ARGM pressure.

A set of 12 advanced medium-duration selections was evaluated at eight sites in six countries (Table 14). IR46 was used as the regional check. Among several outstanding lines, TOX 3233-46-3-3-4-2-2 deserves particular attention because of its superior performance across a wide range of environments, including sites in the Sahel and the humid tropics.

The substantial progress made during 1994 in breeding and selecting high-yielding and broadly adapted cultivars for irrigated rice results from effective region-wide collaboration, involving NARS at an early stage of selection. In 1995 we will continue refining our decentralized approach. Additional emphasis will be given to resistance to RYMV and ARGM, whereas the high level of yield potential already attained allows less emphasis on this objective.

TABLE 14: Top-ranking entries in the second regional irrigated lowland and elite varietal yield trial, medium duration, 1994.

Location	Entry	Yield t ha^{-1}
Ibadan, Nigeria	TOX 3052-46-3-3-1	5.23
	TOX 3233-46-3-3-4-2-2	5.01
	TOX 3107-39-1-2-1-1	4.85
	ITA 306[b]	4.55
	IR 46[a]	4.12
	SE ±	0.29
	CV (%)	11.3
N'Diaye, St. Louis, Senegal	TOX 3233-46-3-3-4-2-2	5.79
	ITA 414	5.69
	IR 46[a]	5.66
	TOX 3109-73-4-4	5.30
	FARO 50	5.08
	SE ±	0.44
	CV (%)	14.6
Tove, Togo	TOX 3255-82-1-3-2	3.90
	TOX 3107-39-1-2-1-1	3.83
	TOX 3233-46-3-3-4-2-2	3.52
	ITA 230	3.35
	TGR 1[b]	3.20
	SE ±	0.89
	CV (%)	17.2
Nyanpkpala, Ghana	ITA 230	3.40
	TOX 3255-82-1-3-2	3.20
	ITA 414	3.00
	GR 18[b]	2.80
	ITA 306[a]	2.80
	LSD (.05)	NS
IDESSA, Camp pénal, Côte d'Ivoire	Bouaké 189[b]	5.51
	Cisadane	5.29
	TOX 3052-41-E1-1-2-1-2	5.27
	TOX 3233-46-3-3-4-2-2	4.83
	TOX 3084-136-1-3-1-2	4.73
	SE ±	—
	CV (%)	—
Kaedi, Mauritania	TOX 3107-39-1-2-1-1	6.07
	TOX 3233-46-3-3-4-2-2	5.85
	ITA 230	5.49
	Jaya[b]	5.39
	ITA 306[a]	4.81
	SE	—
	CV (%)	27.6
Manga, Ghana	TOX 3100-37-3-3-2-9	3.93
	RP 2107-14-12	3.89
	IR 51463-BP3-160-2-2-3-1-2	3.69
	ITA 320	3.66
	GR 19[b]	2.59
	LSD (.05)	0.82
Mbé, Côte d'Ivoire (EVT)	Cisadane	5.11
	TOX 3050-6-E2-3-4	4.98
	WITA 2	4.69
	TOX 3084-136-1-3-1-2	4.36
	Bouaké 189[b]	3.44
	LSD (.05)	1.27
	SE ±	0.74
	CV (%)	21.5

[a] = Regional check [b] = Local check

Breeding for rainfed lowland environments
B.N. Singh

The rainfed lowland rice ecosystem in West Africa has a vast potential for increased rice production through area expansion and intensification. Cultivated lowlands, which are either located in valley bottoms or swamp plains, are resilient, but they are prone to variable periods of either drought or excess water. Water stress reduces crop growth and yield directly, and it renders the plant more vulnerable to diseases and weed competition.

Crop improvement for rainfed lowlands generally requires a high priority to yield stability, even at the expense of some yield potential. Consequently, WARDA's rainfed lowland breeding activities concentrate on materials resistant to blast, rice yellow mottle virus (RYMV), and African rice gall midge (ARGM), with intermediate height to tolerate fluctuating water depth and to suppress weeds. In addition, materials must resist drought at both the vegetative and reproductive stages, and they must avoid late-season drought through short duration. As in WARDA's irrigated lowland breeding program, selection for rainfed lowland adapted rice systematically involves the Lowland Rice Breeding Task Force in order to diversify screening environments and enable national breeders to participate in the selection process. Separate sets of nurseries are composed for drought-prone and favorable rainfed lowland conditions, which sequentially pass through elimination processes in initial blast screening, onstation observational trials (OYT), regional OYT, regional replicated yield trials (RYT), and farmers' field trials.

TABLE 15: Top-Ranking entries in the second regional rainfed lowland drought-prone yield trial, 1994.

Location	Entry	Yield t ha^{-1}
M'bé, Côte d'Ivoire	BG 90-2[a]	4.91
	TOX 3084-136-1-3-1-2	4.90
	ITA 368	4.76
	TOX 3118-47-1-2-3	4.74
	Bouaké 189[b]	4.74
	SE ±	0.96
	CV (%)	26.1
Ibadan, Nigeria	TOX 3100-44-1-2-3-3	1.37
	TOX 3084-136-1-3-1-2	1.24
	TOX 3154-17-1-3-2-2	1.20
	ITA 306[b]	1.16
	BG 90-2[a]	0.54
	SE ±	0.32
	CV (%)	57.8
NCRI, Badeggi, Nigeria	TOX 3154-17-1-3-2-2	3.04
	IR 54	2.55
	IRAT 216	2.51
	FARO 44[b]	2.47
	BG 90-2[a]	1.62
	SE ±	0.43
	LSD (.05)	0.75
	CV (%)	20.7
Gassi, Chad	BG 90-2[a]	4.40
	TOX 3084-136-1-3-1-2	4.28
	TOX 3562-15-3-2-1	4.18
	TOX 3100-44-1-2-3-3	4.10
	IR 46[b]	3.61
	SE ±	
	CV (%)	
Bokle, Cameroon	TOX 3118-47-1-1-2-3	5.07
	IR 54	4.86
	ITA 368	4.56
	TOX 3100-44-1-2-3-3	4.32
	BG 90-2[a]	2.41
	LSD (.05)	0.87
	CV (%)	14.9
Dasilame, Gambia	TOX 3399-108-3-2-2	2.65
	IR 54	2.24
	TOX 3154-17-1-3-2-2	2.09
	TOX 3562-15-3-2-1	1.84
	BG 90-2[a]	1.50
	CV (%)	36.9
Nyankpala, Ghana	TOX 3154-17-1-3-2-2	2.39
	IR 54	1.88
	ITA 368	1.87
	BG 90-2[a]	1.72
	GR 19[b]	1.26
	SE ±	
	CV (%)	

[a] = Regional check [b] = Local check

During 1994, entries selected from 1993 regional OYT and RYT were evaluated for a second year in drought-prone regional OYT and RYT. In the RYT, 12 entries were evaluated at seven sites in six countries (Table 15). Drought was severe at the vegetative and reproductive stages at Ibadan (Nigeria) and Dasilame (Gambia), whereas no drought was observed at M'bé (Côte d'Ivoire) and Gassi (Chad). Wherever drought stress was absent, the regional check BG90-2 outyielded all test entries, but it had inferior yields at drought-prone sites. Among the test materials, TOX 3084-136-1-3-1-2 stood out by having high yields in favorable environments, while also ranking high under drought-stressed conditions. TOX 3100-44-1-2-3-3 also showed broad adaptability, particularly under drought stress. Based on its short duration, plant height, and agronomic performance, TOX 3100-44-1-2-3-3 was selected for farmer field testing in 1995 and was designated 'WITA 4'. A parallel set of nurseries composed of more recently received accessions was tested during 1994 in regional OYT for drought-prone environments. The best-performing entries have been selected for the 1995 regional RYT.

Initial screening during 1994 for blast and drought resistance in the seedbed included 78 F_4 bulk populations. Only resistant plants were transplanted to main plots, and 18,321 F_5 individual plants were selected. We will evaluate them during 1995, using the pedigree method. For hybridization, a new method based on genetic male-sterile progeny was introduced to more efficiently incorporate drought resistance into germplasm with good agronomic performance.

On-farm testing with farmers: joint selection of an elite line, WITA4, for drought-prone rainfed lowlands.

TABLE 16: Top-ranking entries in the regional rainfed lowland favorable yield trial, 1994.

Location	Entry	Yield t ha^{-1}
M'bé, Côte d'Ivoire	ITA 306[a]	6.44
	TOX 3440-132-3-3-1	6.23
	Cisadane	6.17
	TOX 3100-44-1-2-3-3	5.96
	Bouaké 189[b]	5.30
	SE ±	0.41
	CV (%)	8.8
	LSD (.05)	0.71
Ibadan, Nigeria	FARO 15[b]	3.06
	TOX 3963-8-1-3	2.53
	ITA 324	2.48
	TOX 3162-11-1-2-1-1	2.43
	ITA 306[a]	1.92
	SE ±	0.16
	CV (%)	13.1
Bokle, Cameroon	TOX 3967-17-1-1	7.36
	TOX 3100-44-1-2-3-3	5.84
	ITA 306[a]	5.64
	TOX 3095-52-3-2-3	4.82
	IRAT 112[b]	3.24
	LSD (.05)	1.24
	CV (%)	15.6
Kaedi, Mauritania	ITA 306[a]	7.15
	TOX 3967-17-1-1	6.72
	Jaya[b]	6.70
	Cisadane	6.64
	TOX 3069-66-2-1-6	6.64
	SE ±	—
	CV (%)	17.3

[a] = Regional check [b] = Local check

A separate breeding activity was conducted for the more favorable, less drought-prone lowlands. Twelve lines from the 1993 regional and onstation trials were selected for the regional favorable rainfed lowland trial in 1994. Four sets of accessions were evaluated at four sites in four countries (Table 16). At Bokle in Cameroon, the regional check ITA 306, which has an extremely high yield potential, was susceptible to leaf blast and was significantly outyielded by blast-resistant TOX 3967-17-1-1. At M'bé, where ARGM pressure was high, the resistant accessions TOX 3440-132-3-3-1 and Cisadane had significantly higher yields than the local check Bouaké 189. These materials will be further characterized in 1995 in order to compose onfarm trials. From the 1994 regional OYT, 18 lines have been selected in Sierra Leone, 21 in Nigeria, and 13 in Côte d'Ivoire. They will form the 1995 regional RYT for favorable rainfed lowlands.

Observations during 1994 showed that under favorable rainfed lowland conditions, the yield potential of regional check ITA 306 will be difficult to beat. There is scope, however, for further improvement of blast and ARGM resistance, and the 1994 results are encouraging in this respect. For the drought-prone lowlands, significant progress was made in the selection of materials with broad adaptability. The relatively new disease RYMV, however, remains a major challenge in breeding for both environments. The natural pressure is too variable to permit reliable field screening, and no lowland-adapted indica materials resistant to RYMV are as yet available. This will be a major focus of WARDA's research in 1995 and beyond.

TABLE 17: Top-ranking entries in first regional low-input-yield trial, 1994.

Location	Entry	Yield t ha^{-1}
Dasilame, Gambia	TOX 3055-10-1-1-3-3-1	2.35
	TOX 3050-46-E2-3-3-3	2.17
	TOX 3561-56-2-3-2	1.96
	Mahsuri[a]	1.51
	DJ 12-519[b]	0.85
	CV (%)	27.0
	LSD (.05)	1.02
Seme, Togo	TOX 3055-10-1-3-2-2	1.08
	TOX 3053-46-E2-3-3-3	1.00
	Suakoko 8	0.93
	TGR 1[b]	0.83
	Mahsuri[a]	0.51
	SE	0.73
	CV (%)	17.1
Rokupr, Sierra Leone	TOX 3499-84-2-1-3	4.27
	Mahsuri[a]	3.24
	IR 48028-B-B-126-3	3.48
	TOX 3561-56-2-3-2	3.06
	Bojou 130021[b]	3.06
	LSD	0.19
	CV	3.97
Badeggi, Nigeria	TOX 3100-44-1-2-3-3	4.51
	7106-2-3-3-1	4.13
	TOX 3499-84-2-1-3	4.13
	FARO 35[b]	3.56
	Mahsuri[a]	1.16
	LSD (0.05)	0.72
	CV (%)	15.5
Contuboel, Guinea Bissau	TCA 80-4	1.95
	IR 48028-B-B-126-3	1.66
	SPT 7106-2-3-3-1	1.61
	Senquere[b]	1.45
	Mahsuri	0.98
	SE ±	—
	CV (%)	—

[a] = Regional check [b] = Local check

Selecting rainfed lowland lines for low-input conditions

B.N. Singh

Most resource-poor farmers in West Africa cultivate rainfed lowland rice in inland valley swamps with very low fertilizer and management inputs. In such environments, many of the widely used semidwarf varieties perform no better than the traditional tall varieties because they compete poorly with weeds, and they achieve their yield potential only if resources are abundant. A specific breeding activity was initiated in 1994 to develop lowland rice materials with intermediate plant type, multiple biotic and abiotic stress resistance, and high seedling vigor that will yield a crop even under substantial weed pressure.

During 1994, 12 lines selected from the 1993 observational yield trial were evaluated by the Lowland Rice Breeding Task Force in a regional replicated yield trial (RYT) in five countries (Table 17). Mahsuri, a variety released as ROK 24 in Sierra Leone, was used as the regional check. Twenty kg N ha^{-1} were broadcast as a single dose after manual weeding, 25-30 days after planting.

Yields were highest at Rokupr in Sierra Leone and at Badeggi in Nigeria, at which sites TOX 3499-84-2-1-2 gave the highest yields of more than four t ha^{-1}. At Seme in Togo and Dasilame in Gambia, yields were much lower and the best-performing variety at both sites was TOX 3055-10-1-1-3-3-1. In Contuboel, Guinea Bissau, yields were also very low, but the spectrum of best-performing lines was entirely different from that of the other sites. Significant yield differences between WARDA selections and either the local or regional checks were found only in the three sites having the highest yields, Dasilame, Rokupr, and Badeggi.

These results, once confirmed in 1995 and analyzed for the site-specific constraints encountered in 1994, will enable us to target low-input-adapted varieties to specific stress environments. Also in 1995, we will test in regional RYT the best selections from last year's observational yield trial of 50 entries, from which 10 were nominated at Ibadan in Nigeria and 17 at Contuboel in Guinea-Bissau.

Advances in breeding for iron toxicity tolerance

B.N. Singh

Iron toxicity is a major problem in many lowlands in the humid and subhumid zones of West Africa, particularly in the bottoms of inland valleys. High concentrations of reduced iron in the soil severely affect the nutrition and growth of

TABLE 18: Top-ranking entries in the second regional iron-toxicity tolerance and elite variety trial, 1994.

Location	Entry	Yield t ha^{-1}
Edhozigi, NCRI Nigeria	CK 73	3.20
	TOX 3052-4-E1-2-1-2	2.38
	TOX 3069-66-2-1-6	2.16
	Suakoko 8[a]	1.94
	FARO 8[b]	1.87
	LSD (.05)	0.37
	CV (%)	12.2
Kabala, Sierra Leone	CK 4	3.20
	TOX 3050-46-E3-3-2-3	2.84
	Suakoko 8[a]	2.83
	TOX 3100-32-2-1-3-5	2.80
	Gissi 27[b]	2.06
	LSD (.05)	0.34
	CV (%)	9.44
Sikasso, Mali	Suakoko 8[a]	4.13
	TOX 3050-46-E3-3-3-3-3	4.09
	BR4[b]	3.67
	TOX 3052-41-E1-2-1-2	3.57
	TOX 3100-32-2-1-3-5	3.51
	CV (%)	26.0
Bordo, Guinea	DR 33-PD5-PD2-PD4-PD1	4.60
	TOX 3093-10-2-3-2	4.57
	ITA 234	4.23
	Vijaya	4.20
	CK 4[b]	4.03
	CV (%)	17.8
Menchum, Cameroon	CK 73	6.47
	TOX 3069-66-2-1-6	4.98
	TOX 3100-32-2-1-3-5	4.29
	TOX 3052-41-E1-2-1-2	4.06
	Suakoko 8[a]	1.66
	LSD (.05)	0.85
	CV (%)	14.0
Korhogo, Côte d'Ivoire	TOX 3118-6-E2-3-2	6.66
	TOX 3052-41-E1-2-1-2	6.30
	TOX 3081-36-2-3-1	6.17
	Bouaké 189[b]	4.69
	Suakoko 8[a]	3.73
	LSD (0.05)	1.1
	CV (%)	15.0
Djibelor, Senegal	Suakoko 8[a]	3.36
	DJ 684-D[b]	1.92
	WITA 2	1.46
	TOX 3081-36-2-3-1	1.28
	TOX 3027-43-1-E3-1-1-1	1.25
	SE ±	—
	CV (%)	—
Anfani WARDA, Nigeria	TOX 3118-6-E2-3-2	3.12
	CK 73	2.90
	WITA 3	2.88
	CK 4	2.84
	Suakoko 8[a]	2.79
	LSD (.05)	0.70
	SE ±	0.24
	CV (%)	19.1

[a] = Regional check [b] = Local check

rice. Varietal tolerance to this stress is generally the most cost-effective means to improve rice production on iron-toxic soils. In our work to develop new varieties with enhanced iron toxicity tolerance, we concentrate on regional hotspots. These include Edozhigi and Ikot Obong in Nigeria (severe toxicity), Badeggi in Nigeria and Korhogo in Côte d'Ivoire (moderate to severe), and at Djibelor in Senegal (a combination of stresses associated with acid sulphate soils). Regional varietal testing at these hotspots is coordinated by the Lowland Rice Breeding Task Force.

During 1994 we selected from segregating generations, observational nurseries, and nonreplicated yield trials at Edozhigi, Nigeria. Observational (OYT) and replicated yield trials (RYT) for advanced selections were conducted at several locations with various NARS collaborators. The Lowland Rice Breeding Task Force conducted two regional replicated yield trials for elite selections. All trials used Suakoko 8 as the regional tolerant check, and one or more local checks.

In the 1994 observational nursery, 300 fixed lines were evaluated at Edozhigi, using an augmented nonreplicated design. Forty-five lines were resistant and another 55 were moderately resistant. These lines will be evaluated in WARDA's OYT during 1995. In the 1994 OYT, 270 lines were evaluated with Suakoko 8, IR46, Mahsuri, and TOX 3069-66-2-1-6 as checks. Selected lines will be tested in the regional OYT during 1995. In the 1994 regional OYT, 50 lines were evaluated at four sites in Nigeria (Edozhigi and Ikot Obong), Sierra Leone (Kabala), and Senegal (Djibelor). At Edozhigi, where iron

toxicity was severe, we found that 14 lines were resistant and only eight lines outyielded the regional check. At Ikot Obong, iron toxicity was also severe, and only 20 lines survived, out of which we selected eight lines. At Kabala, 18 lines were selected, with WAR 100-2-12-1 giving an outstanding yield of 3.85 t ha^{-1}. At Djibelor, representing a mangrove rice ecosystem, iron toxicity was coupled with aluminum and hydrogen sulphide toxicities. In this environment, none of the entries exceeded the yield of Suakoko 8. The best-performing lines from each site will form the 1995 regional RYT.
Also during 1994, the Lowland Rice Breeding Task Force evaluated 12 elite lines in a regional RYT comprising eight sites in seven countries (Table 18). In five of the seven sites (Edozhigi, Kabala, Bordo, Menchum, and Korhogo) various entries significantly outyielded both local and regional checks.
Particularly promising are CK73 and TOX 3050-46-E3-3-2-3, which outyielded checks at two sites and CK4 and TOX 3100-32-2-1-3-5 (at one site). The CK lines are from the Guinean national program and were recently identified by the Lowland Rice Breeding Task Force.

Our hybridization activities in 1994 made use of genetic male sterility to more efficiently transfer iron-toxicity tolerance to progeny with improved plant type. Bulk selections were made from 27 F_2 populations grown at Edozhigi and 25 F_3 populations at Ibadan.
During the 1994/95 dry season, the genetic male-sterile population, WATMSP1, was subjected to a second outcrossing cycle with 10 improved iron-toxicity lines as "male parents". Tolerant lines will be y parents selected from male-fertile plants using the pedigree method, and evaluated during the 1995 wet season at Edozhigi.

Screening for rice yellow mottle virus in a screenhouse at Ibadan, Nigeria. All but the center variety are affected by the virus.

Also in 1994, we continued our search for better introduced and local genetic sources of iron-toxicity tolerance. Fifteen cultivars popular among farmers in the Bida area in Nigeria were evaluated for their iron-toxicity tolerance, and all of them were resistant to moderately resistant. They will be further tested at Ikot Obong and Edozhigi in 1995.

It is now clear that our research to improve iron-toxicity tolerance since 1990 has yielded a large number of materials that show stable performance across some, but not all, of the diverse test environments in the region. Many of these significantly outyield the check varieties. To make even more rapid progress, we need more information on the spatial and temporal (e.g., seasonal) variability of iron toxicity and on the trade-offs between yield potential and physiological tolerance. Intensified research in these areas during the next few years will enable us to improve our screening methodologies and target specific stress intensities and combinations through breeding.

Breeding lowland rice for resistance to RYMV
B.N. Singh

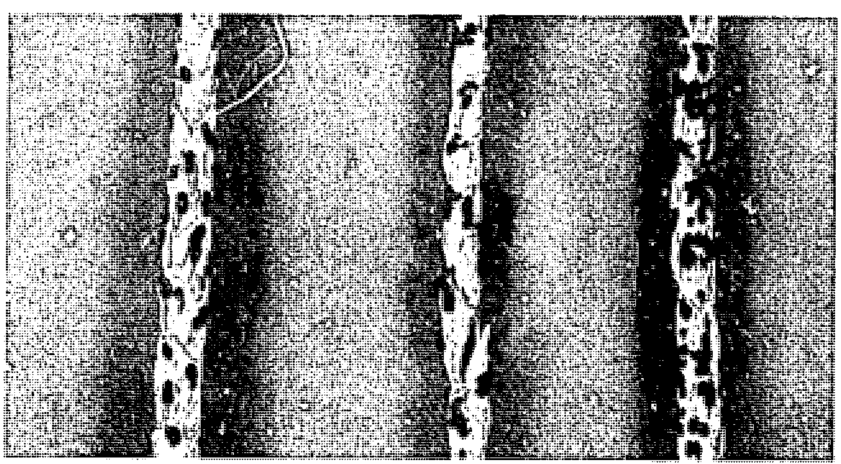
Rice yellow mottle virus (RYMV), leaf and panicle blasts, leaf scald, and bakanae are the major diseases of lowland rice in West Africa. Hybridization and selection from segregating populations and fixed lines continued during 1994 to develop stable resistance. A fungal disease not described before in the region, udbatta, was identified at Ibadan, Nigeria. Although the disease had been present in a mild form during past years, it became severe in some trials and varieties during the 1994 wet season.

TABLE 19: Top-ranking entries in the second regional Task Force trial for RYMV resistance, 1994.

Location	Entry	Yield t ha^{-1}
IITA, Ibadan	TOX 3440-176-1-2-1	5.13
	ITA 212[b]	5.03
	TOX 3440-171-1-1-1-1	4.87
	TOX 3553-36-2-2-2	4.83
	ITA 306[a]	4.62
	SE ±	0.27
	CV (%)	10.1
M'bé, Bouaké	Bouaké 189[b]	4.80
	TOX 3440-16-3-3-2-2-3	4.55
	TOX 3217-69-3-1	4.47
	TOX 3553-36-2-2-2	4.31
	ITA 306[a]	3.90
	SE ±	0.74
	CV (%)	31.9
Rokupr, Sierra Leone	TOX 3553-36-2-2-2	4.23
	TOX 3211-14-1-2-1-2	4.18
	TOX 3058-28-1-1	3.86
	TOX 3052-46-E2-2-2-4-3	3.84
	ITA 306[a]	3.60
	SE ±	0.15
	CV (%)	9.2
Niono, Mali	TOX 3058-28-1-1	9.03
	ITA 306[a]	8.54
	TOX 3440-176-1-2-1	8.49
	BG 90-2[b]	8.12
	TOX 3440-171-1-1-1-1	7.77
	SE ±	—
	CV (%)	—

[a] = Regional check [b] = Local check

RYMV disease has become a major constraint to rice production in Mali and Côte d'Ivoire, where large areas under irrigated rice have become affected since 1992. During three years of onstation and onfarm testing in Côte d'Ivoire, the two lines showing apparent RYMV resistance under natural disease pressure, TOX 3440-171-1-1-1-1 and TOX 3440-176-1-2-1, were designated as WITA 7 and WITA 8, respectively, for large-scale testing in farmers' fields. No advanced lowland materials resisting artificial inoculation are available to date, however; so we have intensified our search for indica-type donors of stable resistance.



Udbatta disease, as seen at Ibadan, Nigeria, observed for the first time in the 1994 wet season.

In a parallel approach, we are also trying to utilize the rich sources for RYMV resistance present in the upland-adapted tropical japonica group and in the African rice species *Oryza glaberrima*. These groups are genetically and agroecologically distant from the indica rice types preferred in lowland rice cultivation, but encouraging progress was made by WARDA breeders during 1994 towards the realization of wide crosses and the retention of desirable traits from both parents.

A biotechnological approach to generating RYMV-resistant lowland rice progeny is also being initiated in collaboration with research institutes in the UK and France. Projects will begin during 1995 to map and mark RYMV resistance loci in different rice groups and species, and to transfer either natural or synthetic transgenes for RYMV resistance.

In order to provide farmers in the shortest possible time with cultivars that are at least moderately resistant to RYMV, WARDA's conventional breeding and varietal selection program has also been intensified, in collaboration with the Lowland Rice Breeding Task Force. During 1994, the third regional RYMV observational yield trial (OYT) was conducted at four sites in Côte d'Ivoire, Sierra Leone, and Nigeria, composed of 40 entries selected from the 1993 onstation OYT. Moderate RYMV pressure was observed at M'bé in Côte d'Ivoire and Rokupr in Sierra Leone, but was absent at Ibadan in Nigeria and Camp Penal in Côte d'Ivoire. The 12 highest-yielding entries having appropriate plant type, no RYMV and low blast symptoms, were nominated for the 1995 regional replicated yield trial (RYT). In the 1994 regional RYT conducted by the Lowland Rice Breeding Task Force, RYMV pressure was also low at most sites, and varietal selection was mainly based on yield and resistance to stresses like blast and African rice gall midge (ARGM).

We made several crosses during 1994 in order to study the genetics of RYMV resistance and to generate pedigree lines for selection. Preliminary results will be available in 1995. A general problem in breeding for RYMV resistance is the high temporal variability of the natural disease pressure, which prevents reliable screening for resistance in the field. This may change soon because RYMV pressure across the region is generally rising, but in order to pre-empt such a development, breeding for RYMV resistance must now be accelerated using controlled infection in protected environments. WARDA is currently expanding its screenhouse facilities to realize this objective.

Breeding lowland rice for resistance to blast
B.N. Singh

Leaf and panicle blast represent major and consistent constraints to rice production in all West African rice ecosystems except the Sahel. Because blast resistance is generally a necessary prerequisite for stable varietal performance in rainfed and irrigated lowlands, WARDA scientists systematically screen all new introductions and segregating populations to eliminate highly susceptible materials.

During 1994, in order to develop varieties with stable and durable resistance, lines were screened under both natural and artificial disease pressure using infector rows. In the regional leaf and panicle blast screening nursery conducted jointly by the Lowland Rice Breeding Task Force and WARDA scientists, 100 lines were evaluated for resistance to leaf blast in the Mbo plains and at Karewa in Cameroon, Ibadan in Nigeria, and Rokupr in Sierra Leone. Panicle blast was screened only at Ibadan, where incidence was very high. Disease incidence was low at Karewa and high at Rokupr. Varietal patterns of leaf blast response varied among the four sites. During 1995, 35 lines that showed stable resistance across several sites will be tested in observational yield trials (OYT) in the Mbo plains.

In an effort to select high-yielding lowland lines with stable blast resistance and resistant donors for our hybridization program, we evaluated 112 improved breeding lines for leaf blast response in replicated screenhouse yield trials (RYT). Infector rows seeded two weeks earlier than the test entries were inoculated with field isolates of leaf blast at Ibadan. Disease development based on lesion size and leaf area infestation was measured at weekly intervals during the vegetative growth phase. We identified four lines, ITA 324, IRAT 216, TOX 3118-47-1-1-2-3, and TOX 3226-5-2-2-2, that were immune. Another 23 lines were resistant to moderately resistant. These lines will be used as parents in subsequent crosses. Using the same screening system, we evaluated 567 selections from a genetic male sterile-facilitated recurrent selection program and found excellent results. Thirty percent of the lines were immune and another 21% were resistant to moderately resistant to leaf blast. Most of the lines are of a plant type suited to rainfed lowland ecosystems. Once fixed, we will test the selected lines in an onstation OYT.

Breeding lowland rice for resistance to leaf scald
B.N. Singh

Only moderate progress was made in 1994 towards achieving resistance to leaf scald, a fungus disease. Leaf scald is a major problem in drought-prone rainfed lowland environments, for example at Nyankpala in Ghana and in the Mbo plains in Cameroon. To select resistant lowland adapted lines as donors for hybridization, we screened 925 lines for leaf scald resistance in regional and onstation trials, in collaboration with the NCRI research station at Amakama in Nigeria. Forty-three percent of the lines were rated susceptible or highly susceptible. Only 10 lines (1%) were rated resistant and 60 lines (6%) as moderately resistant. All except the susceptible and highly susceptible lines will be further screened during 1995. From

TABLE 20: Top-ranking entries in the regional replicated Task Force trial for ARGM resistance.

Location	Entry	ield t ha^{-1}
M'bé, Côte d'Ivoire	BG 90-2[a]	4.91
	TOX 3084-136-1-3-1-2	4.90
	ITA 368	4.76
	TOX 3118-47-1-2-3	4.74
Ibadan, Nigeria	TOX 3223-46-3-3-4-2-2	4.10
	BW 348-1	4.10
	ITA 306[a]	4.00
	Suakoko 8	3.70
	Cisadane	0.31
	SE±	5.1
	CV %	4.50
M'bé, Côte d'Ivoire	Cisadane	3.76
	ITA 306	3.75
	Suransksha	3.74
	TOX 3967-17-1-3	3.67
	Bouaké 189[a]	2.80
	LSD (.05)	0.45
	CV %	7.64
Gadza, Nigeria	TOX 3967-17-1-3	4.56
	TOX 3876-56-1-4	3.70
	Cisadane	3.57
	Suraksha	3.56
	ITA 306	2.90
	SE±	0.35
	CV (%)	18.5
Gassi, Chad	BW 348-1	4.88
	TOX 3876-56-1-4	4.73
	Suraksha	4.60
	TOX 3967-17-1-3	4.56
	ITA 306[a]	3.41
	SE±	—
	CV (%)	
Badeggi, Nigeria	TOX 3093-35-2-3-3	2.40
	TOX 3255-82-1-3-2	2.40
	TOX 3233-46-3-3-4-2-2	2.23
	FARO 29[b]	1.97
	ITA 306[a]	1.78
	LSD (.05)	ns
	CV (%)	2.2
Karfiguela, Burkina Faso	Suraksha	4.88
	Cisadane	4.65
	TOX 3255-82-1-3-2	4.38
	BW 348-1	4.24
	ITA 306[a]	1.52
	LSD	0.85
	CV (%)	13.1

[a] = Regional check [b] = Local check

African rice gall midge incidence at Rokupr, Sierra Leone, seen for the first time in 1994.

a previous hybridization activity, 15 F_2 populations were also grown at Amakama during 1994, and bulk and individual plants were selected for further evaluation in 1995.

Breeding for resistance to insect pests in lowland rice
B.N. Singh

Insect pests in West African lowland rice ecosystems are particularly abundant where production systems have been intensified. Varietal resistance is a major and cost-effective method of controlling insect pests, particularly if employed as one of several components of an integrated pest management (IPM) approach.

The most important insect pests in West African lowland ecosystems are the African rice gall midge *Orseola oryzivora* (ARGM), the stalk-eyed fly *Diopsis* spp., and the white stemborer *Maliarpha separatella*. WARDA entertains specific breeding programs to develop genetic resistance to these pests, whereas other insects with more local or minor significance are addressed only through routine elimination of susceptible rice lines.

TABLE 21: Top-ranking entries in the second regional quality rice-yield trial, 1994.

Location	Entry	Yield t ha^{-1}
Ibadan, Nigeria	Niaris 85-12	4.45
	Kilombero	4.16
	Eguazampa	4.10
	IR 841	4.09
	ITA 222[a]	3.83
	SE ±	0.29
	CV (%)	13.3
NCRI, Badeggi	DR2	1.15
	Basmati 217	1.09
	ITA 222[a]	1.06
	Niaris 85-12	0.97
	Kilombero	0.91
	SE ±	0.17
	CV (%)	34.9
Ambedane, Chad	Niaris 85-12	9.88
	IR 841	9.70
	DR2	9.24
	Basmati 219	8.48
	ITA 222[a]	8.48
	CV (%)	12.2
Sikasso, Mali	IR 841-85-1-1	3.94
	RD15	3.91
	IR841	3.79
	Niaris 85-12	3.69
	ITA 222[a]	3.06
	CV (%)	22.0
Contuboel, Guinea Bissau	RD 15	1.80
	Pusa Basmati	1.35
	SiK 3	1.26
	DR2	1.22
	ITA 222[a]	1.07
	SE ±	—
	CV (%)	—

[a] = Regional check [b] = Local check

ARGM: ARGM is probably the most significant rice insect pest in West Africa. We complement our breeding activities for varietal resistance genetic studies, characterization of the ecology of ARGM conducted in collaboration with NRI in U.K., and germplasm exchange with the NARS in India. The aim of the latter is to test whether Asian rice gall midge resistant materials from India may be resistant to ARGM.

During 1994, 110 lines were tested in a regional observational yield trial (OYT) at Rokupr in Sierra Leone and at Gadza, Afani, Itoikin, and Ibadan in Nigeria. Severe ARGM incidence was observed for the first time in Rokupr. We rated 25 lines (23%) as moderately resistant and the remaining lines as moderately to highly susceptible. Incidence was also severe at Gadza, Afani, and Ibadan, but it was low at Itoikin. ARGM infestation was as high as 36% of tillers in an independent upland blast screening trial at Ibadan with 100 entries, from which 21 resistant lines were selected and shifted to the 1995 ARGM on-station OYT.

In the 1994 regional replicated yield trial (RYT) for ARGM conducted by the Lowland Rice Breeding Task Force, 12 lines selected from the 1993 regional OYT were evaluated at 6 sites (Table 20). Low incidence was observed at Ibadan and Badeggi in Nigeria, at M'bé in Côte d'Ivoire, and at Gassi in Chad. High incidence was observed at Karfiguela in Burkina Faso and Gadza in Nigeria. At Karfiguela, four entries (Suraksha, Cisadane, TOX 3255-82-1-3-2, and BW348-1) significantly out-yielded the regional check ITA 306. At Gadza, Cisadane and Suraksha also achieved high yields, but only TOX 3967-17-1-3 gave significantly higher yields than the check. The trial will be repeated in 1995 using a subset of the entries.

Although a number of high-yielding varietal selections rated resistant to ARGM during 1994 under significant natural pressure in the field, our screening trials under controlled conditions showed that no truly resistant materials are so far available. The main mechanism of resistance to ARGM as observed in local cultivars like Cisadane appears to be based on compensatory tillering in combination with a relatively long duration. In 1995, we will intensify our search for ARGM-resistant germplasm, particularly for donors of additional traits of resistance.

Stalk-eyed fly: For resistance to stalk-eyed fly, we evaluated in the field 20 lines selected during 1993 in replicated screenhouse trials. The resistance to stalk-eyed fly was confirmed for all entries. Four lines significantly out-yielded the susceptible check Suakoko 8, but none had higher yields than ITA 306, the regional high-yielding check. The best-performing resistant entries were TOX 3440-176-1-3-2-2 and TOX 3440-133-2-3-2-3, both of which yielded 4.6 t ha^{-1}.

White stem borer: In 1994 we evaluated under lowland field conditions 16 lines selected for resistance to white stem borer during 1993 in screenhouse trials. Ten hills were randomly collected for stem dissection at 30, 60, and 90 days after transplanting (DT). The average infestation increased from 14% at 30 DT to 28% at 60 DT and 52% at 90 DT. At grain maturity, only Cisadane (34%) and ITA 382 (40%) had low infestation compared to the regional check ITA 306 (63%). In 1995, we will further test the best selections from this trial and determine relationships between infestation and yield loss.

Breeding rice varieties for medium-deepwater environments

B.N. Singh

Flooding is associated with a significant risk of crop submergence in two lowland rice sub-ecosystems in West Africa. First, traditional and extensive deepwater rice systems exist in the seasonally inundated floodplains of large rivers. These production systems, which mainly use elongating *O. glaberrima* rices, have been marginalized by the general trend towards intensification and are not any more addressed by WARDA's research programs. Second, medium deep flooding also occurs in rainfed lowland rice environments in inland valleys and floodplains with poor water control. Water depth frequently exceeds 50 cm there, and rice yields are limited by poor plant survival and lodging. Farmers use several methods to avoid plant submergence; for example, planting tall upland varieties and/or transplanting older, and therefore taller, seedlings; or planting on artificial ridges to avoid plant submergence. During the past three years, WARDA has conducted a small-scale breeding program for medium deepwater ecologies in collaboration with the Lowland Rice Breeding Task Force.

During 1994, a regional observational yield trial (OYT) with 90 entries was conducted at Ibadan in Nigeria and Madina Gambiel in Guinea Bissau. The entries had been selected from an onstation replicated yield trial (RYT) during 1993. Water depth did not exceed 50 cm at Ibadan, whereas it was 150 cm for extended periods at Madina Gambiel. Fifteen lines showed high survival rates and yielded at least as much grain as the local check Septmet. At Ibadan we identified 20 promising lines. These lines will be tested in the 1995 regional RYT. The 1994 regional RYT was conducted at three sites, but early submergence devastated the trial at one site, Birni Kebbi in Nigeria. Yields were highest for TOX-3440-164-3-3-2 and TOX 3399-64-2-2-1 in The Gambia and for ITA 236 at Ibadan. But no significant differences among entries were observed due to high variability.

Also in 1994, we conducted in collaboration with national scientists in Gambia an onfarm trial with five elite lines selected during 1993. The lines were planted on farmers' fields near the villages of Dasilame, Sutusinjang, Ndemban, and Somita. TOX 3399-64-2-2-1 gave consistently high yields and was appreciated by farmers for its sturdy plant type and its long and erect flag leaves which help control bird damage.

During 1995, varietal selection and transfer to NARS will continue. However, we decided to suspend the hybridization component of this activity in order to provide more focus to the lowland rice breeding program as a whole. This decision will be reviewed on the basis of the hydrological characterization of West African inland valleys which is presently being conducted by the Inland Valley Consortium.

Selecting lowland rices with superior grain quality for emerging markets

B.N. Singh

Consumer preferences for grain type and quality vary among countries and ethnic groups in West Africa. Until the late 1980s, however, the regulated rice markets and (particularly in the irrigated sector) production and transformation systems provided growers little incentive to produce rice with superior grain quality or specific grain characteristics. With the implementation of structural adjustment and market liberalization, profitable market segments for high-quality rices are now likely to develop, which will compete more effectively than at present with quality imported rice. It is also likely that milling recovery might also become an additional factor determining paddy prices.

Most urban rice consumers in West Africa prefer long, slender, translucent grain types. Aromatic rices are also popular in some areas, but they are scarce and expensive. To provide consumers and rice growers with high-quality rice varieties having acceptable yield potential, in 1994 WARDA initiated a specific varietal selection program

TABLE 22: Grain quality traits of entries in second quality-rice-yield trial, 1994.

Designation	Origin	Paddy 1000 grain weight, in gm	Brown rice			Milled rice	
			Length (mm)	Width (mm)	L/W ratio	Milling yield (%)	Head yield (%)
Basmati 217	India	23.6	7.41	2.04	3.6	60.4	57.4
DR2	Côte d'Ivoire	25.1	6.72	2.32	2.9	66.9	87.0
Eguazampa	Nigeria	30.7	8.03	2.31	3.5	57.7	53.5
IR841	IRRI	27.4	7.01	2.35	3.0	63.9	75.6
IR841-67-1-1	IRRI	28.0	7.06	2.40	2.9	64.7	81.9
IR841-85-1-1	IRRI	24.4	6.97	2.17	3.2	66.4	90.4
Kilombero	Tanzania	34.3	7.86	2.50	3.1	63.2	72.6
Niaris 85-12	Benin	30.6	7.62	2.36	3.2	71.0	35.3
Pusa Basmati	India	23.9	8.16	1.85	3.4	62.2	59.4
RD15	Thailand	29.5	8.04	2.55	3.2	66.6	79.3
Khao Dawk Mali 105	Thailand	23.0	6.43	2.45	2.6	68.7	90.5
ITA 222 (check)	Nigeria	29.1	6.79	2.50	2.7	65.7	71.6

for the irrigated and favorable rainfed lowland ecosystems. During 1993 a first set of entries, including long-slender and extra-long-slender grain types, such as the Basmati varieties, was characterized in observational yield trials. In 1994, 12 selections from this trial were tested in regional replicated yield trials in collaboration with the Lowland Rice Task Force at five sites in four countries (Table 21). Among the quality criteria were extra-long-slender or long-slender grain shape and high milling and head rice recovery. Details of variety origin and grain properties are presented in Table 22.

Grain yields varied more among sites than among varieties. Yields were generally extremely high at Ambedane in Chad, exceeding eight $t\ ha^{-1}$, even for the traditional aromatic variety Basmati 219. By contrast, yields were generally only around one $t\ ha^{-1}$ at the iron-toxic Badeggi site in Nigeria. Niaris 85-12, a lowland rice from Benin with extra-long-slender grain and good milling recovery, gave the highest yields under favorable irrigated conditions in Ambedane and Ibadan, Nigeria.

During 1995 we will evaluate these same 12 materials in different lowland evironments in which, because of their morphological plant type, they might show specific adaptation. We will also characterize in more detail the chemical properties and eating quality of these rices, and we will test a subset of the materials in farmers' fields.

Rice varieties from other rice-growing regions of the world that have superior grain qualities are tested under West African conditions and carefully stored for further study.

SAHEL IRRIGATED RICE PROGRAM

Yield potential (grain yield obtained under ideal conditions) in the Sahel is particularly high because of high solar radiation and the widespread adoption of high-yielding varieties. To exploit this potential, huge investments in large-scale irrigation schemes were made in the 1980s, using mainly technologies imported from Asia. Results have often been disappointing, however, because of inappropriate cultural practices, poor soil and water management, resulting in soil degradation, and varieties whose duration conflicted with the objective of double cropping. These trends have drawn into question the sustainability of irrigated rice production in the Sahel.

Since 1990, WARDA has addressed this complex of problems through its Sahel Irrigated Rice Program, via three major research projects: (1) characterization of the Sahelian environment for irrigated rice production; (2) development of suitable germplasm; (3) development of sustainable cropping systems. From 1990 to 1994, emphasis was on the first two projects, to gain a better understanding of the Sahelian environment, to quantify yield potential as a function of genotype x environment interactions, and to continue an existing varietal selection project that has in the past provided most of the varieties that are now grown by farmers.

Our agroecological characterization studies have highlighted the complexity of the Sahelian environment, and showed the importance of spatial and temporal variability of temperature for cropping calendars and yield. They have found that the most promising mechanism for sustaining high yields is to develop appropriate site-specific combinations of cultural practices, cropping calendars, and genetic materials. Powerful simulation tools to match varieties with cropping calendars were developed. Many varieties were characterized for their photothermal responses and their performance under adverse soil salinity and alkalinity conditions.

At the same time, our germplasm improvement program focused on the selection of high-yielding varieties with different growth durations to fully exploit the Sahelian climatic conditions. This approach has already achieved some early success, as in 1994, three varieties from the germplasm development project were released by the Senegal Ministry of Agriculture.

Research on the development of sustainable cropping systems was initiated in 1994, with field experiments at WARDA's research farms at Ndiaye and Fanaye and on farmer's fields to determine the effect of surface drainage and double/single cropping on soil salinization. Research on crop establishment practices initiated in 1992, such as wet direct seeding and transplanting, was continued in 1994.

Collaboration with national programs through the Sahel Task Force and WARDA-sponsored studies at benchmark sites in Senegal, Mali, and Burkina Faso also continued. These mechanisms of collaboration greatly increased the exchange of germplasm and information within the region, helped initiate a new regional research focus on crop and resource management, and provided valuable information on interactions between the genotype and the climatic and edaphic environments.

PROJECT 1: SAHEL CHARACTERIZATION

The use of systems analysis and simulation modeling at WARDA has facilitated the agroecological characterization of the Sahel in terms of climatic constraints to cropping calendars and yield.

During the last three years, two powerful simulation tools were developed to match varieties with cropping calendars and to predict climatic risks associated with any climate x variety x calendar scenario:

- RIDEV: a model simulating growth duration and spikelet sterility of 50 varieties as a function of planting date and method, and climatic conditions in the Sahel;

TABLE 23: **LP model results for representative farms for two areas in the Niger River valley.**

Produced with access to land in:	Say				Tillaberi			
	Rainy Season		Dry Season		Rainy Season		Dry Season	
	R[a]	S[a]	R	C[a]	R	S	R	C
	Percent of irrigated land cultivated in crop							
Public scheme only								
(1) Base model	100	–[b]	100	–	100	–	100	–
(2) With rotations: short run[c]	100	0	100	0	100	0	100	0
(3) With rotations: longer run[c]	100	0	32	68	73	27	0	100
Private scheme only								
(1) Base model	100	–	100	–	100	–	100	–
(2) With rotations: short run	73	27	0	100	58	42	0	100
(3) With rotations: longer run	73	27	0	100	58	42	0	100
Both public and private schemes								
(1) Base model	100	–	100	–	100	–	100	–
(2) With rotations: short run	100	0	100	0	100	0	96	4
(3) With rotations: longer run	61	39	0	100	0	100	61	39

a: R = rice; S = sorghum; C = cowpeas
b: Irrigated sorghum and irrigated cowpeas are not included in the base model, since they are not currently practiced.
c: In the short-run scenario, only variable costs are considered. The longer-run scenario takes into consideration fixed costs as well.

- OryzaS: a crop growth simulation model for irrigated rice production, originally developed for Asia, but adapted to Sahelian climatic conditions.

RIDEV and OryzaS require basic climatic data, including daily solar radiation (only OryzaS), minimum and maximum temperature. A climatic database for a large number of sites in the Sahel is already available at WARDA-Sahel. Micrometeorological stations have also been installed at five benchmark sites in three countries to obtain real-time weather and micrometeorological information: Ndiaye and Fanaye (WARDA stations in Sénégal), Niono (Mali), Sourou and Kou valleys (Burkina Faso).

Crop parameters for key varieties needed as inputs for OryzaS and RIDEV were obtained from continuous cropping, rice-garden, and mini-rice-garden trials with monthly plantings. These experiments were used to develop a varietal catalogue of genotypic constants describing variety-specific spikelet sterility and growth-duration responses to photoperiod and temperature. Fifty varieties, including the ones most commonly cultivated in the Sahel, have already been characterized and were completely documented in 1994. In 1995, a user-friendly version of RIDEV, along with a manual, will be transferred to NARS and other collaborating institutions.

The mini-rice-garden trials will be continued and used to expand the varietal catalog in 1995. The rice-garden experiments at Ndiaye and Fanaye, however, will be replaced by a trial focusing on nitrogen (N) use efficiency of irrigated rice as a function of variety, crop establishment method, and timing and dose of N fertilizer. Results will be used to optimize fertilizer application and to develop a simple N uptake routine for the yield model OryzaS.

Economic constraints to irrigated rice-based cropping systems in Niger
A.A. Touré and T. Randolph

Continuous rice double-cropping, such as is practiced on irrigation schemes in Niger, incurs a number of potential agronomic and economic risks. This study evaluates the economic feasibility of introducing alternative crop rotations to minimize such risk. (See Table 23.)

To assess current practices and technical parameters for irrigated rice production in Niger, a two-stage survey was conducted during the 1993/94 cropping season consisting of a village-level census of rice production in 22 villages along the Niger River valley, followed by a series of farmer interviews among a sample of 70 rice producers from four of the villages. Based on data from the survey, multi-period farm-level Linear Programming models were developed for a single crop year cycle for producers on both public and private schemes. The economic impact of crop diversification was then simulated by introducing alternative cropping patterns into the base models.

The simulation indicates that producers on private schemes are likely to integrate sorghum-rice and rice-cowpea rotations into their irrigated cropping patterns, but not producers on public schemes, at least in the short run. When fixed costs are taken into account, diversification in cropping patterns becomes economically feasible for all producers. The results suggest that subsidized irrigation services and inputs on the public schemes discourage the introduction of rice-based rotations, since savings related to lower water requirements are not expressed in terms of lower producer costs and improved returns.

Genotype and climate effects on rice grain weight distribution in the Sahel
M. Dingkuhn and M. Cisse

Adverse temperatures during grain ripening can severely reduce rice grain quality and milling recovery under Sahelian conditions. During 1993 and 1994 we studied one component of grain quality, the variability of filled grain weight, as a function of season and genotype.

Locally cultivated Jaya and the advanced selections ITA306, IR13240-108-2-2-3, IR31785-58-1-2-3-3, and IR64 were planted in 1993 and '94 at monthly intervals in rice-garden trials with two replications, at Ndiaye and Fanaye.

In all test varieties, mean grain weight was significantly positively correlated ($P < 0.05$) across planting dates with the minimum air temperature (Tmin) observed during the first 15 days after flowering. Grain weight was constant and maximal at Tmin > 20° C, but decreased sharply as Tmin dropped below this limit. Grain weight was not directly correlated with solar radiation (Rs), but the correlation between grain weight and Tmin improved further if observations associated with low Rs were disregarded. Consequently, grain filling mainly depended on temperature and to a much lesser extent on Rs.

Analysis of variance for mean grain weight using four replications (both sites pooled) showed significant interactions between genotype and planting date. IR13240 had the most stable and ITA306 the most variable grain weight. ITA306 had been specifically selected for the thermally stable wet season, and IR13240 for good adaptation to both the wet and hot-dry seasons. Figure 24 shows the grain weight distribution for ITA306 planted on four key dates at Ndiaye. The highest grain weight was observed

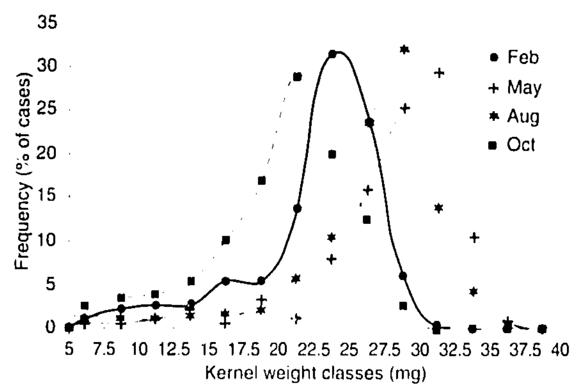


FIGURE 24: Grain weight distribution of ITA306 rice for four planting dates in 1993/94 at Ndiaye, Senegal.

for May (inter-season, the season having the lowest solar radiation but the highest Tmin during ripening), followed by August (wet season), February (hot-dry season), and October (a planting time associated with low Tmin). Low Tmin induced a general shift of the bell-shaped distribution towards lower grain weight by up to 10 mg per kernel, 40% of the maximal weight.

We conclude that among weather parameters, Tmin limited rice grain filling the most. Genotypes differed strongly, and their response to Tmin reflected the seasonal environment for which they were selected. More research is needed on the implications for grain quality, milling losses, and breakage. Preliminary results showed that IR13240 not only has the most constant grain weight, but also has the lowest breakage among the five test genotypes.

M&M: Planting method: transplanting at 20 X 20 cm; fertilization: 150/60/60 kg N/P/K ha^{-1} (3-split for N); kernel weight determination: oven-drying at 70° C of 5-gram subsamples from yield component samples, followed by individual weighing of kernels (resolution of balance: 0.0001 g).

PROJECT 2: GERMPLASM IMPROVEMENT

During the last several decades, rice farmers in the Sahel have operated within a rigid framework set by parastatals. Germplasm made available to them was selected mainly on the basis of high yield potential and constituted a relatively narrow genetic base. A broader spectrum of varieties considering duration (photothermal response) and adaptation to different planting methods would provide Sahelian rice farmers with more options for different crop calendars and management systems. Varieties should be high yielding, tolerant or resistant to major biotic and abiotic stresses, and have a crop duration suited to the local cropping calendars. The demand to broaden cultural options has increased substantially since structural adjustment and market liberalization were implemented in most countries in the Sahel beginning in the mid-1980s.

In 1994, more than 500 new entries received from INGER and IRRI were evaluated in initial evaluation trials, and previously received entries were tested in season-specific initial evaluation, observational, preliminary yield, and advanced yield nurseries. Advanced selections were also included in WARDA's continuous salinity trial to determine their response to soil salinity, and in WARDA's mini-rice-garden trial to determine the photothermal constants that govern the variability of crop duration.

Varietal selection trials were conducted at WARDA's research farms at Ndiaye (an arid site influenced by the ocean, with moderate temperatures and a long cool season), and Fanaye in Senegal (an arid inland site with high temperature fluctuations). Plants were generally transplanted from a seedbed at 25 DAS at 20 x 20 cm spacing. Each plot received 120kg N ha^{-1} applied as urea in a triple split, 60kg P ha^{-1} as single superphosphate and 60 kg K ha^{-1} as KCl. Weeds were controlled with propanyl (10 liters ha^{-1}), followed by hand weeding at midseason. Insect pests and diseases were not controlled. The trials at Ndiaye were covered with fishnets to protect them from bird damage.

One short-duration selection (IR13240-108-2-2-3 from the Philippines) and two medium-duration selections (ITA306 from Nigeria and BW293 from Sri Lanka) were released to farmers in Senegal in 1994. IR13240 is particularly suited to rice double-cropping, whereas the two other selections show a very stable and high yield potential in the wet season. The varieties are expected to be widely adopted because of their good grain quality, climatic adaptation, and crop durations suited to local cropping systems.

Identification of stable high-yielding varieties for the wet season

K. Miézan and S. Gaye

We evaluated eight medium-duration and seven short-duration entries selected in 1994 from preliminary yield nurseries after three years of testing (1991-1993), for the first time in two advanced yield nurseries at Fanaye and Ndiaye. Jaya and BW293-2 (medium duration) and I Kong Pao and IR13240-108-2-2-3 (short duration) were used as checks. IR13240 was released in 1994 to farmers in Senegal because of its

SENEGAL RELEASES THREE NEW VARIETIES SELECTED BY WARDA

K. Miézan and S. Diack

The Senegal Ministry of Agriculture released three rice varieties in 1994 that were specifically selected by WARDA for irrigated rice environments in the Sahel.

Two varieties dominated rice cultivation in the Senegal River valley and delta during the last fifteen years: Jaya, a medium-duration indica variety, and I Kong Pao (IKP), a short-duration variety with short bold grain. Rice double-cropping, wherever it was practiced, was mostly based on the alternating use of the two cultivars, with Jaya grown in the wet season. Where time constraints or the difficulty of maintaining a pure seed base called for it, short-duration IKP was grown in both seasons.

IKP and Aiwu, both selections from WARDA-coordinated trials, owed their adoption largely to short-duration and agronomic robustness, but they were generally considered a second-best choice because of unpopular grain type and quality. The full liberalization of rice markets and prices in 1994 in Senegal, however, is expected to further increase the demand for varieties that combine slender grains with high yield potential, cold tolerance, and short duration. In Mauritania, where structural adjustment was implemented earlier than in Senegal, IKP has already been replaced by IR28, a variety with superior grain quality but with suboptimal agroecological adaptation.

After a series of onstation trials and onfarm tests conducted from 1990 to 1994, IR13240-108-2-2-3 (short duration), and ITA306 and BW293-2 (medium duration) were selected for their high and stable yields and good grain quality. These cultivars were selected from INGER nurseries through ongoing collaboration with IRRI. Following consistently superior performance in trials on farmers' fields jointly conducted with SAED and ISRA, the cultivars were released in 1994 by the Senegal Ministry of Agriculture under the names Sahel 108 (IR13240-108-2-2-3), Sahel 201 (BW293-2), and Sahel 202 (ITA306).

Sahel 108 matures in less than 105 days under direct-seeded culture in the wet season and, as compared to other genotypes cultivated in the region or selected by WARDA, it has the most stable crop duration across seasons. Its droopy panicles and erect, dark-green flag leaves hide the grains from the view of birds and permit high photosynthetic rates during grain filling. The cultivar out-yielded the local check IKP in all environments where it was tested, except under severe salinity, to which IKP is better adapted. Sahel 108 is expected to be widely adopted by farmers in Senegal for both double and single rice-cropping systems, because its yield potential is similar to that of the local medium-duration cultivar Jaya, despite two to three weeks earlier maturation.

Sahel 201 and 202 resemble the local check Jaya in duration and yield potential. Sahel 201 (BW293-2), however, is more salt tolerant, and Sahel 202 (ITA306) can significantly outyield Jaya under favorable conditions. Both cultivars are adapted to the wet season and were selected to broaden the genetic spectrum available to Sahelian farmers, thereby rendering it less vulnerable to pests and diseases.

We expect the new varieties, particularly Sahel 108, to contribute significantly to the adoption of rice-rice and other rice-based double-cropping systems in the Senegal River valley and delta.

superior yield potential and stability in both the wet and hot-dry seasons. BW293-2, which was released at the same time, is particularly well adapted to the wet season.

At Fanaye, the highest yields in the medium-duration group were obtained with BG380-2 (8.5 t ha^{-1}), ITA234 (7.8 t ha^{-1}), UPR2542547 (7.7 t ha^{-1}), and ITA232 (7.6 t ha^{-1}), as compared to 7.0 t ha^{-1} and 7.5 t ha^{-1} for Bw293-2 and Jaya. The $LSD_{0.05}$ was 0.5 t ha^{-1}.

Also at Fanaye, two entries in the short-duration group, IR32307-107-3-2-2 (7.9 t ha^{-1}) and IR31851-96-2-3-2-1 (7.2 t ha^{-1}), performed at least as well as IR13240-108-2-2-3 (7.0 t ha^{-1}). The average yield for the local short-duration check I Kong Pao was 6.7 t ha^{-1}. The $LSD_{0.05}$ was 0.5 t ha^{-1}. Results at Ndiaye showed similar trends, but differences among materials were not significant.

Our results indicate that the best-performing short-duration selections (110-112 days, under transplanted conditions) gave about the same yield as the medium-duration checks (120-130 days), which are also modern, high-yielding materials. Through their short duration, such varieties will help save irrigation water and reduce the time constraints in rice double-cropping systems, without sacrificing yield potential. Multilocation tests to be initiated in 1995, however, will have to show whether these materials also share the superior yield stability of the three recently released varieties IR13240-108-2-2-3, ITA306, and BW293-2.

Identification of new high-yielding stable varieties for the hot-dry season
K. Miézan and S. Gaye

For the third consecutive year we tested a set of eight short-duration entries selected for the hot-dry season in advanced-yield nurseries at Fanaye and Ndiaye. Because of low night temperatures, the crop duration is 20 to 35 days longer in the hot-dry season than in the wet season. I Kong Pao (IKP) was used as the check.

Our results confirmed the superior performance of IR22107-14-2-1, identified as a hot-dry-season variety with an average yield of 5.6 t ha^{-1}, compared to 5.1 t ha^{-1} for the local check IKP. IR50, IR13240-108-2-2-3, IR3957-133-3-2-2-2, and IR31785-58-1-2-3-3 also significantly out-yielded IKP at Fanaye ($P < 0.05$), but differences were not significant at Ndiaye. The main advantage of these selections over IKP, however, was their significantly shorter duration. For example, IR39357-133-3-2-2-2 and IR39422-75-3-3-3-2 matured in 119 days and had at least as much yield as IKP, which matured in 134 days.

By identifying varieties with a much shorter duration and yields similar to the local hot-dry-season check, we will soon be able to provide farmers with new options for rice double-cropping. The relatively low yields in the hot-dry season remain problematic, however. They are due to a number of environmental constraints, some of which have been studied (e.g., chilling resulting in poor crop establishment, poor leaf area growth, and stunting), and some of which call for further research (e.g., atmospheric drought). New cultivars with more promising yield potential, which were tested in preliminary yield nurseries in 1994, have now been selected for advanced yield nurseries in 1995. The best of the presently described materials will be tested in multilocational and onfarm trials.

Rice species, cultivars, and breeding lines are carefully packaged for storage or shipment to national partners, who use them in their breeding programs or test them for performance under their conditions.

A varietal catalogue for irrigated rice in the sahel
F. Asch, M. Dingkuhn, and K. Miezan

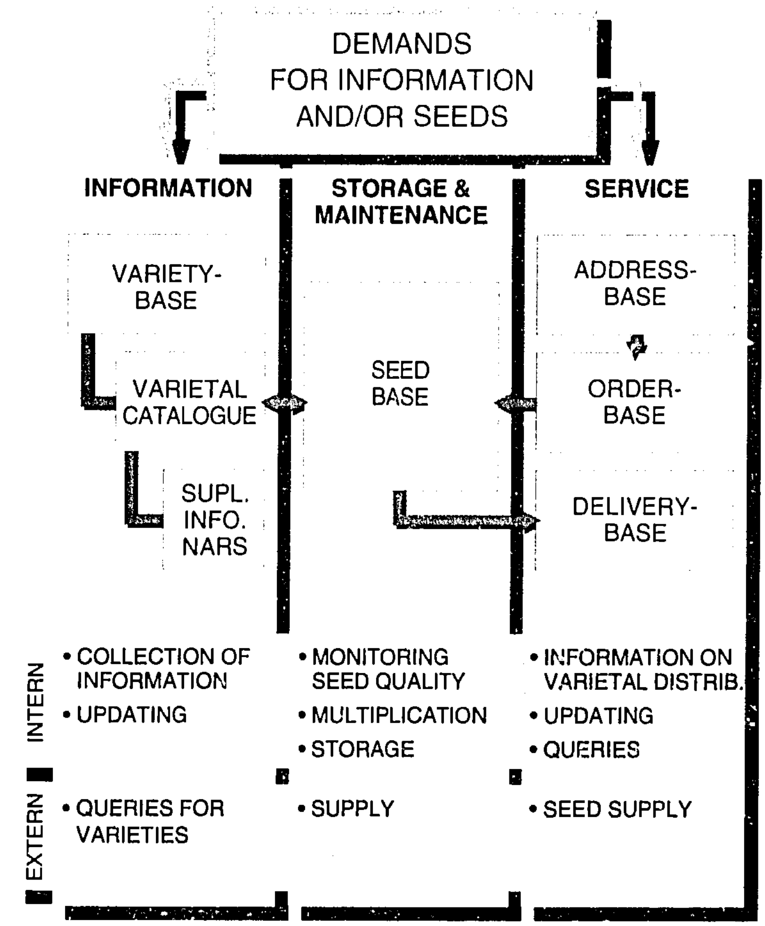
The 1994 annual meeting of the Sahel Irrigated Rice Task Force identified the lack of a regional data pool on varietal performance in different Sahelian environments as a major constraint to varietal improvement in the Sahel. They decided to install a germplasm database and a seed pool at WARDA/Sahel, open to all NARS and partner institutes, to avoid duplicate testing of genotypes in the region.

Following the recommendation of the Sahel Task Force, we developed a varietal catalogue consisting of a system of interlinked databases (Figure 25). The heart of this system is data on all entries and their history in WARDA's varietal improvement project. Another database contains information on varietal performance at NARS sites. The main database consists of detailed information on a subset of entries that are either already cultivated in the region or have proven adaptation to one or more environments in the Sahel. This catalogue of advanced accessions includes ecophysiological and agronomic varietal profiles, consisting of detailed information on agronomic traits; grain properties; tolerance to climatic, soil-related, and some biotic stresses; adaptation to transplanting and/or direct-seeding; release to and adoption by farmers; and more. The catalogue will be continuously updated and can draw on supplementary information databases I and II. The three databases allow multicriteria varietal searches, or queries that can be compiled into a variety characterization sheet.

We have also interfaced the varietal catalogue with WARDA's seed-base inventory system which is used to manage onstation seed multiplication and stock-keeping. The seed base serves the experimental seed requirements of WARDA and our NARS partners.

This database system permits close monitoring of varietal performance in the Sahel and also provides information on the distribution and adoption of new varieties in the region. The program will be fully operational in 1995.

FIGURE 25: **Varietal catalogue and seedpool for irrigated rice in the Sahel.**



Effects of season on varietal responses to soil salinity
E. Asch and M. Dingkuhn

As early as 1992 we reported trial results indicating that varietal responses to salinity differed markedly between the Asian-monsoonal and the Sahelian environments. In 1994 we intensified our study of how season affects varietal patterns of salt tolerance in the Sahel.

We tested 41 cultivars in WARDA's continuous salinity trial at Ndiaye in at least one dry and one wet season. Varieties were classified according yield reduction (YR) relative to freshwater controls. In the hot-dry season the minimum yield reduction was 31%, whereas in the wet season it was 4% (tolerant check IR4630-22-2). Maximum YR was similar in both seasons, 85% and 83% for the susceptible check IR31785-58-1-2-3-3.

Varieties were classified as susceptible (YR > 60%), moderately susceptible (51-60%), moderately tolerant (41-50%), or tolerant (0-40%). Varieties were further grouped according to the season-specificity of YR, Group I (13 entries) showing no season effect on YR, Group II (15 entries) showing a slightly stronger YR in the dry season, Group III (nine entries) showing a moderately stronger YR in the dry season, and Group IV (4 entries) being more than twice as susceptible in the dry season as in the wet season (details of magnitude limits in Table 24).

Group I genotypes ranged from highly susceptible to tolerant types but showed little interaction with the seasonal climate. This group includes the bulk of short-duration varieties grown in or selected for the hot-dry season, including I Kong Pao, SIPI6920-33, Aiwu, and KH998 (locally cultivated); IR13240-108-2-2-3 (released in 1994); and IR50, IR31785-58-1-2-3-3 and IR29725-40-3-2-3 (currently undergoing onfarm tests). By contrast, none of the Group III and IV entries have so far qualified for onfarm testing, and only one entry (IR28) is grown on a small scale by farmers, for its particular grain characteristics.

ATABLE 24: Varietal responses to salinity by season.

Season effects expressed as decrease of yield reduction from hot-dry season to wet season

YR(WS) > 0.8 YR(HDS)

Variety group I	HDS	WS
	tolerance class	
IR 31785-58-1-2-3-3	S	S
IR 50	MS	MS
BG 400-1	MS	MS
ITA 230	MS	MS
KH 998	MS	MS
BW 293-2	MS	MS
AIWU	MT	MT
IR 29725-40-3-2-3	MT	MT
SIPI 6920-33	MT	MT
IR 52718-2B-6-2B-1-1	MT	MT
IR 13240-108-2-2-3	MT	MS
I Kong Pao	T	T
C.S.R. 11	T	T

0.6 YR(HDS) < YR(WS) < 0.8 YR(HDS)

Variety group II	HDS	WS
	tolerance class	
ITA 306	S	MS
S449-B-28	S	MS
JAYA	S	MS
IR 9884-54-3-IE-P	S	MT
IR 68	S	MT
IR 3941-86-2-2-1	S	MT
IR 31851-96-2-3-2-1	MS	MT
32 Xuan 5c	MS	T
IR 29692-117-1-2	MS	T
IR 22107-14-2-1	MS	T
IR 29725-76-3-3-2	MS	T
IR 44658-81—3-13	MS	T
B 5322-PN-LMS-1-KP-1	MS	T
TOS 103	MT	T
IR 64	T	T

0.4 YR(HDS) < YR(WS) < 0.6 YR(HDS)

Variety group III	HDS	WS
	tolerance class	
IR 4422-98-3-6-1	S	MT
IR 9764-46-2-2	S	MT
RAU 2004-6-69-2-1-3	S	MT
IR 28	S	T
IR 55237-3B-3-2	S	T
TNAU-78-93	S	T
IR 32429-47-3-2-2	MT	T
C.S.R. 10	MT	T
IR 46330-PMI-2-2-1-3	T	T

YR(WS < 0.4 YR(HDS)

Variety group IV	HDS	WS
ITA 222	S	T
IET 6279	S	T
IR 42	S	T
IR 4630-22-2	MT	T

YR = yield reduction; HDS = hot-dry season; WS = wet season; S = susceptible (YR > 60%);
MS = moderate susceptible (YR = 51%-60%); MT = moderate tolerant (YR = 41%-50%); T = tolerant (YR < 40%)

We conclude that rice salt tolerance can be highly season-specific, and that varieties differ markedly in this respect. This result has two major consequences for our future work in the Sahel. First, it is now clear that screening for tolerance to abiotic stresses must be conducted in the climatic seasonal environment for which the germplasm is targeted. Second, the interactions between climatic and other stresses are far from being fully understood and warrant further research.

Preliminary evidence points at crucial varietal differences in leaf area expansion and root growth under conditions of low humidity and high temperature fluctuations, probably involving regulatory mechanisms of leaf gas exchange. This hypothesis will be tested in 1995.

M&M: The salinity field trial at Ndiaye has 2 treatments (floodwater electric conductivity maintained at 3.5 and 0.5 mS cm^{-1}) and 3 replications. N-P-K inputs are 120-60-60 kg ha^{-1}.

Field-testing of rice plants regenerated from salt-stressed callus cultures

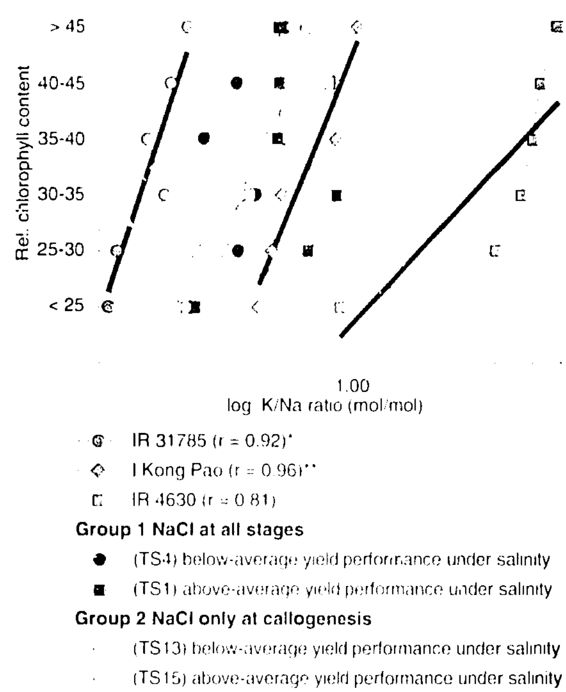
F. Sow, F. Asch, and M. Dingkuhn

Salt tolerance in rice has many physiological components, ranging from avoidance mechanisms (e.g., selective uptake of salt by the root) to tissue-level tolerance. Our past work on selective uptake and transport of inorganic cations was presented in earlier annual reports (1992, '93).

Callus culture, selection, and regeneration of I Kong Pao (IKP) rice were conducted at the Catholic University of Louvain La Neuve in Belgium. To assess genetic variation

Highly skilled technicians can grow the undifferentiated callus tissue shown here into mature rice plants, or they can use the tissue to test for tolerance to adverse conditions like salinity.

FIGURE 26: Field performance of four lines selected from IKP callus tissue that had been stressed with salt (NaCl).



in tissue-level salt tolerance, we related leaf chlorophyll content (CHL), a common indicator of salt stress, to leaf Na^+ and K^+ relationships. In Figure 26 we present results for four lines selected from IKP calli, including two that had been stressed with NaCl only at callogenesis, and that were stressed during all phases of in-vitro culture. In addition, the IKP source material, WARDA's tolerant check IR4630-22-2 and the susceptible check IR31785-58-1-2-3-3, were tested.

Genotypes differed strongly in the K/Na ratio (Figure 26). Within genotypes, CHL content was in most cases positively ($P < 0.05$) correlated with the K/Na ratio. In contrast to theory, however, the tolerant check did not have higher CHL content at given K/Na ratios than the susceptible check. IKP and its in-vitro derivatives had intermediate K/Na ratios, the derivatives being closer to the susceptible check. Moreover, salt-treated plants were generally greener than controls, but plants were smaller and less vigorous.

We hypothesize that under the high solar radiation in the Sahel, leaf CHL content is a function of growth-induced dilution of absorbed N and not of salt stress, even under salinity levels that would substantially reduce yield. Salt stress reduced growth more than N uptake, and thereby masked any stress-induced chlorophyll degradation.

Our results suggest two conclusions. First, relationships between leaf CHL content and Na concentration (or Na/K ratio), although commonly used as an indicator for tissue salt tolerance, should probably only be used under controlled low-light and high-N conditions. Second, in-vitro callus-based selections for salt tolerance differed from the original IKP genotype. These selections, however, showed a distinct shift towards the characteristics of the susceptible check, which is the opposite of what was intended. Consequently, varietal selection for salt tolerance should not be based on tissue properties alone, but must also take into account the morphological organization of the plant and its interactions with the environment. In 1995 we will test and implement new screening tools for salt tolerance that are based on this principle.

M&M: Plants were grown in WARDA's salinity trial at Ndiaye with 3 replications and either irrigation with freshwater or a constant electric conductivity of 3.5 mS cm^{-1} in the floodwater. Fertilizer application was 120-60-60 kg N-P-K ha^{-1}. For first and second fully expanded leaves, the chlorophyll content was measured at booting stage in the field, the leaves were grouped in chlorophyll classes, and were analyzed for Na and K contents. No diseases were observed that might have affected chlorophyll content.

Varietal responses to soil alkalinity in Mali

F. Asch, N. Mall, and M. Dicko

Soil alkalinization is an increasingly important constraint to rice production at the Office du Niger irrigation schemes in Mali. In order to evaluate potentially tolerant germplasm under sodic-alkaline conditions, we conducted a varietal trial in the wet season of 1994 in collaboration with IER at Niono in Mali.

We tested fourteen varieties at two sites. One site was non-saline and moderately alkaline, and the second was slightly saline and strongly alkaline. The test varieties included the local checks BG90-2 and China 988, locally bred Kogoni 91-1, and WARDA's salt-tolerant and susceptible checks. The remaining entries were selected from WARDA's advanced germplasm in Senegal on the basis of their salt tolerance and yield stability.

At both the moderately and strongly alkaline sites, BW293-2 had the highest yields, with 5.6 and 4.1 t ha^{-1}, respectively. BW293-2 is a high-yielding medium-duration WARDA selection which is moderately salt tolerant and was released in 1994 to farmers in Senegal. Compared to BW293-2, the local check BG90-2 had inferior yields under moderate alkalinity (4.1 t ha^{-1}; $P < 0.01$) and high alkalinity (1.8 t ha^{-1}; not significant) and, in fact, ranked 14th (last) in the varietal spectrum at the two sites. A good performance in both environments was observed for WARDA's advanced selection TOS103 and the locally cultivated varieties Kogoni 91-1 and I Kong Pao.

No correlation between varietal tolerance to salinity (WARDA's site at Ndiaye) and alkalinity (present study) was observed. WARDA's salt-tolerant check IR4630-22-2 ranked 13th under severe alkalinity (2.1 t ha^{-1}), whereas the susceptible check IR31785-58-1-2-3-3 ranked fourth (3.8 t ha^{-1}). The validity of WARDA's varietal classification for salt tolerance, however, was fully confirmed for saline acid-sulphate soils in Djibelor, Casamance, in an independent study by Dr. Mbeye Sylla of ISRA.

Our results suggest that breeding for salt tolerance as currently performed at WARDA is applicable

TABLE 25: Grain yield of selected rice varieties in various problem soils in the Sahel. I: non-saline, moderately alkaline (Niono, Mali); II: saline, highly alkaline (Niono); III: non-saline, neutral (Ndiaye, Senegal); IV: highly saline, neutral (Ndiaye). All data given in g m^{-2}.

Genotype	duration	I	II	III	IV	
BW 293-2	medium	564	414	706	355	
China 988	short	545	284	—	—	
ITA 222	medium	531	334	612	456	
Sipi 6920-33	short	518	256	626	325	
IR31785-58-1-2	short	513	358	631	114	(salt-susc.check)
Kogoni 91-1	medium	487	405	—	—	
ITA 123	short	475	245	—	—	
Jaya	medium	436	337	700	346	
TOS103	short	421	407	609	237	
IR64	short	419	313	600	445	(intl. check)
I Kong Pao	short	417	393	744	487	
BG90-2	medium	414	136	678	407	(local check, Mali)
IR28	short	409	253	571	364	
IR4630-22-2	medium	406	205	390	375	(salt-tol.check)
LSD (0.05)		—	—	177	245	

to saline environments, including neutral and acid-sulphate soils, but not to the degraded, sodic-alkaline soils in Mali. The good performance under both salinity and alkalinity of BW293-2, however, shows that high-yielding varieties with broad adaptation to problem soils can be developed.

In 1995 we will intensify comparative varietal testing at saline and alkaline sites in the Sahel. This research will be closely coordinated with complementary studies on soil fertility management.

M&M: Fourteen varieties were tested in two trials with four replications using a randomized complete block design during the 1994 wet season at Niono, Mali. The first site had a "Dian" soil (soil electric conductivity, EC [1:2.5] = 0.1 to 0.3 mS cm^{-1}; pH [1:5 H_2O] 7.5 to 9.0) and the second, a highly degraded "Danga" soil at Niono in Mali (EC 0.3 to 0.6 mS cm^{-1}; pH 9.5 to 10.5). Plots were fertilized with 120/46/60 kg ha^{-1} NPK.

PROJECT 3 : DEVELOPMENT OF SUSTAINABLE CROPPING SYSTEMS

Rice cropping systems in the Sahel differ in cropping intensity, degree of mechanization, association with upland cereals or irrigated vegetable crops, and the degree to which the individual producer depends on (or is participating in) the management of the irrigation scheme. Structural adjustment and market liberalization during the past few years have created new opportunities for the diversification of rice-based cropping systems, but have also raised environmental concerns. Farmers require technology options that meet their means and economic objectives, and at the same time help sustain the natural-resource base they depend on.

During the past four years WARDA has established a regional breeding and ecophysiological research program with emphasis on climatic constraints in the Sahel. In 1995 and beyond, we plan to complement this research with an additional focus on sustainable crop and resource management, and to fully integrate it with the germplasm improvement and agroecological characterization projects.

Research will focus on developing and testing technology packages for sustainable irrigated rice production in the Sahel at different scales (plot, irrigation scheme, and regional levels). Packages will consist of varieties adapted to the targeted cropping calendars, climatic and edaphic environments, and consumer preferences; water and soil management practices that help control weeds and prevent soil salinization and alkalinization; and fertilizer management practices that provide higher return to investment.

Package development will be guided by problem-oriented applied research, explanatory and extrapolative modelling, and onfarm validation studies. Modelling will also provide simple simulation tools that help NARS scientists, extension agents, and irrigation scheme managers to identify technology options to improve system sustainability and efficiency.

HEALTH IMPLICATIONS OF INCREASING RICE CULTIVATION IN WEST AFRICA

Rice consumption in West Africa is expected to increase by at least 5% per year for the foreseeable future. Increased consumption requires increased production and, for lowland rice, this also means larger areas of standing water. Standing water, in turn, can lead to higher incidence of water-related diseases like malaria and schistosomiasis.

Concern over the potential health implications of increased rice production led WARDA to seek the assistance of the Panel of Experts on Environmental Management for Vector Control of the World Health Organization to develop a major research project on the human health risks associated with lowland rice cultivation. The objectives of the initial three-year research phase are to characterize lowland rice ecosystems as they relate to human health risks, and to identify how agricultural practices might be modified to reduce the build-up of harmful vectors.

The research is being conducted in selected villages in Côte d'Ivoire and Mali. Institutions participating in this phase are the Institut Pierre Richet and the Centre Universitaire de Formation en Entomologie et Vétérinaire in Côte d'Ivoire, and the Ecole Nationale de Medicine et de Pharmacie, the Institut National de Recherche en Sante Publique, and the Institut d'Economie Rurale in Mali.

In December 1994, the first meeting of the project's advisory committee was held to review progress in project planning and implementation. The committee is composed of public-health experts from the United Kingdom, Denmark, Belgium, and France. This meeting was shortly followed by the appointment of a Swiss-born physician with public-health expertise as coordinator, based at WARDA headquarters.

The International Development Research Centre of Canada, the Danish Agency for International Development Assistance, and the government of Norway have pledged US$1.5 million for the project.

Dynamics of soil salinity at two sites in the Sahel

M.C.S. Wopereis and R. Samba

Poor plot-level water management, for example, inadequate surface drainage, is a major cause of soil salinization in irrigated rice fields in the Sahel. Particularly in private and village-based irrigation schemes, which are spreading since the recent liberalization of markets, poor plot levelling and drainage give rise to rapid soil degradation.

We examined the dynamics of floodwater and soil salinity in a long-term study initiated in 1994 in collaboration with ORSTOM. The experiment has a factorial design with two drainage regimes (weekly surface drainage vs. drainage only once at 28 days after sowing), two cropping intensities (one or two crops per year), and two sites (WARDA's farm at Fanaye and the salinity-prone farm at Ndiaye). Components of the water balance for each plot are monitored daily. Modelling approaches will be used to understand climatic and cultural effects on water and salt movements in the crop-soil system.

Groundwater was saline (4 to 10 mS cm^{-1} electric conductivity) and close to the surface (0.2 to 0.8 m) at the Ndiaye site, whereas in Fanaye, the soil was free-draining, with a groundwater table constantly at more than 2 m depth. No treatment effects on grain yield were observed during the first season.

A simple spreadsheet model was written to simulate daily changes in the electric conductivity of the floodwater. Daily measured components of the water balance of each field (evapotranspiration, seepage and percolation, rainfall, irrigation) and the electric conductivity of the irrigation water were used as inputs.

Results are shown for one field at Ndiaye that was drained only once during the growing season (Figure 27). Simulations underestimated measurements at the beginning of the cropping season. The discrepancy was due to salt coming from the soil, accumulated by capillary rise from the saline groundwater table during the previous dry season. Some of this salt was removed during surface drainage conducted early in the season. Salt levels in Fanaye were about 10 percent of those at Ndiaye.

The experiment will be continued in 1995 to follow cumulative effects of drainage on topsoil salinity and pH. From this we plan to develop a modelling tool that can be employed to predict the effect of existing and improved water management practices on salinity. This model will then be combined with WARDA's existing crop calendar planning and climatic risk assessment tool, RIDEV.

M&M: The experiment had 3 factors (site, cropping intensity, drainage) with 2 levels each and 3 replications. Plot size was 10 x 13 m, excluding a 10-m fallow border. IR13240-108-2-2-3 rice was broadcast seeded and fertilized with 120/60/60 kg N/P/K ha^{-1}. Combined seepage and percolation rate was measured with a sloping gauge. Evapotranspiration was determined with closed-bottom lysimeters. Groundwater table depth was measured using piezometers. Electric conductivity (EC) was converted into NaCl concentrations (SC) by the equation [SC (ppm) = 640 x EC (mS cm^{-1})].

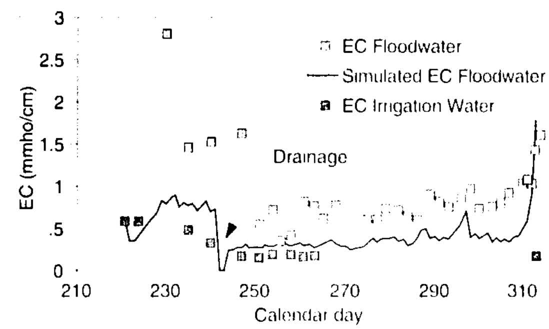


FIGURE 27: Simulation of electric conductivity (as an indicator of salinity) of a field at Ndiaye, compared with actual measurements taken in the same field.

Evolution of soil fertility under continuous double-cropping

M. Dingkuhn and S. Ducheyne

Rice double-cropping is one of the major objectives of most national agricultural development agencies in the Sahel. Among the numerous socioeconomic and biophysical constraints to rice double-cropping, however, is an apparent decrease in soil fertility reported by NARS scientists for a range of irrigation schemes.

In 1991, WARDA initiated continuous fertility trials at its farms at Ndiaye and Fanaye in Senegal, in order to evaluate the effects of a range of N, P, and K fertilizer regimes on soil fertility parameters. In 1994, after five consecutive rice crops, an interim assessment of soil chemical properties was made for the Ndiaye experiment in collaboration with the Catholic University of Leuven in Belgium.

Highest yields were generally obtained at 120/60/60 kg NPK ha^{-1}, the officially recommended rate, in the wet season (WS) (Figure 28). In the hot-dry season (HDS), the highest yields were observed at 180/60/60 kg NPK ha^{-1}. Yields were higher in the WS than in the HDS, probably because the short-duration variety grown in the HDS had a lower yield potential than the medium-duration variety grown in the WS. The slight but consistent decline in yields during the five seasons was not statistically significant.

Two significant changes in soil properties were observed. First, the soil pH(H_2O) increased from 5.4 to 6.6 in a gradual and spatially homogeneous way. Fertilizer treaments had no effect on pH. Second, the available (Olsen) P content of the topsoil significantly ($P < 0.01$) decreased from 2.5 to 0.3 mg kg^{-1} in the unfertilized (0/0/0 NPK) treatment, and from 2.3 to 0.4 mg kg^{-1} in the treatment fertilized only with nitrogen (120/0/0 NPK). This decrease by almost one order of magnitude indicates that the soil P reserves of this heavy, slightly saline clay soil are easily depleted. The available P did not change in plots fertilized with 120 kg P ha^{-1} as single superphosphate.

NPK treatments had no effect on the C/N ratio, which varied

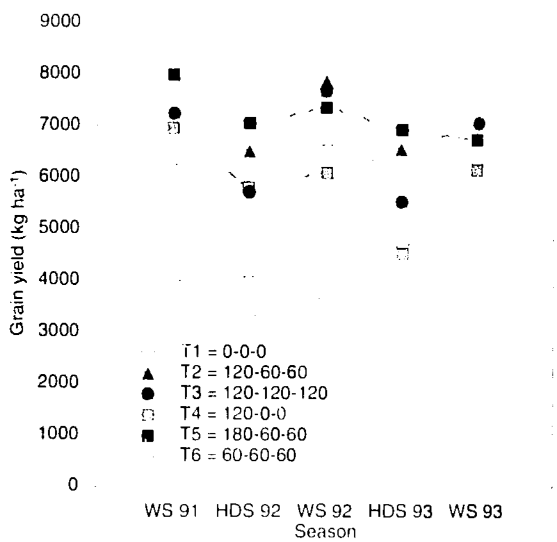


FIGURE 28: Effect of six different fertilizer regimes on grain yield at WARDA's Ndiaye farm. Highest yields were generally obtained at T2, the officially recommended rate, in the wet season.

between eight and 10 and remained constant throughout the five cropping seasons. The mean total N content of the topsoil was 0.08% and was stable.

The results show that the site at Ndiaye, which is representative of large irrigation schemes in the Senegal River delta, is prone to rapid depletion of available P under intensive cultivation. In 1995 a similar analysis will be conducted for the Fanaye site in the Senegal middle valley. Both experiments will be continued in order to follow soil fertility parameters through a longer period.

M&M: The continuous fertility trial at Ndiaye was conducted on an acid (pH-H_2O 5.3) clay soil with 39% clay, 39% silt, and 22% sand in the topsoil (0-20 cm). Water table was at ca. 80 cm. Short-duration IR50 and medium-duration Jaya were transplanted in the hot-dry season (February) and the wet season (July). The trial had a randomized complete block design with 4 replications and NPK treatments 0/0/0, 120/0/0, 120/60/60, 120/120/120, 60/60/60, and 180/60/60 kg ha^{-1}.

TRAINING AND COMMUNICATIONS

OVERVIEW

Anthony Youdeowei
Director of Training and Communications

Training activities in 1994 concentrated on organizing the last set of five group training courses specified in the UNDP-supported Communications and Training Project. In addition, three complementary courses were organized with funds from other sources, thus making a total of eight courses run during the year.

Collaboration with other CGIAR centers in sub-Saharan Africa was intensified, in support of CGIAR efforts to optimize the use of funds and facilities within international centers, and to minimize duplication of training efforts in the system. Highly successful collaborative training activities were established with ICRAF in Nairobi, ICRISAT Sahelian Center, Niamey, IIMI in Niamey, and IRRI in the Philippines.

Selection of training participants for courses in 1994 was intentionally extended to sub-Saharan countries outside the WARDA member states, enabling training participants from Gabon, Ethiopia, Madagascar, and Lesotho to attend training courses at WARDA.

The second in the series of WARDA/NARS training seminars was organized in May 1994. It brought together NARS directors and training specialists from national programs, as well as from other CGIAR centers and international agencies, to discuss training and job performance in rice science in West Africa.

A highlight of the division's activities was the signing of a Memorandum of Understanding with CTA during the visit of the Director of CTA, Dr. Assoumou Mba, in early 1994. In the context of this memorandum, collaborative training and communications activities between WARDA and CTA were intensified during the year.

The Director of Training and Communications attended the meeting of the Inter-Center Training Group in Lilongwe, Malawi, where WARDA played a leading role in the identification of the elements of a mechanism for the establishment of an inter-center training program. Decisions were made at this meeting to prepare a project document for an inter-center training program for CGIAR centers in sub-Saharan Africa.

WARDA's training and communications activities continued to be supported with funds from UNDP, IDRC, CTA, and IFS.

SUMMARIES OF TRAINING ACTIVITIES

Anthony Youdeowei, Alassane Diallo, Cheikh Diop

TRAINING ACTIVITIES

Group technical training

The group training courses organized with funds from UNDP were: Computer Applications and Statistical Analysis in Agricultural Research, Development of Training Materials, Rice Agronomy, Integrated Crop Protection, and Water and Irrigation Management for Rice Production.

Complementary courses run were Genetic Evaluation and Utilization of Rice, in collaboration with IRRI; Use of CD-ROM for the Management of Agricultural Information, in collaboration with CTA; and Scientific Writing for Agricultural Research Scientists, in collaboration with CTA, ICRAF, and SAFGRAD. Brief descriptions of these training activities follow, and the country distribution of training participants is provided in Table 26.

Mr. Seth Ohemeng-Dapaah, from the Crop Research Institute, Kumasi, Ghana, was a regular resource person at WARDA's group training courses in computer applications and statistical analysis in agricultural research. Here Mr. Ohemeng-Dapaah (pointing at the screen) instructs in the use of GENSTAT software in the management of research data.

Computer applications and statistical analysis in agricultural research

In collaboration with ICRISAT Sahelian Center Niamey, the training course in computer applications and statistical analysis in agricultural research was organized in French for 14 NARS scientists from 10 WARDA member countries. In addition, 3 WARDA research assistants were admitted into this course. Based on the experience and feedback of trainees who took this course in 1992, the course content was redesigned with the addition of GENSTAT to the statistical software handled during the course.

Trainees spent considerable time on hands-on practical training in the management of their research data which they brought to the course. The resource persons for

Mr. J. Beniest, from ICRAF, was a resource person on the development of the training materials course.

TABLE 26: Country distribution of training participants at WARDA's group training courses in 1994.

Country	Training courses							
	CAppl	TMat	RAgr	C.Prt	WIrg.Mgt	GEU	CDROM	SWtg
Benin	2	2	2	-	-	-	1	4
Burkina Faso	2	1	1	2	2	1	2	5
Cameroon	1	-	1	-	-	1	2	4
Chad	1	2	-	1	1	1	2	-
Côte d'Ivoire	3	3	4	3	-	1	1	3
Ethiopia	-	-	-	-	-	-	-	1
Gabon	-	-	-	-	-	-	1	-
Gambia	-	-	-	2	-	1	-	-
Ghana	-	3	-	2	-	1	-	2
Guinea	1	1	-	-	-	-	-	1
Guinea Bissau	1	2	2	2	2	-	-	-
Lesotho	-	-	-	-	-	-	-	1
Liberia	-	-	-	-	-	-	-	-
Madagascar	-	-	-	-	-	-	1	-
Mali	1	2	-	1	1	-	2	3
Mauritania	-	2	-	-	-	-	1	1
Niger	1	1	1	1	4	-	-	1
Nigeria	-	-	3	2	6	1	-	5
Senegal	1	-	3	4	-	-	-	2
Sierra Leone	-	-	-	2	2	1	-	1
Togo	-	1	2	2	2	1	-	1
WARDA	3	-	-	-	-	-	-	-
Totals	17	20	19	24	21	9	13	35

TOTAL = 158

Key

CAppl = Computer Applications and Statistical Analysis in Agricultural Research
TMat = Development of Training Materials
RAgr = Rice Agronomy
C.Prt = Integrated Crop Protection in Rice
WIrg.Mgt = Water and Irrigation Management for Rice Production
GEU = Genetic Evaluation and Utilization of Rice
CDROM = Use of CD-ROM in the Management of Agricultural Information
SWtg = Scientific Writing for Agricultural Research Scientists

this course included Dr. Roger Stern from ICRISAT and Mr. Seth Ohemeng-Dapaah from the Crops Research Institute, Kumasi, Ghana.

Development of training materials

Based on the experience gained in 1993, when this course was first organized in English, the course curriculum was redesigned with the assistance of a training materials development specialist, Dr. J. Kwarteng, who joined the division for one year. The new curriculum emphasized the planning and low-cost production of selected training materials. Mr. Jan Beniest, training materials specialist from ICRAF, also assisted as a resource person for this four-week course, which was organized at the Ghana Atomic Energy Agency Commission at Kwabenya, near Accra. It was successfully run as a bilingual course in French and English, with very efficient simultaneous interpretation. The Department of Agricultural Extension of Ghana's Ministry of Agriculture provided considerable logistic support for this course. The training participants were 11 men and nine women, which is the largest female participation ever recorded in WARDA's group training courses. At the end of the training course participants evaluated the course as highly successful; one woman remarked that the course had enabled her to more effectively plan for the production of simple and culturally relevant training materials for women rice farmers in her country. The text of a training manual was also successfully field tested during this course. This manual will be published in 1995.

Rice agronomy

A rice agronomy group-training course was first organized in collaboration with the Institute of Agronomic Research (IRA) at Garoua, Cameroon in 1993, when it was taught in English. The same course, but with minor changes, was organized in 1994, at WARDA's training center in Bouake, for francophone scientists. Nineteen participants from nine countries attended the course from July 4 to August 12, 1994.

Integrated crop protection in rice

This bilingual French and English group-training course was organized at WARDA's training center from August 15 to September 9, 1994. There were 24 participants from 12 WARDA member countries. During this course, some practical aspects of integrated pest management practice received special attention. These included sampling of rice pests and estimation of damage in the field; the identification of major rice pests and diseases and their causative agents; augmentation of the natural enemies of major rice pests; sampling and evaluation of weeds in rice; biological control in integrated pest management; and farmers' perceptions of rice pests and their control. Participants presented case studies of farmers' perceptions of rice pests and their control in their own countries in a lively open discussion session. The draft of a farmer-oriented field training manual on integrated management of rice pests was tested during this course, with a view to publishing it in 1995.

Water and irrigation management for rice production

Following successful collaboration with IIMI, Burkina Faso, in organizing this course in Ouagadougou in 1992, it was restructured and designed to be more relevant to the target audience. The 1994 course was organized in collaboration with IIMI, Colombo, Sri Lanka, and with the IIMI field station in Niamey, Niger, as well as the national program, INRAN. For this course WARDA was pleased to obtain the expert inputs of Dr. Jacob Kijne, IIMI's Director of Research, and Dr. Charles Abernathy, Technical Adviser to IIMI, who assisted with course design and as resource persons during the training course in Niamey. This further consolidated the WARDA/IIMI inter-center collaboration in training initiated in 1992.

Dr Jacob Kijne, Director of Research at IIMI, Sri Lanka, was a resource person at the water and irrigation management course in Niamey.

Dr. M. Becker, a WARDA research scientist, conducts a field practical in the design of rice agronomy trials.

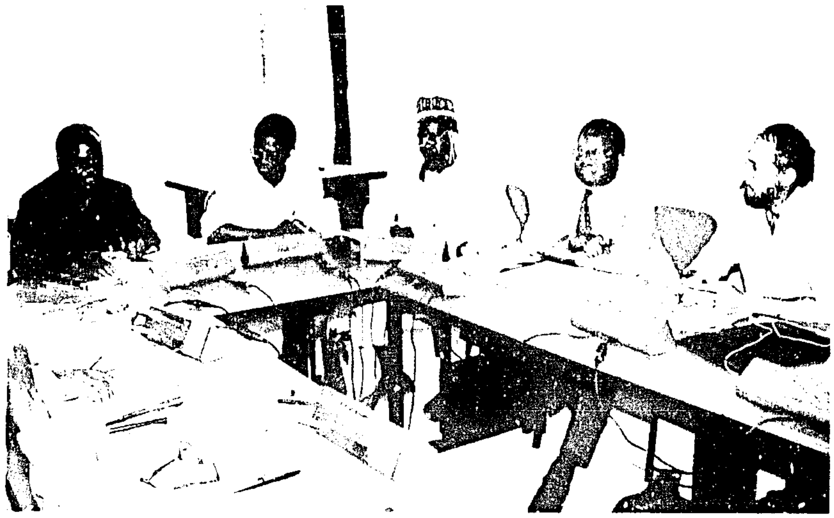
COMPLEMENTARY GROUP TRAINING COURSES

Genetic evaluation and utilization of rice

This was a six-week WARDA/IRRI collaborative group training course. The detailed curriculum was designed by Dr. Ike Navarro, from IRRI, and WARDA scientists, during early 1994. The course was delivered for NARS rice breeders in September 1994. Trainees for this course were young NARS rice breeders who are actively engaged in varietal improvement research. Nine participants from nine anglophone and francophone countries were given extensive field practical training in methods of evaluating the performance of rice varieties to different environmental stresses.

Use of CD-ROM for the management of agricultural information

In the context of the WARDA/CTA Memorandum of Understanding, the first in a series of group training courses in the use of CD-ROM for management of agricultural information was organized at WARDA's Library and Documentation Center in October 1994. This course was designed to upgrade the knowledge and skills of practicing documentalists in the management of agricultural information, using state-of-the-art technologies. Documentalists who have received this training can provide superior technical support to agricultural researchers in sub-Saharan Africa. The 13 trainees who attended this course were specially selected from nine French-speaking countries in sub-Saharan Africa.



Dr. Koffi Goli (left), Director of IDESSA of Côte d'Ivoire, chaired a session at the WARDA NARS training seminar on the topic, "Training and Job Performance in Rice Science"

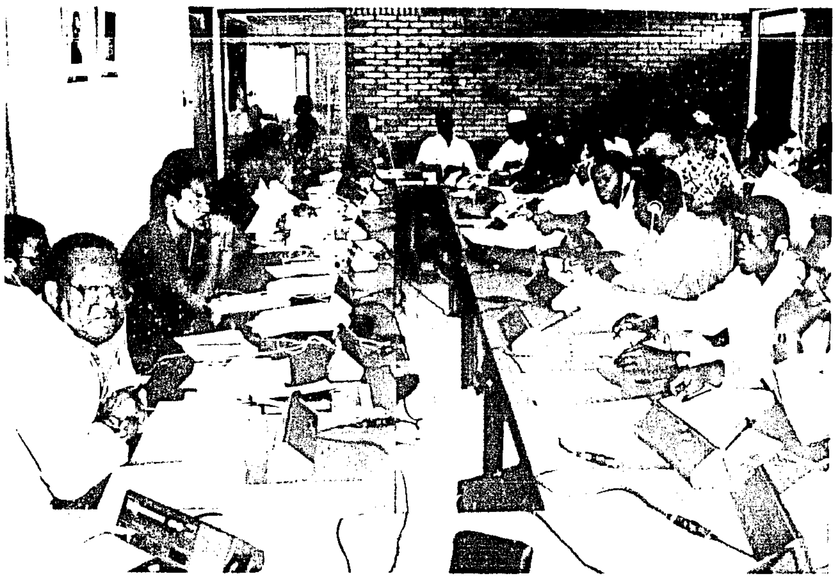
Scientific writing for agricultural research scientists

The third in the series of group training courses in scientific writing for agricultural research scientists was organized at IITA's Biological Control Center for Africa at Cotonou, Benin in November. This course was a collaborative effort between WARDA, CTA, SAFGRAD, and ICRAF. The course curriculum was basically the same as used in previous courses, but important changes were introduced from the feedback obtained from trainees attending previous courses. For example, some emphasis was given to using posters to present scientific research results, as well as procedures for writing scientific research project proposals and reports. There were 35 trainies in two groups (anglophone and francophone) drawn from 15 countries in sub-Saharan Africa. Major financial support for this course was provided by IFS Sweden, CTA Holland, and ICRAF, Kenya.

Follow-up study of trainees

In 1993, Dr. J.A. Kwarteng was commissioned to undertake a trainee follow-up study, which was completed in 1994, and the results were analyzed. The major objectives of this study were to determine how well the knowledge and skills acquired during training courses had been utilized, and to assess the contribution of training to job performance.

A trainee follow-up study questionnaire was developed, validated, and used for data collection. Part I of the questionnaire sought to gather current background information on former trainees, part II elicited



Participants at the WARDA NARS Training Seminar on "Training and Job Performance in Rice Science."

information on current employment, and part III gathered data on courses attended and general comments on them. The questionnaire was distributed to 270 trainees in 14 WARDA member countries, and 118 were returned completed, giving a response of 44%. The data were summarized and analyzed using an SPSS.PC+ package, and measures of central tendency were computed to describe the responses to a selected series of variables. Quantitative summaries of open questions were also made. Conclusions from this study were summarized:

"WARDA's training courses have had a positive impact on trainees through contributing to increasing the professional confidence of trainees, improving self reliance, increasing cooperation with professional colleagues, high utilization of the knowledge and skills acquired during training, strengthening trainees' research competence, and strengthening their ability to write and publish research papers. In a few cases, recognition, promotion, and professional advancement were directly linked to improved performance due to WARDA training. A strong desire was expressed for greater correspondence between WARDA and former trainees and for attendance at more of WARDA's training courses. Critical areas of training needs for national programs were recommended; these include computer applications in agricultural research, integrated crop protection, water management in rice production, postharvest handling, scientific writing, and agricultural information management."

The conclusions and recommendations from this study are being used to guide WARDA's future training activities.

WARDA/NARS training seminar

In May the second in the series of WARDA/NARS training seminars was held at WARDA headquarters, M'bé, Côte d'Ivoire. More than 30 participants from 15 WARDA member countries; from other CGIAR centers, regional, and international organizations; and from NGOs, attended the seminar. The theme for the seminar was "Training and Job Performance in Rice Science", and the topics discussed were WARDA's training programs; impact of WARDA training on job performance; and national policies for rice science training. A meeting of the WARDA/NARS Training Working Group (TWG) was held on the last day of the seminar, when the WARDA Alumni Association was also launched.

The proceedings of the seminar containing full texts of the papers presented, briefs on the discussions of presentations, the seminar recommendations, and the report of the TWG meeting will be published in 1995.

TABLE 27: **Research scholars at WARDA, 1994.**

Name	Country	Degree and University	Topic	Supervising WARDA scientist and discipline
J.V.K. Afun	Ghana	Ph.D., Wye College, Univ. of London, U.K.	The roll of weeds in the natural control of upland rice insect pests in Côte d'Ivoire	D. Johnson (weeds) E. Heinrichs (entomology)
M. Ahonsi	Nigeria	M.Sc., ABU, Nigeria	Studies of false smut of rice induced by *Ustilaginoidea virens*	A. Sy (pathology)
R.N.A. Ahoyo	Benin	Ph.D., Univ. of Hohenheim, Germany	Cost and profitability of rice production systems in southern Benin	A. Adesina (agricultural economics)
F. Asch	Germany	Ph.D., Univ. of Hamburg, Germany	Salt tolerance of irrigated rice in the Sahel	M. Dingkuhn (physiology)
D. Birmingham	U.S.A.	Ph.D., Univ. of Wisconsin, U.S.A.	Indigenous soils classification and management by farmers in three regions of Côte d'Ivoire	A. Adesina (agricultural economics) K. Sahrawat (soil science)
A.O. Daleba	Côte d'Ivoire	Doc. 3e cycle, Univ. of Abidjan, Côte d'Ivoire	Developing drought-resistant rice varieties using biotechnology techniques	M. Jones (breeding)
A. Diallo	Senegal	Doc., Univ. CAD, Dakar, Senegal	Access of women to irrigation resources in rice production: a case study of the Goye zone of the upper valley of the Senegal River	T. Randolph (agricultural economics)
H. Diandue	Côte d'Ivoire	D.E.A., Univ. of Abidjan, Côte d'Ivoire	Screening interspecific rice crosses for resistance to blast and drought	M. Jones (breeding)
S. Diatta	Senegal	Doc., Univ. of Nancy, France	Interactions of pedologic and hydrologic processes on the growth of rice along a toposequence in central Côte d'Ivoire	K. Sahrawat (soil science)
K.K. Djato	Côte d'Ivoire	Doc. 3e cycle, CIRES, Univ. of Abidjan, Côte d'Ivoire	Comparative analysis of small-scale and large-scale rice production systems in Côte d'Ivoire	A. Adesina (agricultural economics)

TABLE 27 (cont'd)

Name	Country	Degree and University	Topic	Supervising WARDA scientist and discipline
M. Dobo	Côte d'Ivoire	Doc. 3e cycle, Univ. of Abidjan, Côte d'Ivoire	Determining the ecosystems that promote anther culturability in various rice varieties	M. Jones (breeding)
B. Fofana	Togo	Ph.D., Univ. of Giessen, Germany	Effect of morphological traits on the competitiveness of upland rice cultivars with weeds	D. Johnson (weeds)
N. Fofana	Côte d'Ivoire	Doc. 3e cycle, CIRES, Univ. of Abidjan, Côte d'Ivoire	Women in rice production systems: a comparative study of extensive systems in Gagnoa, southwest Côte d'Ivoire, and intensive systems in Korhogo, northern Côte d'Ivoire	A. Adesina (agricultural economics)
A.V. Houndékon	Benin	Doc. 3e cycle, CIRES, Univ. of Abidjan, Côte d'Ivoire	Economic analysis of rice production systems in northern Benin	A. Adesina (agricultural economics)
A.O. Joda	Nigeria	Ph.D., Univ. of Ibadan, Nigeria	The bio-ecology and control of *Aspavia armigera* on rice in Nigeria	B. Singh (breeding)
E.B. Kouassi	Côte d'Ivoire	D.E.A., Univ. of Abidjan, Côte d'Ivoire	Study of interspecific rice crosses for weed supression or tolerance	M. Jones (breeding)
A.T. Maji	Nigeria	M.Sc., Univ. of Ibadan, Nigeria	Evaluation of drought tolerance and other agronomic traits in African rice varieties (*O. glaberrima*)	B. Singh (breeding)
S. Nacro	Burkina Faso	Ph.D., Univ. of Rennes, France	Ecology, biology, and parasites of African rice gall midge	E. Heinrichs (entomology)
L.T. Narteh	Ghana	Ph.D., Univ. of Ghana, Legon	Iron toxicity in West African soils: the roll of other nutrients	K. Sahrawat (soils)
P. N'guessan	Côte d'Ivoire	Doc., Univ. of Montpellier, France	Epidemiology and variability of the marbrure virus on rice	A. Sy (pathology)
J.O. Nipah	Ghana	M.Phil., UST, Kumasi, Ghana	Varietal screening and genetic analysis for iron toxicity tolerance in rice	M. Jones (upland breeding) B. Singh (lowland breeding)

TABLE 27 (cont'd)

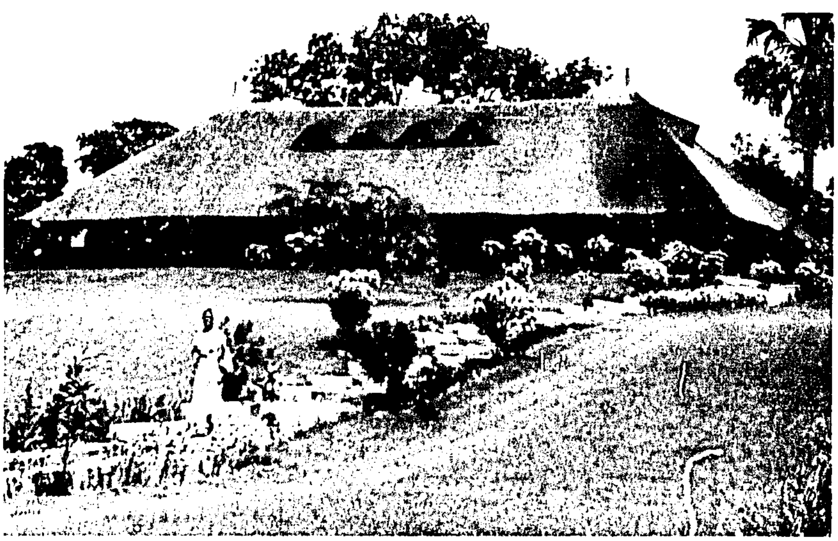
Name	Country	Degree and University	Topic	Supervising WARDA scientist and discipline
A.O. Olaleye	Nigeria	Ph.D., Univ. of Ibadan, Nigeria	Suitability evaluation, characterization, and rice yields in selected iron-toxic soils in Nigeria	B. Singh (breeding) K. Sahrawat (soils)
A.A. Omoloye	Nigeria	Ph.D., Univ. of Ibadan, Nigeria	Mechanisms of resistance in rice cultivars to the African rice gall midge, *Orseolia oryzivora*	B. Singh (breeding) C. Williams (entomology) E. Heinrichs (entomology)
A. Ouattara	Côte d'Ivoire	Doc. 3e cycle, CIRES, Univ. of Abidjan, Côte d'Ivoire	Ex-ante analysis of the financial profitability and constraints to adoption of new rice production technologies in the Korhogo region of Côte d'Ivoire	A. Adesina (agricultural economics)
R. Samba	Senegal	Ph.D., Univ. CAD, Dakar, Senegal	Effect of rice cropping systems and drainage on salinization and alkalinization of soils in the Senegal River valley and delta	M. Wopereis (agronomy)
M. Sié	Burkina Faso	Doc., Univ. of Montpellier, France	The use of thermal constants as selection criteria for rice varieties adapted to irrigated rice cultivation in the Sahel	K. Miezan (breeding) M. Wopereis (agronomy) M. Dingkuhn (physiology)
N.T. Sow	Senegal	Ph.D., Cath. Univ. of Louvain, Belgium	Improving rice tolerance to salinity through somaclonal variation	K. Miezan (breeding) M. Dingkuhn (physiology)
K. Tari.ondé	Tchad	Doc. 3e cycle, Univ. of Abidjan, Côte d'Ivoire	Determining characteristics that give rice varieties the ability to surpress or tolerate weeds	M. Jones (breeding)
A.A. Touré	Nigeria	M.Sc., Purdue Univ., U.S.A.	Economic constraints to rice-based rotations in Niger	T. Randolph (agricultural economics)

TABLE 27 (cont'd)

Name	Country	Degree and University	Topic	Supervising WARDA scientist and discipline
C.O. Traoré	Mali	Doc. 3e cycle, CIRES, Univ. of Abidjan, Côte d'Ivoire	Economic constraints to irrigated rice production in the Selingue rice scheme in southwestern Mali	A. Adesina (agricultural economics)
J.P. Tré	Côte d'Ivoire	M.Sc., Purdue Univ., U.S.A.	aRates of return to mangrove rice research in Sierra Leone	A. Adesina (agricultural economics)

TABLE 28: Short-term WARDA trainees in 1994.

Name	Country	Institution	Discipline
G Coquais	France	ISTOM	Pathology (RYMV)
C. Dankers	Netherlands	Agricultural Univ. of Wageningen	Entomology
S. Masselot	France	ISTOM	Pathology (Blast)
J.B. Onivogui	Guinea/Con	SOGUIPAH	Multidisciplinary
N. Ritzenthaler	France	ISTOM	Agronomy
Y. Sylla	Côte d'Ivoire	ENSA	Pathology (RYMV)



WARDA's dining hall is a friendly gathering place for lunches and meetings of the entire WARDA staff.

SUMMARIES OF COMMUNICATIONS ACTIVITIES

Anthony Youdeowei, Alassane Diallo, Cheikh Diop

PUBLICATIONS

The publication effort initiated in 1993 was continued in 1994 with the production of a series of publications with assistance of freelance editors and book designers. Research papers published by WARDA scientists in various journals were reissued in a WARDA Reprints Series for more targeted distribution.

Publications issued in 1994:

- WARDA Annual Report 1993 (French and English)
- Current Contents at WARDA (monthly)
- WARIS Brochure (French and English)
- WARIS Poster (French and English)
- Directory of Rice Scientists in West Africa (English)
- Training in Mangrove Rice Production — Instructor's Manual (English)
- WARDA Reprints Series Numbers 1 to 14

TABLE 29: **Breakdown of translation volume from 1991 to 1994.**

Year	1991	1992	1993	1994
Research	277	2000	750	620
Director General's Office	389	500	1212	1520
Training & Coms.	785	1000	1100	1274
Administration	404		210	302
Miscellaneous	253	250	14	310
TOTAL	2108	3750	3286	4026
GRAND TOTAL				13 170

Translation and interpretation services

The staffing situation in the Translation and Interpretation Services Unit stabilized very quickly, and work progressed rapidly and satisfactorily during the year. Because the volume of translations requested continued to rise, we were compelled to depend on freelance translators to cope with the workload for both English-to-French and French-to-English translations.

For interpretation services, the staff interpreter continued to work with freelance interpreters to service the Board of Trustees meeting, the Research Task Force meetings, and group training courses. Table 29

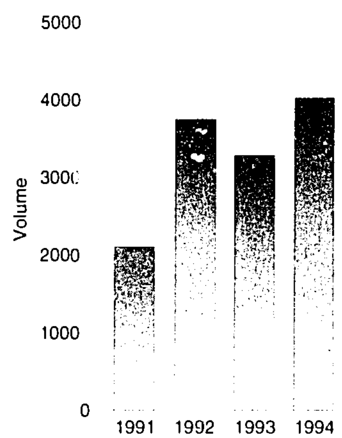


FIGURE 29: Translation volume trend for 1991 to 1994.

summarizes the numbers and types of documents translated in 1991-1994, while Figure 29 presents data showing the trends in translation volume for 1991 to 1994.

LIBRARY AND DOCUMENTATION CENTER

Formulated in 1989, and approved in June 1990 by the International Development Research Centre (IDRC) of Canada, the West Africa Rice Information System (WARIS) Project came to an end in December 1994.

The overall objective of the project was to strengthen and upgrade WARDA's Library and Documentation Center services and put in place the infrastructure necessary for the development of effective information services in rice research and production in the region. The implementation of the WARIS project has resulted in upgraded rice library and documentation collections and improved and expanded information services for the benefit of WARDA and its NARS scientists.

The documentalist undertook a one-week mission to the WARDA Sahel Program in November 1994 to evaluate progress made and implement necessary changes to improve library facilities and services. The Sahel Program's secretary in charge of the library was offered a second training session at WARDA headquarters in December 1994, in library and database management.

Scientists of the WARDA Sahel Program, ISRA, and SAED now have access to a well-stocked and well-managed library. The library is adequately housed, and it is equipped with a powerful computer, a CD-ROM drive, SESAME, AGRICOLA, and CIARL BRS CD-ROM databases. Two databases, SAHEL for monographs, and NDIAY for periodicals, are used for managing the library holdings.

Library collections

Library acquisitions between 1990 and 1994 were as shown in Table 30.

The library subscribed to 170 journals, in addition to several journals received free of charge and on an exchange basis. Books relevant to rice were purchased.

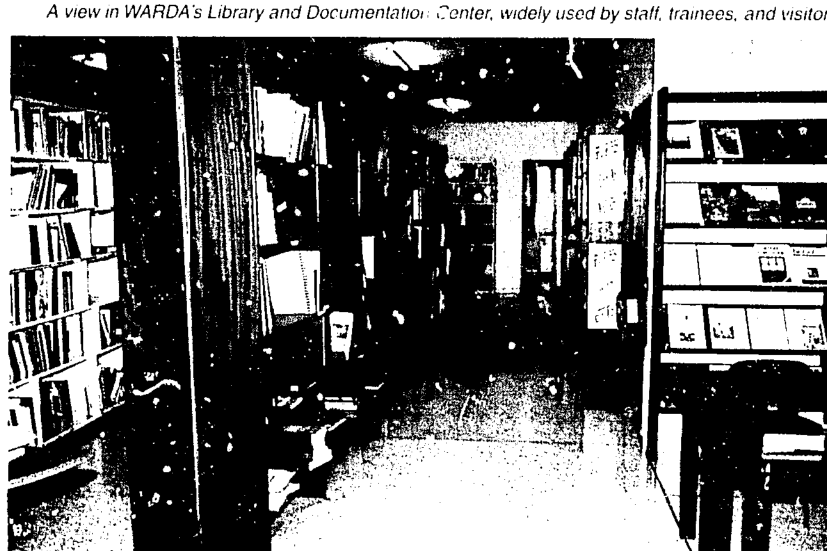
"Grey" literature was actively collected during missions undertaken by WARDA's documentalist and junior librarian, by WARDA staff, and through WARDA's Task Forces and working groups. Emphasis is placed on collecting theses and research reports throughout WARDA member countries.

Database management

In-house databases—West African Rice Bibliographic Database (WARBI), periodicals database (PERIO), WARDA mailing list database, the West African rice scientists (RSCWA), and reprints database (RPRIN)—were continuously updated and improved.

With financial and technical support from the Technical Centre for Agricultural and Rural Cooperation (CTA), The Netherlands, through its CD-ROM project, from the International Development Research Centre (IDRC), Canada, and from core funds, WARDA received regular updates of the following agricultural databases:

A view in WARDA's Library and Documentation Center, widely used by staff, trainees, and visitors.



Publications and posters produced in 1994.

on CD-ROM:

- Agronomy Journal
- AGRICOLA
- AGRIS
- CAB ABSTRACTS
- CRIS/ICAR
- KIT ABSTRACTS/TROPAG & RURAL
- SESAME

on diskette:

- ADI (African Development Indicators data on diskette) of the World Bank
- CURRENT CONTENTS ON DISKETTE (agriculture, biology, environmental sciences) WITH ABSTRACTS
- RICE ABSTRACTS

Rice science information services

An increasing number of requests for exhaustive searches was received from both WARDA and NARS rice scientists. An average of 15 requests were received monthly.

The number of literature searches increased by threefold between 1990 and 1994 (Table 31).

"Current Contents at WARDA"

The monthly publication "Current Contents at WARDA" was published regularly and distributed every month to NARS rice scientists and institutions. Rapidly increasing interest expressed by rice researchers in WARDA member states has caused the number of copies distributed to increase from 46 in February 1991 to 200 in March 1994, as illustrated by the data in Table 32.

A new cover was designed to improve on the presentation of this publication.

Document delivery

WARIS provides a book- and other document-lending service, including free delivery. In addition, photocopies of journal articles and book chapters are being provided free of charge on request. Beneficiaries of WARIS literature searches, and recipients of SDI and [illegible] Contents at WARDA, are [illegible]ys assisted in obtaining hard copies of relevant references.

Documents provided to rice scientists from 1991 to 1994 are indicated in Table 33.

Directory of Rice Scientists in West Africa

The English edition of the Directory of Rice Scientists in West Africa was released in 1994. The French edition is being printed and should be available in May 1995. Both editions will be circulated to rice scientists and relevant institutions, along with a form for amendments. This first edition is expected to attract more scientists and data, and it will lead to the publication, in 1996, of a second more comprehensive edition.

The purpose of the directory is to facilitate contacts and exchange of information among researchers. The directory is also expected to serve as a medium for enhancing exchange of researchers, as well as for promoting utilization of expertise available in the WARDA region.

This directory, with information on 216 scientists, contains a black-and-white identity-card-format photograph and personal biographical data of scientists working with rice at WARDA and its member countries, arranged according to the fields of specialization, as well as scientists' names, subject matter, institutions, and countries.

TABLE 30: **Library acquisitions.**

Year	1990	1991	1992	1993	1994
Books	762	564	415	453	769
Periodicals	6824	2009	1161	1275	2961
Annual reports	362	106	249	255	340
Catalogs/Pamphlets	238	195	454	457	576
Reprints/Photocopies	2268	3650	3675	3715	3995
Miscellaneous	159	84	394	402	1249
Totals	10 613	6608	6348	6557	9890

TABLE 31: **Number of main literature searches performed for rice scientists.**

Year	1990	1991	1992	1993	1994
Number of main Searches	40	50	70	110	135

TABLE 32: **Number of copies of "Current Contents of WARDA".**

Year	1991	1992	1993	1994
Number of copies	46	150	195	200

TABLE 33: **Number of documents provided to rice scientists.**

Year	1991	1992	1993	1994
Publications	350	375	450	530
Photocopied pages of articles and book chapters	33 356	43 000	49 000	52 358

The directory will be widely distributed in WARDA member countries and to the international rice community.

WARIS poster

Both English and French versions of the WARIS poster were published and distributed in 1994.

WARIS brochure

Attractive and colorful English and French editions of the WARIS brochure were designed and produced in two formats. The brochure gives an introduction to WARIS and the services it provides. It also invites all potential users of WARIS to make maximum use of the various services offered.

MAIN LITERATURE SEARCHES CONDUCTED BY WARDA IN 1994

Agricultural and rice research in WARDA member countries (for Dr. T. Randolph, WARDA headquarters)
Agricultural systems and technical change (for Dr. P. Matlon, WARDA headquarters)
Alternative host plants of insect pests and parasitoids (for Miss Cobblah, Department of Zoology, University of Ghana-Legon, Ghana)
Birch effect (for Mrs. D. Birmingham, WARDA headquarters)
Breeding rice for soil acidity resistance (for Mr S. Y. Dogbe, INCV, Lomé, Togo)
Burning and ash in fallow systems (for Mrs D. Birmingham, WARDA headquarters)
Chemical weed control in rice and application methods (for Mr. J. K. Kehinde, NCRI, Badegi, Nigeria)
Cropping systems and parasitoids (for Miss M. A. Cobblah, Department of Zoology, University of Ghana-Legon, Ghana)
Development and growth of the rice leaf (for Dr. Moussa Sié, WARDA, Senegal)
Exchange rate policy in WARDA member countries (for Dr. T Randolph, WARDA headquarters)
Fertilizers and weed development (for Mr. S. Traore, IDESSA, Côte d'Ivoire)
Genetic x environment interaction (GxE) for rice, maize, sorghum, and wheat (for Dr. R. Guei, WARDA headquarters)
Influence of Leguminosae in the nitrogen uptake of upland rice and weed control (for Mr. Segda Zacharie, INERA, Farako-Bâ, Burkina Faso)
Host-plant resistance acreage (for Dr. E. Heinrichs, WARDA headquarters)
Irrigated rice, women, and productivity in the Sahel (for Mr. A. Diallo, SAED, Bake, Senegal)
Land-clearing in fallow systems (for Mrs. D. Birmingham, WARDA headquarters)
Maintenance of *Rhizobium* strains (for Mr. K. Kouame, IDESSA, Bouaké, Côte d'Ivoire)
Morphological and physiological traits of cereals related to the response to low temperature (for Dr. Moussa Sié, WARDA, Senegal)
Parasitoids and vegetable pests (for Miss M. A. Cobblah, Department of Zoology, University of Ghana-Legon, Ghana)
Parasitoids of rice insects (for Miss M. A. Cobblah, Department of Zoology, University of Ghana-Legon, Ghana)
Mangrove rice in Africa (for Mr. J. P. Tre c/o Dr. Adesina, WARDA headquarters)
Preservation and utilization of germplasm (for Dr. R. Guei, WARDA headquarters)
Rice grain discoloration (for Mr. D. R. Taylor, RRS, Sierra Leone)
Rice production and policy of WARDA member countries (for Dr. T. Randolph, WARDA headquarters)
Rice production in Nigeria (for Prof. V. Awoderu, Ogun State University, Ago-Iwoye, Nigeria)
Rice Yellow Mottle Virus: update (for Mr. D. R. Taylor, RRS, Sierra Leone; Dr. E. Imolehin and Mr. M. E. Abo, NCRI, Nigeria, Dr. A. A. Sy, WARDA headquarters; Mr. M. M. Coulibaly, Programme Riz Irrigué, Niono, Mali)
Seed classification (for Mr. N'Cho, IDESSA, Côte d'Ivoire)
Species concepts of insects (for Miss M. A. Cobblah, Department of Zoology, University of Ghana-Legon, Ghana)
Stalk-eyed flies (*Diopsis*) (for Dr. B. N. Singh, WARDA, Nigeria)
Taxonomy of parasitic Hymenoptera (for Miss M. A. Cobblah, Department of Zoology, University of Ghana-Legon, Ghana)
Transportation costs in West Africa (for Dr. T. Randolph, WARDA headquarters)
Utilization of Leguminosae in upland rice (for Mr. Segda Zacharie, INERA, Farako-Bâ, Burkina Faso)
Weed control in irrigated rice in the Sahel (for Dr. D. Johnson, WARDA headquarters)
World fertilizer markets (for Dr. T. Randolph, WARDA headquarters)
World rice markets (for Dr. T. Randolph, WARDA headquarters)
Zoogeography of insects (for Miss M. A. Cobblah, Department of Zoology, University of Ghana-Legon, Ghana)

The WARIS brochure, together with the WARIS poster, are being widely distributed to WARDA member countries' rice scientists, to research, development, and educational institutions, and to libraries and information services, in order to publicize WARIS services.

Improvement of national capacities

The rice research information systems of WARDA member states are provided access to all WARIS services at no charge. In addition, links are forged and maintained with the staff of NARS libraries, so that they are kept abreast of new information technologies and training opportunities. More specifically, WARIS provides them with expertise and advisory missions to assist in the use of new technologies and to upgrade procedures, management, and services. On-the-job training programs are organized upon request. Regular formal group training courses are expected to commence in 1995.

Training

Since WARIS became operational in early 1991, demand for information services has expanded well beyond projected expectations in:

- the number of scientists requesting information services;
- the diversity of information demands, covering all aspects of agricultural research;
- increasing requests for training of NARS librarians and documentalists at WARDA on agricultural information management and use of new information management technologies.

With the development of modern agricultural information facilities at WARDA's Library and Documentation Center, considerable potential exists for WARDA to design, organize, and manage individual and regional group training in agricultural information management and use of new information management technologies.

WARDA has in the past organized such regional training courses and is offering an increasing number of short-term on-the-job training programs to upgrade the skills of NARS information staff.

The objectives of the training program are:

- to enlarge national capacities in procedures for the organization and management of agricultural information;
- to facilitate access to, and dissemination of, agricultural information;
- to develop the "computer and new technologies culture" of NARS agricultural information personnel;
- to promote the dissemination of agricultural information in WARDA member countries through the organization of group training courses focusing on the use of new information technologies.

On-the-job training

Following requests received from member countries' national programs, 10 staff (five men and five women) in charge of agricultural information services were trained in library and database management between 1990 and January 1995.

Training in library and database management in 1994

Mr. Falankoi M. S. Janneh, in charge of the Gambia Library of Agricultural Research (GLAR) of the National Agricultural Research Institute (NARI), Yundum, The Gambia, 14-28 February 1994.

Mr. Celestin Kodé Dadié, student at the Département Information-Communication of Université Pierre Mendès France Grenoble II, Institut Universitaire de Technologie II, Grenoble, France, 6 June to 5 September 1994, for on-the-job training and writing of a dissertation on the establishment of a database on rice research institutions of WARDA member countries.

Mr. Mamadou Cissé, in charge of the Documentation Center of Centre de Formation et de Recherche en Animation Rurale (CFRAR), Abidjan, Côte d'Ivoire, 18 April to 18 June 1994.

Mrs Aïda Ndiaye, in charge of the library of the WARDA Sahel Irrigated Rice Program, Ndiaye/Saint-Louis, Senegal, 22 November to 4 December 1992, and 26 December 1994 to 6 January 1995.

Miss Marie Mbengue, in charge of the Documentation Center of

Société d'Aménagement et de Mise en Valeur du Delta du Fleuve Sénégal (SAED), Ndiaye/Saint-Louis, Senegal, 23 December 1994 to 6 January 1995.

Training focused on the design of bibliographical databases and improved library operational procedures to be used by the trainees to more efficiently manage their libraries and documentation centers. During the training, WARDA Library and Documentation Center staff visited with the Ivorian trainees at their respective services and held meetings with the administrators of their institutions.

Training in information retrieval for scientists

Numerous scientists and staff from Opportunities Industrialization Centers International, Inc. (OIC), an NGO in Bouaké, have been trained in the use of word-processing and database management software, and information retrieval from in-house and CD-ROM databases.

GROUP TRAINING

Participation in group training

The WARDA Library and Documentation Center organized and hosted the CTA/WARDA collaborative group training course on the "Utilization of CD-ROM for Agricultural Information Management". This course, held from 10 to 21 October 1994 at the WARDA Training Center at headquarters, was attended by thirteen participants from nine African francophone countries: Benin, Burkina Faso, Cameroon, Central African Republic, Chad, Côte d'Ivoire, Madagascar, Mali, and Mauritania.

The objective of this training course was to upgrade the skills of staff in charge of CTA-funded CD-ROM stations in the following areas:

- basic functions of information retrieval tools used to search CD-ROM databases;
- MS-DOS;
- downloading of data from CD-ROM databases to WordPerfect and CD-ISIS software;
- installation of CD-ROM hardware and software;
- products and services developed using CD-ROM databases.

The WARDA documentalist delivered lectures at these courses:

- WARDA Training Course on Computer Applications and Statistical Analysis in Agricultural Research, M'bé/Bouaké, Côte d'Ivoire, January 1994.
- WARDA Training Course on Scientific Writing for Agricultural Research Scientists, IITA Biological Control Center for Africa, Cotonou, Benin, 14-24 November 1994.

Assistance to national programs through follow-up missions

Responding to requests from national programs, and as follow-up missions to training programs, working visits were undertaken in WARDA member countries and other countries:

- The Gambia Library of Agricultural Research (GLAR) of the National Agricultural Research Institute (NARI), Yundum, The Gambia, 22-28 May 1994.
- Centre de Formation et de Recherche en Animation Rurale (CFRAR), Abidjan, Côte d'Ivoire, 8-10 September 1994.
- Documentation Center, National Agricultural Research Institute of Benin (INRAB), Cotonou, Benin, 21-25 November 1994.

The purpose of the follow-up missions to the institutions of staff trained at WARDA headquarters was to help in solving problems encountered after the training program has taken place; design, adopt, or adapt more efficient library management and organization procedures; install hardware and software for database management.

REGIONAL AND INTERNATIONAL COOPERATION

CTA/ECOWAS Project: a Study of Agricultural Information Needs for the Countries of West Africa, and an Integrated Information Program for Agricultural Development in West Africa

WARDA is still playing a major role in this very important undertaking through its director of training and communications and its documentalist.

WARDA organized the First Meeting of the Regional Action Committee for Evaluation, Planning, and Monitoring of Agricultural Information Activities in West Africa (CREPS) held from 5 to 8 April 1994 in Abidjan, Côte d'Ivoire and participated in the CTA/ECOWAS CREPS meeting on the finalization of the project document "Integrated Information Program for Agricultural Development in West Africa", from 20 to 21 December 1994 at ECOWAS headquarters, in Lagos, Nigeria.

WARDA has already been identified as the lead institution, CTA will collaborate to implement its regional scientific and technical information program for West Africa, and ECOWAS will be relied upon to coordinate and implement the Integrated Information Program for Agricultural Development in West Africa.

WARDA sees this as a major contribution to WARIS for better dissemination of agricultural information within West Africa, and in sub-Saharan Africa.

REDACI, Côte d'Ivoire

WARDA library and documentation staff regularly visit relevant institutions and information services in the Bouaké and Abidjan areas in order to establish and strengthen cooperative links. WARDA staff also participate actively in the activities of the Ivorian Agricultural Information Network (REDACI), and its quarterly meetings held 19 January, 13 April, 13 July, and 12 October 1994 in Abidjan were attended by the WARDA junior librarian.

WEST AFRICA RICE DEVELOPMENT ASSOCIATION

Statement of Financial Position as of December 31, 1994
(Expressed in U.S. dollars)

ASSETS	1994	1993
Current Assets		
Cash and Cash Equivalents	1 073 994	286 742
Accounts Receivable:		
Donors	1 774 569	1 525 151
Employees	279 490	179 297
Others	728 030	380 341
Inventories	684 391	468 443
Prepaid Expenses	216 418	306 239
Total Current Assets	4 756 892	3 146 213
Fixed Assets		
Property, Plant and Equipment	14 509 084	13 832 232
Less: Accumulated Depreciation	(2 283 224)	(1 750 827)
Total Fixed Assets - Net	12 225 860	12 081 405
TOTAL ASSETS	16 982 752	15 227 618
LIABILITIES		
Current Liabilities		
Bank Overdraft		276 309
Accounts Payable:		
Donors	2 516 744	1 933 822
Employees	66 243	63 332
Others	2 034 827	1 550 765
Accruals and Provisions	462 967	772 818
Total Current Liabilities	5 080 781	4 597 046
Long-Term Liabilities	0	0
TOTAL LIABILITIES	5 080 781	4 597 046
NET ASSETS		
Capital Invested in Fixed Assets:		
Center Owned In Custody	12 225 860	12 081 405
Capital Fund	(1 636 637)	(2 796 734)
Operating Funds	1 312 748	1 345 901
TOTAL NET ASSETS	11 901 971	10 630 572
Total Liabilities & Net Assets	16 982 752	15 227 618

The financial statements were approved by the Board of Trustees on 26 April 1995 and were signed on their behalf by:

Dr. Eugene R. Terry,
Director General

Mr. Kwame Akuffo-Akoto
Head of Finance & Support Services

WEST AFRICA RICE DEVELOPMENT ASSOCIATION

Grants and Contributions for the Year ended 31 December 1994
(Expressed in U.S. dollars)

CORE UNRESTRICTED	1994	1993
Canada (CIDA)	507 246	547 707
France	195 960	141 379
Germany (BMZ/GTZ)	367 102	301 929
Japan	1 416 328	1 280 277
Korea	50 000	50 000
The Netherlands	270 438	137 715
Sweden	467 221	490 732
United Kingdom (ODA)	172 057	165 506
United States (USAID)	50 000	
World Bank		1 400 000
SUBTOTAL	**3 496 353**	**4 515 245**
CORE RESTRICTED		
AfDB - Institutional Support	838 072	782 976
AfDB - Integrated Pest Management	126 051	379 997
Canada - (IDRC) Small Grants Project	44 850	81 441
Canada - (IDRC) West African Info. System Project	112 313	12 470
EEC - Crop and Resource Management	562 001	748 973
France - Agro-Physiology Project	12 134	1 463
Germany (BMZ/GTZ) - Temperature Stress Project	282 655	228 574
Germany (BMZ/GTZ) - Salinity Project	73 323	
Japan - Grain Quality Studies	36 178	43 041
Rockefeller Foundation - Post-doc Fellowship		3 000
Rockefeller Foundation - Anther Culture Project	31 980	
UNDP - Training and Communications	445 204	630 876
United Kingdom (ODA/NRI) - Weeds Project	35 108	
United Kingdom (ODA) - INGER Project	55 197	
United States (USAID) - Rice Network Project	366 315	189 432
SUBTOTAL	**3 021 381**	**3 102 243**
TOTAL CORE GRANTS	**6 517 734**	**7 617 488**
COMPLEMENTARY		
Canada (IDRC) - Vector Borne Diseases Project	22 129	
The Netherlands - Inland Valley Consortium Project	173 556	49 863
United Kingdom (ODA/NRI) - Nematology Project	7 807	
United Kingdom (ODA/NRI) - Weed/Insect Inter. Pro.	17 667	
United Kingdom (ODA/NRI) - Gall Midge Project	21 347	
TOTAL COMPLEMENTARY GRANTS	242 506	49 863

WEST AFRICA RICE DEVELOPMENT ASSOCIATION

Statement of Activity by Funding Source for the Year ended December 31, 1994
(Expressed in U.S. dollars)

	UNRESTRICTED CORE	RESTRICTED CORE	COMPLEMENTARY	TOTAL	1993
REVENUE					
Grants	3 496 353	3 021 381	242 506	6 760 240	7 667 351
Member States Contributions	64 045			64 045	74 520
Other Revenue	36 541			36 541	85 459
Total Revenue	3 596 939	3 021 381	242 506	6 860 826	7 827 330
OPERATING EXPENSES					
Research Programs	1 811 840	2 463 863	242 506	4 518 209	4 230 189
Training and Communications	490 005	557 518		1 047 523	1 136 873
Admin. Expenses & General Operations	1 972 788			1 972 788	2 175 255
Gross Operating Expenses	4 274 633	3 021 381	242 506	7 538 520	7 542 317
Recovery of Indirect Charges	(205 847)			(205 847)	(139 755)
Net Operating Expenses	4 068 786	3 021 381	242 506	7 332 673	7 402 562
Excess/(Deficit) of Revenue Over Expenses	(471 847)	0	0	(471 847)	424 768
Extraordinary Items	0	0	0	0	(385 233)
Excess/(Deficit) of Revenue Over Expenses	(471 847)	0	0	(471 847)	39 535
ALLOCATED AS FOLLOWS					
Operating Fund	(471 847)	0	0	(471 847)	39 535
	(471 847)	0	0	(471 847)	39 535

MEMO ITEM

Operating Expenses by Natural Classification

Personnel Costs	*2 197 885*	*1 154 860*	*19 792*	*3 372 537*	*3 915 698*
Supplies and Services	*1 403 107*	*1 691 446*	*213 957*	*3 308 510*	*2 726 111*
Travel	*219 152*	*97 522*	*5 619*	*322 293*	*378 841*
Depreciation	*454 489*	*77 553*	*3 138*	*535 180*	*521 667*
TOTAL	*4 274 633*	*3 021 381*	*242 506*	*7 538 520*	*7 542 317*

WARDA STAFF

As of December 31, 1994

OFFICE OF THE DIRECTOR GENERAL

Eugene R. Terry, Ph.D.	Director General
Robert Cathcart Lemp, M.A.	Special Assistant to the DG
Marie-Therese Gohou, B.T.S.	Executive Secretary
Simplice Koffi Kra, Lic.Es.	Personnel & Liaison Services Manager
Casimir Grouto, Ing. Bat.	Physical & Plants Services Manager

Support personnel

Karim Abdoul Sylla
Focouo Kouakou Badou
Boniface Lokou Bligui
Kassinibeh Coulibaly
Keita Djedy
Sylvain Gnazale
Coulibaly Karamoko
Theodore N'Guessan Kouassi
Joseph Essoh Lasme
Sylvin Lokougna Okou
Sie Sou
Jean de Dieu Toni
Sekou Conde
Kifoulih Souly Bakary
Anatole Tehe Djedea Bah
Thomas Bregue Bogui
Christal Jean Dali
Pascal Kakou Edi
Francois Haba
Siriki Kone
Georges Brou Kra
Veronique Moquet
Kanakoba Ouattara
Eby Tanoh
Boureima Zerbo
Josephine Pannah Freeman
Leopold Amon
Amade Belem
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Far left: Mr. Zongo Dramane is seen here receiving the Director General's Ebony Daba (Farmer's Hoe) Award for best male WARDA field worker in 1994.

Left: Mme. Boni N'Dri Françoise is seen here receiving the Director General's Ebony Daba (Farmer's Hoe) Award for best female WARDA field worker in 1994.

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PUBLICATIONS BY WARDA STAFF IN 1994

Adesina, A.A., Johnson, D.E., and Heinrichs, E.A. 1994. Rice pests in the Ivory Coast, West Africa: farmers' perceptions and management strategies. *International journal of Pest Management*. 40(4); 293-299

Adesina, A.A., Djato, K.K., and Pegatienan, J. 1994. Relative efficiency of rice farms in Northern Côte d'Ivoire: Profit function analysis. Abstract in: *Proceedings of the 1995 Annual Meeting of the American Agricultural Economists Association, American Journal of Agricultural Economics*. Vol. 76 (50), (December) (in press).

Adesina, A.A. 1994. Pesticide use and policy in West Africa: An overview. In: Agne, S., Fleisher, G., and Waibel, H. (eds.). *Proceedings of Gottingen Workshop on Pesticide Policies.*, 28 February - 4 March 1994. Gottingen, Germany. pp. 27-42.

Andriesse, W., Van Duivenbooden, N., Fresco, L.O., Windmeijer, P.N. 1994. A multi-scale approach to characterize inland valley agro-ecosystems in West Africa. *Netherlands Journal of Agricultural Science*. 42: 159-179.

Audebert, A., and Siband, P. 1994. Cotton crop on granitic gneiss bedrock in Togo. In: *Proc. 3rd ESA Congress*, Abano-Padova 19-22/09/1994.

Becker, M., Ladha, J.K., and Ali, M. 1995. Green manure technology: potential, usage, and limitations. A case study for lowland rice. In: *Proc. 15th World Congress of Soil Sci.* 1994. ISSS, Acapulco, Mexico.

Becker, M., Ladha, J.K., Simpson, I.C., and Ottow, J.C.G. 1994. Parameters affecting residue nitrogen mineralization in flooded soils. *Soil Sci. Soc. Am. J.* 58:1666-1671.

Becker, M., Ladha, J.K., and Ottow, J.C.G. 1994. Nitrogen losses and lowland rice yield as affected by residue nitrogen release. *Soil Sci. Soc. Am. J.* 58:1660-1665.

Bouman, B.A.M., Wopereis, M.C.S., Kropff, M.J., ten Berge, H.F.M., and Tuong, T.P. 1994. Understanding the water use efficiency of flooded rice fields. II. Validation and seepage losses. *Agricultural Water Management*. 26:291-304.

Diatta, S., and Sahrawat, K.L. 1994. Performance of rice cultivars along the upland/inland swamp continuum in the M'bé valley, Côte d'Ivoire. In: *Transactions of 15th World Congress of Soil Science*. Vol. 7b (commission VI): 190-191. Acapulco, Mexico, July 10-16, 1994.

Dingkuhn, M. 1994. Systems research at WARDA. In: *Opportunities, Use, and Transfer of Systems Research Methods in Agriculture to Developing Countries*. Edited by Peter Goldsworthy and Frits Penning de Vries. Kluwer Academic Publishers, in cooperation with ISNAR and ICASA. pp. 341-349.

Dingkuhn M., Sow, A., Samb, A., Diack, S., and Asch, F. 1994. Climatic determinants of irrigated rice performance in the Sahel. I. Photothermal and micro-climatic responses of flowering. *Agricultural systems*. 48 (1994) 385-410.

Dingkuhn, M., and Miezan, K.M. 1994. Climatic determinants of irrigated rice performance in the Sahel. II. Validation of photothermal constants and characterization of genotypes. *Agricultural Systems*. 48 (1994) 411-434.

Dingkuhn, M. 1994. Climatic determinants of irrigated rice performance in the Sahel. III. Characterizing environments by simulating crop phenology. *Agricultural Systems*. 48 (1994) 435-456.

PUBLICATIONS BY WARDA STAFF

Gilbert, E., Matlon, P.J., and Eyzaguirre, P. 1994. New perspectives of vulnerable institutions: Agricultural research systems in the small countries of West Africa. *ISNAR Briefing Paper No. 14*. International Service for National Agricultural Research (ISNAR). The Hague, The Netherlands.

Heinrichs, E.A. 1994. Development of multiple pest-resistant crop cultivars. *J. Agric. Entomol.* 11: 223-253.

Heinrichs, E.A. 1994. Rice. In: Heinrichs, E.A. (ed.), *Biology and Management of Rice Insects*. Wiley Eastern, New Delhi and the International Rice Research Institute, Manila, Philippines. pp. 3-11.

Heinrichs, E.A. 1994. Host plant resistance. In: Heinrichs, E.A. (ed.), *Biology and Management of Rice Insects*. Wiley Eastern, New Delhi and the International Rice Research Institute, Manila, Philippines. pp. 517-547.

Heinrichs, E.A. (ed.) 1994. *Biology and Management of Rice Insects*. Wiley Eastern, New Delhi and the International Rice Research Institute, Manila, Philippines. 779 p.

Heinrichs, E.A. 1994. Impact of insecticides on the resistance and resurgence of rice planthoppers. In: Denno, R., and Perfect, J. (eds.), *Management of Leafhoppers and Planthoppers*. Chapman and Hall, New York. pp. 571-598.

Jamin, J.Y., 1994. Normes and techniques et diversite sociale.: L'agriculture irreguee sahelienne peut-elle s'intensifier en prenant en compte la diversite des exploitations? In: *Proc. FSRE/CIRAD-INRA-ORSTROM Symposium Recheches systeme en agriculture et developpement rural*. Montpellier, France. novembre 1994.

Jones, M.P. 1994. WARDA'S work and progress in upland rice breeding for West Africa. In: *Proc. International Upland Rice Breeders' Workshop: Scientific Papers*. Montpellier, France. September 6-10, 1993.

Jones, M.P., Singh, B.N., and Meizan, K. 1994. WARDA'S varietal nomenclature system. In: *Proc. International Upland Rice Breeders' Workshop: Recommendations*. Montpellier, France. September 6-10, 1993.

Jones, M.P. 1994. Germplasm collection and conservation activities in West Africa: The role of the West Africa Rice Development Association. In: *Proc. Action Plan on Safeguarding and Preservation of the Biodiversity of the Rice Genepool*. IRRI, Los Baños, Philippines. February 28 - March 3, 1994.

Jones, M.P. 1994. Agroecological zones and rice production systems in sub-Saharan Africa. In: *Training in Mangrove Rice Production. Instructor's Manual*. West Africa Rice Development Association. pp. 3-16.

Jones, M.P. Characteristics and breeding of mangrove rice varieties. In: *Training in Mangrove Rice Production. Instructor's Manual*. West Africa Rice Development Association. pp. 45-74.

Jones, M.P. 1994. Growth and development of the rice plant. In: *Training in Mangrove Rice Production. Instructor's Manual*. West Africa Rice Development Association. pp. 31-45.

Matlon, P.J. 1994. Indigenous land use systems and investments in soil fertility in Burkina Faso. In: *Searching for Land Tenure Security in Africa*. Bruce, J.W. and Migot-Adholla, S. (eds.). Kendhall/Hunt Publishing Company, Dubuque, Iowa, U.S.A. pp. 41-69.

Matlon, P.J., and Adesina, A.A. 1994. Potential IARC contributions to building social science capacity in NARS. In: *Social Science in the CGIAR. Proceedings of a Meeting of CGIAR Social Scientists*. Held at the International Service for National Agricultural Research (ISNAR), The Hague, The Netherlands, August 1992. Collinson, M.P., and Platais, K.W. (eds.) CGIAR Study Paper No. 28. The World Bank, Washington, D.C., U.S.A.

Matlon, P.J. 1994. Research needs for sustainable rice production in West Africa: WARDA'S assessment and response. In: *Proceedings of the 17th Session of the International Rice Commission.* 4-9 February 1990, Goiana, Goias, Brazil. *International Rice Commission Newsletter.* 1994. Vol. 39, FAO, Rome, Italy. pp. 231-239.

Reardon, T., Kelley, V., Delgado, C., Matlon, P., and Badiane, O. 1994. Is income diversification agriculture-led in the West African semi-arid tropics (WASAT)? Nature, causes, effects, distribution, and production-linkages of off-farm activities. In: *Economic Policy Experience in Africa - What Have We Learned?* Atsain, A., Wangwe, S., and Drabeck, A.G., (eds.). African Economic Consortorium, Nairobi, Kenya. pp. 207-229.

Sahrawat, K.L. 1994. Flooding soil: A great equalizer of diverisity in soil chemical fertility. In: *Program and Abstracts of the Third Symposium on Biogeochemistry of Wetlands.* June 26-29, 1994. University of Florida, Gainesville, Florida, U.S.A. p. 91.

Shailaja, S., and Sahrawat, K.L. 1994. Phosphate buffering capacity and supply parameters affecting phosphorus availability in vertisols. *Journal of the Indian Society of Soil Science.* 42: 329-330.

Singh, B.N., and Fashola, O.O. 1994. Sustainable wetland rice production in northern Nigeria. In: *Strategies for the sustainable use of fadama lands in northern Nigeria.* Kolawole, A., Scoones, I., Awogbade, M.O., and Voh, J.P. (eds.). pp. 35-42.

Sy, A.A., Alberti, L., and Moletti, M. 1994. Biological control of rice leaf blast. In: *Rice Blast Disease.* Zeigler. R.S., Leong, S.A., and Teng, P.S., (eds). pp. 521-527.

Tuong, T.P., Wopereis, M.C.S., Marquez, J., and Kropff, M.J .1994. Mechanisms and control of percolation losses in puddled rice fields. *Soil Science Society of America Journal.* 58:1794 1804.

van de Giesen, N.C., Parlange, J.Y., and Steenhuis, T.S. 1994. Transient flow to open drains: Comparison of linearized solutions with and without the Dupuit assumption. *Water Resources Research.* 30(11):3033-3039.

van de Giesen, N.C., and Steenhuis, T.S. 1994. The smallholder farm as an appropriate water management unit in wetland development. In: *Dambo Farming in Zimbabwe: Water Management, Cropping and Soil Potential for Smallholder Farming in the Wetlands.* Owen, R.J.S. et al. (eds.). Ithaca, N.Y., U.S.A. CIIFAD-Univeristy of Zimbabwe.

van de Giesen, N.C., and Andrieni, M.S. 1994. Legal quagmires: Wetland use and development in Rwanda and Zimbabwe. *Rechtsanthtopologisches Jahrbuch.* pp. 124-139.

van de Giesen, N.C. 1994. Agricultural development of wet upland valleys (marais) in Rwanda, Africa. Ph.D. dissertation. Cornell University, Ithaca, N.Y., U.S.A.

van Duivenbooden, N., and Windmeijer, P.N. 1994. Manual for semi-detailed characterization of inland valleys. Characterization of rice-growing agro-ecosystems in West Africa. *Technical Report 4.* WARDA/IITA/SC-DLO/WAU. SC-DLO, Wageningen, The Netherlands.

van Duivenbooden, N., and Windmeijer, P.N. 1994. Final report on project activities by SC-DLO and WAU. Characterization of rice-growing agro-ecosystems in West Africa. SC-DLO Wageningen, The Netherlands.

Windmeijer, P.N., van Duivenbooden N., and Andriesse, W. 1994. Semi-detailed characterization of inland valleys in Côte d'Ivoire. Characterization of rice-growing agro-ecosystems in West Africa. *Technical Report 3.* Volume 1: Main Report; Volume 2, Basic Data. SC-DLO, Wageningen, The Netherlands.

Wopereis, M.C.S., Bouman, B.A.M., Kropff, M.J., ten Berge, H.F.M., and Maligaya, A.R. 1994. Understanding the water-use efficiency of flooded rice fields. I. Validation of the soil-water balance model SAWAH. *Agricultural Water Management*. 26:227-289.

Wopereis, M.C.S., Bouma, J., Kropff, M.J., and Sanidad, W. 1994. Reducing bypass flow through a dry, cracked and previously puddled rice soil. *Soil & Tillage Research*. 29: 1-11.

Youssef ben Kada, M., Bendahmane, B.S., Sy, A.A., Barrault, G., and Albertini, L. 1994. Effect of inoculation of barley inflorescence with *Dreschlera teres* upon the location of seed-born inoculum and its transmission to seedlings as modified by temperature and soil moisture. *Plant Pathology*. 43. pp. 350-355.

ACRONYMS

AfDB	African Development Bank
AUW	Agricultural University of Wageningen (The Netherlands)
BMZ	Bunderministerium für Wirtschaftliche Zusammenarbeit (Germany)
BNDA	Banque national de développement agricole (Mali)
CAD	Cheikh Anta Diop (Senegal)
CD-ROM	Compact disc, read-only memory
CENATEL	Centre national de télédétection et de surveillance du couvert forestier (Benin)
CFA	Communauté financière africaine (franc de la)
CGIAR	Consultative Group on International Agricultural Research (see map, inside back cover)
CIDA	Canadian International Development Agency
CIMA	Centre ivoirien du machisme agricole
CIRAD	Centre de coopération internationale en recherche agronomique pour le développement (France)
CIRES	Centre ivoirien de recherches sociales et economiques
CNRST	Centre national de recherche scientifique et de technologie (Burkina Faso)
CORAF	Conférénce des responsables de la recherche agronomique africaine
CRI	Crops Research Institute (Ghana)
CTA	Technical Center for Agricultural and Rural Cooperation (The Netherlands)
DRA	Direction de la recherche agronomique (Benin)
ECA	Economic Commission for Africa
ECOWAS	Economic Community of West African States
EEC	European Economic Community
FAO	Food and Agriculture Organization of the United Nations
FCFA	Franc, CFA, West African currency unit
GIS	Geographical information system
GTZ	Deutsche Gesellschaft für Technische Zusammenarbeit (Germany)
IARC	International agricultural research center (a generic term)
IDESSA	Institut des savanes (Côte d'Ivoire)
IDRC	International Development Research Centre (Canada)
IER	Ecole inter-etats d'ingenieurs de l'equipement rural (Mali)
IFS	International Foundation for Science (Sweden)
IIE	International Institute of Entomology
INERA	Institut de recherches et d'études agricoles (Burkina Faso)
INGER-Africa	International Network for Genetic Evaluation of Rice (AFRICA branch)
INRA	Institut national de la recherche agronomique (France)
INRAB	Institut national des recherches agronomicoles du Bénin
INRAN	Institut national des recherches agronomiques du Niger
IPM	Integrated pest management
IRA	Institut de recherche agronomique (Cameroon)
IRAT	Institut de recherches agronomiques tropicales et des cultures vivrières (France)
ISRA	Institut sénégalais de recherche agronomique
IVC	Inland Valley Consortium
NARI	National Agricultural Research Institute (Gambia)
NARS	National agricultural research system (a generic term)
NCRI	National Cereals Research Institute (Nigeria)
NPK	Nitrogen/phosphorus/potassium (fertilizer elements)

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ACRONYMS

ODA	Overseas Development Administration (United Kingdom)
OIC	Opportunities Industrialization Centers International, Inc.
ORSTOM	Institut français de recherche scientifique pour le développement en coopération (France)
PEEM	Panel of Experts on Environmental Management for Vector Control
REDACI	Réseau de documentation agricole de Côte d'Ivoire
RRS	Rokupr Research Station (Sierra Leone)
RYMV	Rice yellow mottle virus
SAED	Société nationale d'aménagement et d'exploration des terres du delta du fleuve Sénégal
SAFGRAD	Semi-Arid Food Grain Research and Development
SC-DLO	Winand Staring Centre for Integrated Land, Soil and Water Resources (The Netherlands)
SPAAR	Special Program for African Agricultural Research
TAC	Technical Advisory Committee of the CGIAR
UNDP	United Nations Development Programme
USAID	United States Agency for International Development
WARBI	West Africa Rice Bibliographic Database
WARIS	West Africa Rice Information System
WHO	World Health Organization

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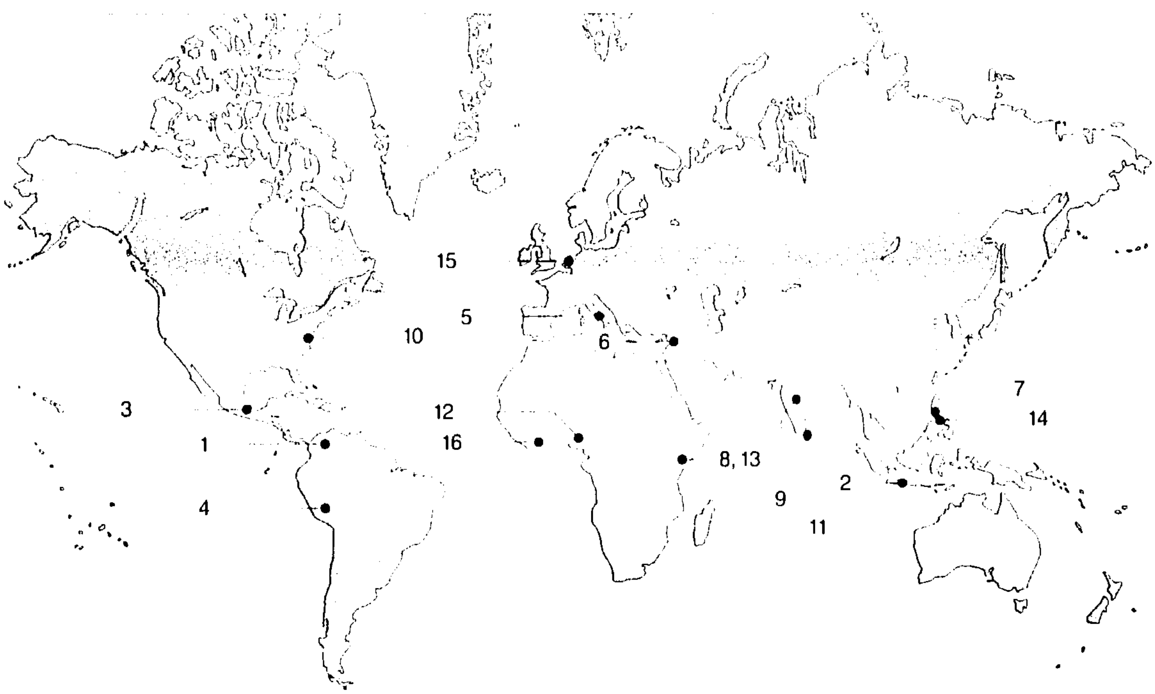

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1.	CIAT	Centro Internacional de Agricultura Tropical, Cali, Colombia
2.	CIFOR	Center for International Forestry Research, Bogor, Indonesia
3.	CIMMYT	Centro Internacional de Mejoramiento de Maiz y Trigo, El Batan, Mexico
4.	CIP	Centro Internacional de la Papa, Lima, Peru
5.	IPGRI	International Plant Genetic Resources Institute, Rome, Italy
6.	ICARDA	International Center for Agricultural Research in the Dry Areas, Aleppo, Syria
7.	ICLARM	International Center for Living Aquatic Resources Management, Manila, Philippines
8.	ICRAF	International Centre for Research in Agroforestry, Nairobi, Kenya
9.	ICRISAT	International Crops Research Institute for the Semi-Arid Tropics, Patancheru, Andhra Pradesh, India
10.	IFPRI	International Food Policy Research Institute, Washington, D.C., U.S.A.
11.	IIMI	International Irrigation Management Institute, Colombo, Sri Lanka
12.	IITA	International Institute of Tropical Agriculture, Ibadan, Nigeria
13.	ILRI	International Livestock Research Institute, Nairobi, Kenya
14.	IRRI	International Rice Research Institute, Los Baños, Philippines
15.	ISNAR	International Service for National Agricultural Research, The Hague, The Netherlands
16.	WARDA	West Africa Rice Development Association, Bouaké, Côte d'Ivoire

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