WARDA

1988 ANNUAL REPORT

WEST AFRICA RICE DEVELOPMENT ASSOCIATION

West Africa Rice Development Association

The West Africa Rice Development Association (WARDA) was formed in September, 1970 by 11 countries with the assistance of the United Nations Development Program (UNDP), the United Nations Food and Agriculture Organization (FAO), and the Economic Commission for Africa (ECA). It is a bilingual, inter-governmental organization presently consisting of 16 West African countries: Benin, Burkina Faso, Chad, The Gambia, Ghana, Guinea, Guinea-Bissau, Cote d'Ivoire, Liberia, Mali, Mauritania, Niger, Nigeria, Senegal, Sierra Leone, and Togo.

In December, 1986, WARDA became a full-fledged member of the Consultative Group on International Agriculture (CGIAR), a network of 13 international agricultural research centers. The mandate of WARDA is to assist its member countries in becoming self-sufficient in rice, a staple food of West Africa.

The Association received funds and assistance in kind from the following countries in 1988:

- *CGIAR funds from the following countries:* Belgium, Canada, the Federal Republic of Germany, France, Japan, The Netherlands, and Sweden; the World Bank, and the International Fund for Agricultural Development (IFAD).
- *International and regional organizations and private foundations*, namely, the African Development Bank (ADB), the European Economic Community (EEC), Organization of Petroleum Exporting Countries (OPEC), United Nations Food and Agriculture Organization (FAO), the United Nations Development Program (UNDP), and the World Bank.
- *Member states*, and
- *International aid agencies of governments of the following countries:* Belgium, the Federal Republic of Germany, France, Italy, Japan, The Netherlands, Switzerland, the United Kingdom, and the United States of America.


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From the Director General

WARDA has entered a new phase in its history. We have taken a critical look at what has been achieved in rice research in West Africa during the past two decades, and now realize that a bold new approach is needed to address the problems and challenges of the present and future.

WARDA has learned that the West African environment imposes strict limits to technology transfer such that we can no longer depend on importing technologies developed elsewhere to meet the needs of the region's farmers. We have also learned that achieving short-term gains is inadequate to meet the rapidly growing demand for rice in West Africa. New technologies must be sustainable to make a significant impact, and this requires that they be in balance with the economic, institutional and ecological context. Finally, it is increasingly clear that for broad and lasting impact, WARDA must not only work closely with national programs, but we must do so in a way which strengthens their long-term capacity. This will require a closely coordinated team effort in the areas of research, training and communications to generate and promote rice science for West Africa.

With these lessons in mind, 1988 marked a turning point in WARDA's research approach. Research efforts during the year were concentrated on five major areas to establish a solid base for take-off into our Five Year Plan: reevaluation and consolidation of previous research results; characterization of the rice growing ecosystems in which WARDA is operating; identification of constraints facing rice farmers in the region in terms of soils, climate, insects diseases, genetic resources and socio-economics; development of new research methods and development approaches; and maintenance of critical on-going activities, such as varietal improvement, that will continue during the Plan period.

Activities in these areas will enhance WARDA's prospects of establishing benchmark data on the region's diverse ecosystems, identify the strengths and weaknesses of our past efforts, and chart new directions for our future efforts.

WARDA is cognizant of the fact that there exists a dearth of appropriately trained rice scientists in the region. WARDA has therefore conducted follow-up studies of our previous training program participants and have critically evaluated our existing training programs. Results of these studies are already helping us to modify our approaches in this critical area. WARDA has recently developed a five year

Contents

The Sahel

Introduction

The Sahel environment in which rice is grown under irrigation is found in parts of Senegal, Mali, Mauritania, Chad, Niger, Nigeria and Burkina Faso. Although there are currently only about 135,000 hectares under irrigated rice cultivation, the technical potential is much greater. It is estimated that there are two million hectares of irrigable land along the Sahel's major rivers and in the Lake Chad Basin. Before development of these lands can be considered economic, however, many of the formidable constraints to high and stable rice yields must be overcome.

The Sahel environment is complex and difficult. The climate is characterized by wide extremes and can be highly erratic even over short periods. There are three seasons in the Sahel region: a rainy season, a cold dry season and a hot dry season. Temperature extremes range from over 43° C during March-May to lows of 10° C in December and January. These temperatures, when they occur at critical times, can cause seedling loss as well as sterility in mature rice plants. Winds that can reach 70 km per hour drive hot sands which further threaten the survival of seedlings. Humidity varies from 80-90 percent in the rainy season to below 10 percent in the dry season and evapotranspiration rates can reach as high as 16 mm per day during the hot dry season.

Annual rainfall is also unreliable, with a coefficient of variation of approximately 40 percent. In areas not served by major dams, this creates high variation in the availability of irrigation water drawn from rivers. Finally, the light soils of the area are not only nutrient poor but generally permeable, leading to substantial water loss through deep percolation.

In addition to these technical constraints, farmers in this sub-region do not have a tradition of farming under irrigated conditions. This creates major problems at the farmer level as entirely new water management practices have to be learned. The lack of tradition can also lead to conflict at the group level when social institutions necessary for cooperative irrigated farming do not yet exist.

All of these factors help explain why large increases in productivity have not yet been achieved, and why results for both farmers and researchers tend to be erratic from one year to the next.

During 1988 WARDA scientists addressed many of these problems through several major research thrusts in the areas of water management, soil fertility and varietal improvement.

Water Management

Water management in the Sahel region involves interaction between the natural and socio-economic environments, and the physical construction and design factors built into irrigation systems. These do not always agree. When they conflict, new institutions, new management systems, and new designs must be developed. This is where the research conducted by WARDA scientists during 1988 and previous years has played a major role.

In a collaborative effort with Wageningen University of The Netherlands, WARDA scientists have analyzed these competing factors and developed design and management concepts to improve the success of small-scale and medium-scale irrigation schemes.

SMALL-SCALE IRRIGATION SCHEMES

Farmers in the Senegal River Valley of the Sahel region suffered from successive years of drought throughout the 1970's and early 1980's. Many turned to irrigation to stabilize food production. When introduced to techniques used elsewhere in the world, farmers began constructing small-scale irrigation schemes, commonly referred to as village schemes. Designed to assure food security regardless of rainfall, donors and government agencies supported their construction through both financial and technical assistance.

Subsequent experience has shown that some of the construction methods and criteria used to design the schemes have not been the most effective. As a result, rice farmers have modified their systems over time to resolve structural problems and to adapt individual schemes to meet their own particular needs. Beginning in 1982, WARDA scientists have carried out research to identify the principal design and management problems which plagued villaged schemes and to develope more productive and sustainable approaches. During 1988, scientists concentrated their efforts on consolidating much of the information gathered over the years into a conceptual format that can be applied more generally throughout the Sahel.

Scientists made particular effort to integrate the lessons learned from studying the social-cultural reality of farmers with the more technical organizational and design aspects. Previous research had generally neglected such socio-cultural dimensions to the detriment of the entire system.

Field studies were conducted since 1982 in three zones of the Senegal River Valley: the Middle and Upper Valleys in Senegal, and in the Rosso zone on the Mauritanian side of the river.

Canal construction for irrigated rice is a project that often involves whole villages.

From these studies scientists were able to:

- determine the criteria and means used to identify sites,
- gather information on the history of the schemes,
- get an insight into the political network of the village schemes,
- isolate some of the technical and organizational aspects that influence water management and management of infrastructures,
- determine labor sources and labor requirements,
- obtain information relating to the competition between irrigation and farmers' other economic activities,

- characterize and identify constraints to women's activities in rice production,
- identify land tenure rights of the groups involved, and
- document some of the criteria used to attribute fields within the irrigation systems.

By studying the daily irrigation practices of farmers in the rice growing village schemes, scientists were also able to calculate: crop water requirements for schemes sampled; field water requirements; system water requirements; field water and system water usage; and conveyance efficiency of each sampled irrigation scheme.

Water Requirements

The Societe Amenagement et Exploitation de Delta in Senegal (SAED) has established seasonal water requirements for the Senegal River valley as a whole, using three common soil types found in the region. These are referred to as "norms" for specific sites. WARDA scientists compared these norms to the actual amounts of field water required within sample plots in six village schemes.

Floating irrigation pumps enable farmers in the Sahel region to be more flexible in the timing of irrigation and movement of water to needed locations.

They found that actual field water requirements are on average 20 percent higher than the norms established by SAED. Field measurements also revealed major differences between plots. Variations between plots in the same schemes often covered ranges in which observed maximum values were double minimum values.

These findings stress the need to verify theoretically derived parameters with systematic field observations and to implement broader safety margins when canal layouts are being planned. Of most importance is the need to adapt the operational aspects of the water management systems to the needs of individual plots.

Irrigation Water Usage

In determining irrigation water usage, scientists focused primarily on the coverage rate and conveyance efficiency of the schemes. The coverage rates were fairly high, but they failed to reflect the great variability of water distribution among plots. Layout quality often plays havoc within many of the schemes. On the basis of topographic surveys, verification of canal-dimensions and monitoring of system operations, it was found that low uniformity of water coverage was due primarily to insufficient canal capacities, low canal beds and/or excessive percolation within the plots.

Although social factors are sometimes cited as contributing to unequal water distribution, survey results showed that the social rules that govern access to water had a consistently positive effect on the uniformity of water distribution among the schemes studied.

The conveyance efficiency of each system was measured by recording the pumping hours and/or diesel consumption and relating this to the field water use.

The irrigation practices used in the schemes studied were found to be generally efficient and effective. The study pointed out that on average farmers do not waste irrigation water. In spite of some of the constraints imposed on farmers, such as poor design or construction, most were able to distribute available water to meet crop water requirements through recourse to labor intensive supplemental activities.

Physical Characteristics

Because of haste, efforts to economize, or poor follow-up on the part of designers and construction contractors, a number of faults were found in many of the schemes visited. Some of the physical defects noted and problems associated with them include:

(1) Low canal capacity. Insufficient capacity retards the rotation cycle, increases water losses and leads to unequal water distribution.

(2) Low canal beds. These reduce water depth for adjacent plots, increase the time needed to conduct field irrigation, and retard the irrigation cycle.

(3) Long canals and high canal densities. Long canals encourage inefficient fuel consumption and high maintenance, and dense canals decrease the net irrigable area while rendering the irrigation practices much less surveyable.

Structural Defects

With regard to structural defects, the most commonly observed problems were:

(1) Insufficient and/or misplaced irrigation structures. These include drop structures, division boxes, and stilling basins. These problems were due to a number of factors, including: farmers economizing on cement; lack of supervision and follow-up during construction; and lack of information given to farmers concerning the purpose of such structures.

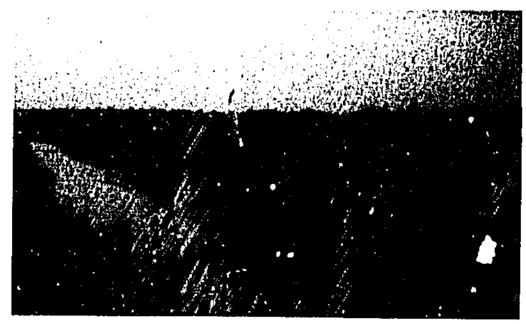
(2) Field inlets constructed with improper materials or methods. These factors contribute to weak canal bunds and degradation of the transverse profile.

Field Leveling and Layout

Improper field leveling and unequal or irregular field dimensions were the most common field design problems identified. Improper field leveling leads to:

- higher water usage,
- higher bund-rupture,
- difficulties for mechanization,
- volatilization of nitrogen,
- higher weed infestation,
- laborious farm construction and maintenance work,
- drainage problems, and
- complicated and time-consuming irrigation.

Unequal and irregular field dimensions do not directly affect water distribution, but they do place higher operating costs on some rice farmers.



Siphon irrigation is used by farmers in the Sahel to overcome some of the structural limitations of many small and medium scale schemes.

Farmer Reactions

The technical constraints observed reduce production, increase labor requirements, pose organizational dilemmas, and escalate the cost of producing rice in the region.

Farmers in the village schemes studied have reacted to these problems in one or more of the following ways:

(1) Adaptation to the water management system. In most of the schemes farmers irrigated from drains or from their neighbors' upstream plots. In a more imaginative variation, the president of the Doue scheme introduced siphon irrigation by means of garden hoses for all farmers with plots adjacent to the main canal. By redivision of the plots, they succeeded in increasing the number of farmers using siphons and improved the water distribution for all participants.

(2) Improvement of the layout by complementary works. Medina farmers tried to cut erosion in their feeder canals by lining

them with concrete. At Donaye III farmers were faced with low capacity due to counter-sloping terrain. Without external assistance they constructed a 300 meter main canal to connect this layout to an adjacent scheme.

(3) Partial rehabilitation. In Medina Gaia I a group of farmers with problem plots diverted their field canal to a higher ridge in order to increase the water depth to their fields. The same problem at Donaye III forced farmers to construct two new field canals.

(4) Abandonment of all or part of the system. In the Pete region 140 of the 600 irrigable hectares were abandoned. Insurmountable technical problems created a downward spiral of usable land.

Each of these farmer responses represents a compromise with optimal system design and operation. These responses could be avoided or lessened if planners and builders consider more closely past experiences and the realities of individual village situations.

MEDIUM SCALE SCHEMES

Experience throughout Sahelian West Africa has demonstrated the lack of success for most large scale irrigation schemes. High investment and operating costs, and disappointing yields have led to the conclusion that most such schemes represent major financial and economic losses. Many of the performance problems are closely related to poor water management and maintenance. These in turn are due in part to inappropriate institutional and organizational structures, and inadequate producer incentives.

In contrast, small scale village irrigation schemes are generally judged successful according to conventional performance criteria. Moreover, their success is in large part due to the basis on which they are organized. Close social solidarity between participating members of the village facilitates communication and problem-solving, two aspects of vital importance in irrigated agriculture. The major fault of the small scale village schemes is the tendency for production to be subsistence oriented with little surplus production directed to national markets.

Intermediate schemes have been conceived as a partial solution to these problems. They combine some of the better structural quality aspects of large scale schemes with the management flexibility, participant solidarity, and producer incentives of the village schemes.

Intermediate schemes tend to be about 50 hectares in area with roughly one hectare plots allocated to individual farmers. Technically such schemes are well designed and constructed, but at a lower cost than large scale schemes. Although the major portion of farmers' plots are sown to rice, sub-plots are set aside for subsistence oriented cultivation to reflect farm families' consumption goals.

WARDA researchers studied these systems to develop clearer concepts of their advantages and disadvantages, and to arrive at recommendations for improvement.

Major advantages with respect to water management efficiency include:

- low labor requirements for irrigation,
- high water allocation flexibility due to designing the canal system to simultaneously serve reservoir and delivery functions,
- good water distribution with use of movable siphons, a system that avoids water theft.

Despite these advantages, production remains well below economic potential, and is often inefficiently distributed across plots. WARDA researchers have shown that these are often caused by problems of social organization, especially:

- land tenure problems,
- absentee ownership of irrigated land,
- sub-division of plots by farmers to meet intra-household production objectives, and

- inadequate integration of irrigation activities into the entire farming system.

Although generally successful, certain intermediate schemes were identified that performed better than others. Comparative analyses of several such schemes identified factors that contribute to their relative success or failure. These include:

- high construction quality,
- easy access to technical support, extension services and inputs,
- integrating the production of crops other than rice,
- selection of farmers with previous experience in irrigation or more progressive farmers, and
- assured markets for surplus production.

Planners and extension personnel should emphasize these points to ensure the viability of future intermediate schemes.

Azolla

Azolla, a nitrogen producing fresh water fern, has been the subject of study in the Sahel region for a number of years. WARDA scientists, working in collaboration with the Universite Catholique de Louvain in Belgium, have shown that including azolla in rice cropping systems can meet a major share of the nitrogen requirements of rice and thereby contribute significantly to rice growth and yield.

The conoweeder can be used to incorporate azolla five times faster than by human trampling.

METHOD OF INCORPORATION

Earlier results have shown that to maximize the availability of fixed nitrogen to the rice plant, the azolla should be incorporated into the soil before rice seedlings are established. However, due to inadequate power incorporation of azolla is difficult for most farmers.

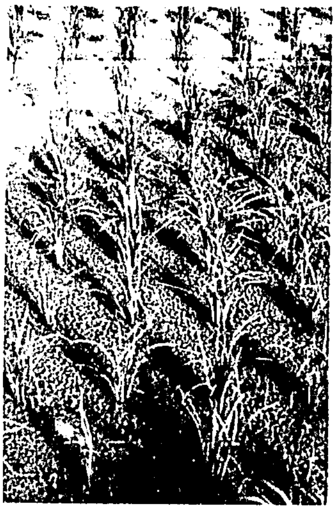
In 1988, WARDA scientists at Saint Louis made a comparison of three methods of azolla incorporation to determine the labor requirements, impact on rice yield, and economic implications of each method.

Experiments were conducted at two sites, one at Fanaye, Senegal, and a second at Kogoni, Mali. In the Fanaye site, two azolla incorporation treatments were tested: trampling by foot and mechanical incorporation by means of a rotary conoweeder. A third treatment left an azolla monocrop unincorporated on the soil surface after drainage and into which rice seedlings were

Table 1. Comparison of two azolla incorporation methods with non-incorporation and their respective effects on rice yield and weed infestation, Fanaye, Senegal, 1988

Treatment	Azolla biomass ($t\ ha^{-1}$) 1 WAT	No. tillers per plant 40 DAT	Grain yield ($t\ ha^{-1}$)	Dry weight of weeds ($g\ m^{-2}$)	Time requirement (hours ha^{-1})
Trampling	0.4	16.3	5.72	30.7	318
Conoweeder	0.4	16.0	5.56	30.9	64
W/O incorporation	2.0	14.3	6.19	3.2	0
C.V. (%)	29.7	7.9	13.4	58.0	
S.E.	2.43	.61	.39	6.26	

WAT = Weeks after transplanting DAT = Days after transplanting



Nitrogen producing azolla offers farmers in the West Africa region an alternative source of fertilization for rice cultivation.

transplanted. Sri Malaysia rice was transplanted two days after each treatment was completed. All treatments received 10 kg P_2O_5 (triple superphosphate) ha^{-1} at the time of azolla inoculation; 10 kg of P_2O_5 ha^{-1} four days following inoculation; 40 kg P_2O_5 (TSP) ha^{-1} and 60 kg K_2O (KCl) ha^{-1} as a base treatment; and 30 kg N ha^{-1} at tillering and panicle initiation.

At the Kogoni, Mali, trial site azolla was incorporated by trampling or by use of oxen drawn plows. BG 90-2 rice was transplanted 2-4 days later. Each treatment received 23 kg N ha^{-1} at panicle initiation and basal applications of 23 kg P_2O_5 ha^{-1} as single superphosphate and 25 kg K_2O ha^{-1} as potassium sulfate.

At the Fanaye site it was observed that high azolla density one week after transplanting in the unincorporated plots significantly reduced tillering, but also significantly reduced weed infestation. There were no significant yield differences between incorporation treatments . This may have been due to the offsetting yield effect of improved weed suppression on the unincorporated treatment, and due to the high split dose of N applied across all treatments which at least partially masked the azolla impact.

Results showed that use of the conoweeder for incorporation was five times faster than incorporation by foot trampling and required only half the number of people than foot trampling.

The study concluded that incorporation by foot was too labor intensive to be recommended for large production areas. In large scale production areas, such as in Mali where preplanting tillage is performed when the soil is moist, the use of animal traction for land preparation and simultaneous incorporation of a preceding azolla crop may be the most appropriate technique. In Senegal, where land is prepared during the off-season before irrigating, full incorporation of an azolla monocrop is not yet feasible. Under these conditions the direct transplanting of rice seedlings into an unincorporated azolla monocrop following drainage shows considerable potential. Further technical and economic evaluation of this method needs to be carried out under a wider range of conditions before final recommendations can be developed.

DATE OF N APPLICATION

Previous studies by WARDA researchers found that incorporating azolla prior to

Table 2. Effect of *Azolla microphylla* incorporation and time of complementary N application on rice yield, Fanaye, Senegal, 1988.

Treatment (kg ha^{-1})	Dry season		Wet season	
	Azolla biomass (t ha^{-1})	Grain yield (t ha^{-1})	Azolla biomass (t ha^{-1})	Grain yield (t ha^{-1})
Azolla monocrop + 60 N (1/2 2 WAT 1/2 6 WAT)	25.3	6.75	10.0	5.24
Azolla monocrop + 60 N 1 WAT	25.2	5.57	9.8	4.57
Azolla monocrop + 60 N 2 WAT	24.9	5.81	9.9	4.63
Azolla monocrop + 60 N 3 WAT	24.9	6.48	9.6	5.16
Azolla monocrop + 60 N 4 WAT	26.6	7.44	9.9	5.65
Azolla monocrop + 60 N 5 WAT	25.2	6.25	10.0	4.99
Azolla monocrop + 60 N 6 WAT	27.8	7.31	10.3	5.96
C..V. (%)		8.2		8.3
S.E.		.247		.204

WAT = Weeks after transplanting

transplanting rice produces a higher yield response than applying azolla after transplanting, especially if complemented with a later application of urea.

Studies in other locations have shown that uptake patterns of nitrogen from urea and azolla are different. In order to optimize the efficiency of both nitrogen sources when used together, WARDA scientists undertook a study to determine the optimum time that complementary urea should be applied with respect to the development of the rice plant.

Azolla microphylla as a monocrop incorporated two days before transplanting together with a split application of 60 kg N ha^{-1} application of urea (at 2 and 6 weeks after transplanting) was compared to six different treatments in which a single application of 60 kg N ha^{-1} was made at 1, 2, 3, 4, 5, or 6 weeks after transplanting.

Results showed that providing a complementary dose of urea to an incorporated azolla monocrop gives the highest yields when the urea is either applied as a split application between tillering and panicle initiation or when N is applied in a single application at least 4-6 weeks after transplanting.

YIELD RESPONSES FROM PHOSPHORUS SOURCES

Phosphorus is an essential element both for azolla production and for generating higher rice yields. However, farmers in West Africa cannot afford the continual application of phosphorus from chemical fertilizers, especially with increasing costs associated with recent reductions of government subsidies. Thus, WARDA scientists are examining the efficiency of lower cost natural rock phosphates as an alternative P source.

Replicated experiments were set up at WARDA's Rokupr, Sierra Leone site, using single superphosphate, Morocco rock phosphate and Tunisia rock phosphate with 12 treatments. Each of these sources of phosphorus were used in three separate treatments: with the azolla strain ADUL 137 Pi, with 60 kg ha^{-1} of urea applied two weeks after transplanting, or with neither azolla nor urea. The phosphorus sources were applied either as a base treatment or split in two with equal application to the azolla crop. The rice variety ROK 11 was used in all treatments.

Results showed that azolla growth was highest with single superphosphate and Morocco rock phosphate. Grain yields did not respond significantly to any of the phosphorus sources when applied either in the absence of azolla or together with urea. However, single superphosphate applied to the azolla monocrop increased rice yields significantly. Subsequent trials will be conducted to confirm these results and to monitor residual effects.

Varietal Development

An important component of the ongoing work of WARDA scientists operating in the Sahel region is to identify high yielding and stress resistant varieties. Blast, stem borers, spidermites and white flies are the most significant pests and diseases. WARDA scientists face an extremely difficult set of climatic and soil constraints as well. Wide diurnal temperature fluctuations, with low temperatures at seedling stage, and high temperatures at vegetative and reproductive stages pose major constraints to seedling survival and subsequent fertility.

The incidence of white heads in rice destroys the grain and is an indication of stem borer activity.

These stresses are believed to explain the inconsistent performance observed for most improved lines in past trials. Wide inter-annual performance variability of most elite lines underlines the need to strengthen WARDA's complementary research in the area of stress physiology and the need for more detailed characterization of the Sahel environment.

WET SEASON TRIALS FOR STEM BORER RESISTANCE

Preliminary screening trials conducted at Fanaye, Senegal, tested short and medium cycle cultivars from three sources for their yield potential and resistance to stem borers under wet season cultivation.

The trial included 150 entries from the African Irrigated Rice Preliminary Screening Set (AIRPSS); 100 entries from the African Irrigated Rice Observational Nursery (AIRON); and 180 entries from the International Rice Observational Nursery (IRON). Twenty-one day old seedlings from each of the nurseries were transplanted in 3-row plots. A basal application of 60 kg P ha^{-1}, 60 kg N ha^{-1} and 60 kg K ha^{-1} was used. At maximum tillering another 30 kg N ha^{-1} was applied, followed by a final dose of 30 kg N ha^{-1} at panicle initiation.

ITA 306 has shown some promise in trials conducted in the Sahel for the past two years.

No pesticides were used, but the plots were kept weed-free through the application of 10 liters of propanil ha^{-1} at seven days after transplanting and through two hand weedings. Screening for insect resistance was conducted under conditions of natural infestation.

Out of the 430 entries, only 35 were selected for further evaluation on the basis of grain yield, plant type, phenotypic acceptability and reaction to borer attack. Forty entries were completely free from borer damage. These cultivars will be re-tested to confirm borer resistance. Sixty-four of the cultivars had a duration of 100 days or less. These will be evaluated again in the hot, dry season to evaluate their suitability as off-season cultivars and for possible use in hybridization.

The seven highest yielding entries were XIANG ZHON 5, IR 13168-143-1, B 3894-22C-78-5, P 2180F4-7-5-1B, IR 28128-45-3-3-2, FARO 36 (ITA 222) and IR 32429-115-3-2-6.

WET SEASON OBSERVATIONAL YIELD NURSERY

Evaluations were made on 50 entries for yield performance, agronomic characteristics and tolerance to stem borers. The entries were selected from the previous season's initial screening.

Although yields were very high and several entries showed promise, none significantly out yielded the check, Jaya (7.45 t ha^{-1}). The highest yielding entry was IR 9884-54-1E-P1 (7.80 t ha^{-1}), followed by Jaya. Seventeen other entries gave yields ranging from 6.65-7.35 t ha^{-1}. Two of the entries, IR 28125-3-3-2 and P 4034-F3-3-3, had no borer incidence. All of the better performing entries will be examined again in 1989.

SHORT AND MEDIUM DURATION WET SEASON VARIETY TRIALS

The 1987 trials which had been conducted in five countries, isolated several entries with high yields in both the Sahelian and humid environments. These were further tested in 1988.

For the short duration entries, seven trials, each composed of 24 entries, were conducted. Two sites in Senegal, two in Mauritania and one each in Guinea-Bissau, Niger and Liberia were used.

The Senegal trials of short duration lines gave very encouraging results. Eight of the entries significantly out yielded the check I KONG PAO (IKP) (3.22 t ha^{-1}). Their yields ranged from 4.24 t ha^{-1} - 4.42 t ha^{-1}. With the exception of TOS 103, these cultivars have shorter growth duration than IKP, though only two were significantly shorter. Four of the entries (ITA 230, IR 39357-133-3-2-2-2, SKL 17-69-11 and TOS 103) had significantly less borer incidence than IKP. However, it is important to note that among the varieties that performed relatively well in this year's

Entries	Yield ($kg\ ha^{-1}$)	Duration (days)	Height (cm)	Borer infestation	
				% Hills affected	% Incidence
IR 39422-75-3-3-3-2	4.42	99	84	21.6	5.3
IR 50	4.35	104	95	24.8	7.3
ITA 230	4.28	115	99	10.9	3.1
IR 39357-133-3-2-2-2	4.28	100	105	12.3	3.1
IR 32419-44-2-3-2	4.28	104	102	19.8	5.3
SKL 17-69-11	4.24	102	97	11.1	2.7
TOS 103	4.24	109	86	9.8	2.7
IR 31785-58-1-2-3-3	4.24	96	89	19.9	4.9
I KONG PAO (check)	3.22	105	99	20.6	6.1
C.V. (%)	13.0	2.6	3.5	24.7	31.6
S.E.	.294	1.5	1.9	2.44	0.85

Table 3. Performance of selected entries in the short duration variety trial, main wet season, Fanaye, Senegal, 1988.

trial, only ITA 230 was also among the best performers in 1987.

At Suakoko, Liberia only two entries out yielded the check, Suakoko 8 (3.1 $t\ ha^{-1}$). IR 13240-108-2-2-3 yielded 4.45 $t\ ha^{-1}$ and TNAU 7893 produced 4.20 $t\ ha^{-1}$. Although screening was conducted under natural conditions, a number of varieties showed few disease symptoms suggesting a degree of resistance. Thirteen of the entries had negligible symptoms of sheath blight. All the entries except SKL 17-69-11 had less damage due to glume discoloration, and all except IR 42015-83-3-2-2 had potential possible resistance to leaf blast.

Nineteen of the medium duration varieties tested at Fanaye yielded significantly higher than the local check, Jaya (1.42 $t\ ha^{-1}$). However, Jaya's low yield can be attributed to the fact that it matured much earlier than the other varieties and suffered from severe bird damage. Also, the yields for the entire trial were lower than expected partially because the rice was transplanted three weeks earlier than other trials. The most promising varieties included ITA 306, BW 293-2, ITA

Entries	Yield ($t\ ha^{-1}$)	Height (cm)	Brown spot	Sheath blight	Iron toxicity	GLD	Leaf blast
BW 293-2	6.29	105	1.0*	1.0	2.3	1.0	2.3
ITA 234	5.52	100	2.0	1.0	2.0	2.3	1.3
ITA 306	5.48	99	2.0	1.0	2.0	1.0	2.3
ITA 222	5.41	98	2.0	1.0	2.7	1.7	1.3
IR 4422-98-3-6-1	5.41	110	1.0	1.0	2.0	1.7	1.7
BG 400-1	5.26	112	1.0	1.0	2.0	1.7	1.7
S 499-B-28	5.04	98	2.0	2.3	3.0	1.0	1.7
UPR 254-85-1-TCA3	4.93	94	1.7	1.0	2.7	1.7	1.0
IR 2042-178-1	4.79	98	1.3	1.7	2.3	2.3	2.3
SUAKOKO 8 (check)	3.55	127	1.3	1.0	1.0	1.0	1.3
C.V. (%)	13.8	3.7	49.1	39.7	44.8	48.9	40.9
S.E.	.359	2.1	.53	.55	.62	.61	.45

* Rating were on a scale of 0-5; 0 = resistant, 1 = high tolerance, 5 = highly susceptible.

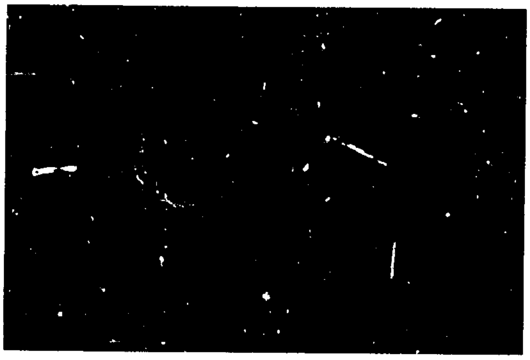
Table 4. Performance of entries in the medium duration variety trial, main wet season, Suakoko, Liberia, 1988.

222, ITA 212, IR 13540-56-3-2-1 and S 499B-28. Only CHIANUNG SEN YU 30 had a higher incidence of stem borers than the check variety from among the top yielders.

It should be noted that in this trial as well none of the top yielding varieties were among the best identified in the 1987 trials. Wide interannual inconsistency in the relative performance of lines included in both the short and medium duration trials adds considerably to the difficulty of selecting new varieties for release.

In Suakoko, Liberia, 10 of the entries significantly out yielded Suakoko 8, the check variety. All the entries showed possible resistance to brown spot and 15 of the entries had significantly lower occurrence of sheath blight than Suakoko 8. Twenty of the varieties also showed some tolerance to iron toxicity at the level of the check variety. For glume discoloration, 21 of those tested had very low symptom expression. Low indications of susceptibility to leaf blast were observed for 22 of the entries, and six of the varieties rated high for phenotypic acceptability (BW 293-2, BG 400-1, ITA 212, S 499B-28, UPR 254-85-1-TCA3 and IR 13429-299-2-1). These materials will be evaluated further in 1989.

The hot, dry winds of the Sahel cause a number of problems that sometimes destroy an entire crop.



Spider mites are one of the three major insects that attack rice grown in the Sahel region.

COLD DRY SEASON VARIETAL DEVELOPMENT

In selecting for dry season rice varieties in the Sahel region, WARDA scientists are looking for cold tolerance at the seedling stage, heat tolerance at the reproductive stage, and resistance to the principal insect pests (spider mites, white flies and stem borers).

Two trials were conducted in 1988 to identify materials well adapted to this harsh environment. WARDA scientists screened 97 elite and 50 traditional rice cultivars in the first trial. The entries were planted in 5-row plots, each three meters long with no replication. The second set of entries (151 from two ecogeographical races, Indica and Japonica) were planted in 4 rows of 3 meters each with no replication.

Among the first set of entries, 14 showed adequate adaptability. IR 39357-45-3-2-3 in particular combined good tolerance to cold at the seedling stage with heat tolerance at the reproductive stage and will be further evaluated for direct release or for use as a parent in subsequent hybridization.

In the second set of entries, seven appeared to be well adapted and have been selected for further evaluation. These include: KALARIS F_1, BARKAT (K 78-13), IR 18043-3-1-1, IR 27877-8145-3-1-3, IR 4-11, IR 30359-B-90-1-2, HPU 74 and TATSUMI-MOCHI.

HOT DRY SEASON VARIETAL DEVELOPMENT

WARDA breeders also conducted two trials to evaluate the performance of elite varieties under hot dry season conditions. Results were generally disappointing, however, as few materials showed higher yield potential compared to the check varieties.

Observational Nursery Variety Trials

Twenty four cultivars were compared with the check, IKP, in a randomized complete block design with three replications. Most of the 24 varieties were obtained from the International Rice Research Institute (IRRI). Entries were planted in 10 row plots, 5 meters long using 21 day-old seedlings for transplants.

All but one of the entries had yields that were not significantly different from IKP. Yields ranged from 3.07 - 4.87 t ha^{-1}. Four good yielding entries were significantly shorter in duration (112-116 days) than IKP. IR 31787-122-1-2-2-3 had the lowest incidence of white head damage of the four entries. And three entries were significantly superior to the check for low percent sterility caused by temperature extremes: IR 28128-45-2, IR 32429-68-3-3-3 and IR 39422-19-3-3-3-3. There was no significant difference in the occurrence of deadhearts for any of the entries tested. IR 32419-81-2-3-3 had the least incidence of spider mite damage.

Advanced Yield Trial

Twenty-four entries, again mostly from IRRI, were included in the 1988 advanced yield trials conducted at Fanaye, Senegal. IKP was again used as a check variety. A randomized complete block design with 10-row plots and three replications was used. Twenty-one day old seedlings were transplanted into the plots.

None of the entries yielded more than IKP (4.39 t ha^{-1}) and 19 had yields which were not significantly different than IKP. However, 15 of the varieties had significantly shorter maturity cycles than IKP, and will be further evaluated.

There were no significant differences in white head incidence, mainly due to low stem borer population pressures, though RAU 2004 had no whiteheads present. Three entries, IR 25898-60-2-3, IR 29692-117-1-2-2 and RAU 2004-6-69-2-13, were superior to the check for stem borer deadheart incidence.

Hybridization and Progeny Selection

Hybridization work began in the Sahel only in 1987. For this reason, the most advanced generations are still in the early segregating stages.

To develop varieties tolerant to the major dry season constraints (cold at the seedling stage, heat at the reproductive stage and high infestations of spider mites and white flies), evaluations of F_2 progenies from nine crosses were carried out in 1988. Segregants that combined these traits were selected for advancement to the F_3 generation trials for further evaluation and selection.

Upland-Inland Swamp Continuum

Introduction

WARDA's upland-inland swamp continuum program based in Bouaké, Côte d'Ivoire focuses on the development of new cultural practices, pest control methods and improved rice varieties. The new technologies are designed to meet the needs of small farmers in the forest and forest-savanna zones of West Africa who cultivate rice on swamp, hydromorphic and upland soils. This environment represents not only the largest rice growing area in West Africa but it is also an area with substantial potential for increases in rice yields. WARDA's research during 1988 produced promising results in the areas of weed control, integrated pest management, alleviation of soil constraints, and varietal improvement.

Soils

NUTRIENT DEFICIENCIES

Much work has been done in West Africa to characterize soil nutrient deficiencies on various parts of the continuum using maize as an indicator crop. However, since plant nutrient requirements vary from one crop to another, there was a need to investigate nutrient deficiencies as reflected in rice cultivation directly. A study was focused on the upland ecosystem in order to assess the current state of soil nutrient reserves and to determine the balance necessary to maintain soil fertility for upland rice cultivation.

The trial was conducted at three locations (Man, Odienne and Bouaké) in Côte d'Ivoire using two short duration varieties (IAC 164

Table 5. Response of selected rice varieties to soil nutrient deficiencies at Bouake, Man and Odienne, Cote d'Ivoire according to the Chaminade Index.*

	BOUAKE		MAN		ODIENNE	
	IDSA 6	WABZI	IAC 164	WABZI	WABC 165	IDSA 6
CP - N	84	83	84	80	29	108
CP - P	64	74	94	42	42	43
CP - K	109	104	115	97	104	95
CP - Ca	123	109	125	122	147	111
CP - Mg	105	99	118	141	134	85
CP - Mg & Ca	107	108	124	146	117	76
CP - Zn	117	118	116	96	104	87

* 80+ = No deficiency; 60-80 = low deficiency; 40-60 = medium deficiency

CP = A fertilizer containing all the recommended levels of necessary nutrients.

P_2O_5 Doses (kg ha^{-1})	Simple superphosphate	Tricalcic phosphate	Aluminum phosphate
0	1.71	1.61	1.51
15	2.23	2.02	2.07
30	2.24	2.07	2.23
45	2.29	2.08	2.49
60	2.37	2.18	2.45
75	2.44	2.39	2.14
90	2.68	2.23	2.46
105		2.39	2.55
C.V. (%)	17.5	20.4	16.8
S.E.	.140	.153	.133

Table 6. Effect of three phosphorus sources on average yield of two medium duration upland rice varieties (t ha^{-1}), Man, Cote d'Ivoire, 1988.

and WABC 165) and two medium duration varieties (IDSA 6 and WABZI).

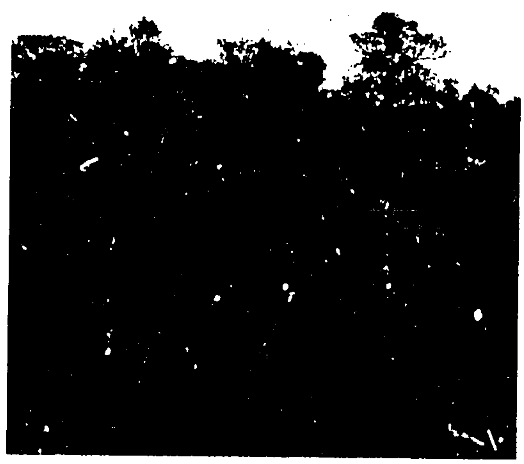
The effect of various nutrients was estimated by comparing the yield obtained using a complete fertilizer with that obtained with a fertilizer deficient in one of the essential nutrients for rice. Nine treatments were employed: zero fertilizer; a complete compound fertilizer containing recommended levels of N, P, K, Ca, Mg and Zn; six treatments each consisting of the complete fertilizer minus one of the nutrient elements; and the complete fertilizer less both calcium and magnesium.

The Chaminade index was calculated to quantify the level of nutrient deficiency. The results from the 1988 season show that phosphorus, followed by nitrogen, deficiencies were the most important. Deficiencies for these two elements were greatest at the Man site in the higher rainfall forest zone, where indexes ranged from 29-42. These results confirm trial data collected during the 1987 cropping season.

EFFECTS OF ROCK PHOSPHATE ON UPLAND RICE

Although chemical sources of phosphorus can be used to alleviate P deficiency, most chemical fertilizers are prohibitively expensive for the majority of farmers in the region. There is a need for cheaper and more efficient sources of P. Because natural rock phosphate is a commonly occurring source for P in the region, WARDA scientists tested two rock phosphates to determine their efficiency in upland rice systems.

Both rock phosphates, Taiba (tricalcic phosphate) and Thies (aluminum phosphate), are from Senegal. These were compared to the use of simple superphosphate. The Taiba rock phosphate used contained 34 percent phosphorus, the Thies rock phosphate contained 35 percent phosphorus, and the simple superphosphate had 18 percent phosphorus.



Soil nutrient deficiencies retard growth and lead to greatly reduced yields.

Seven doses of P_2O_5, increasing in 15 kg ha^{-1} increments, starting from 0 and going to 105 kg ha^{-1}, were applied for each source. Other nutrients (N,K, Ca and Mg) were applied at a rate of 100 kg ha^{-1} in order to meet plant requirements. The trial was conducted in Man, Côte d'Ivoire, in the forest zone.

The largest yield responses were observed from applications of aluminum phosphate fertilizer. Significant yield increases occurred for doses as low as 30 kg ha^{-1} and continued through the highest dose ranges. For simple superphosphate, significant yield increases were registered at the 60 through 90 kg ha^{-1} levels. Tricalcic phosphate produced significant yield increases only with applications of 75 and 105 kg ha^{-1}.

The highly significant effect of aluminum phosphate, compared to the other two phosphorus sources, may be due to its very fine granulometry (160 microns) which increases its solubility in the soil. In contrast, simple superphosphate and tricalcic phosphate are less soluble and release phosphorus into the soil more slowly thus reducing first year effects. This study is being continued in 1989 to measure residual effects on the second year rice crop.

EFFECTS OF CALCIUM AND MAGNESIUM ON UPLAND RICE

Various studies have indicated that in many acid soils of West Africa, micro-nutrient toxicity (Al+++, Fe+++ and Mn ++) can constitute a major constraint to rice cultivation in upland areas. Others have noted that the use of dolomite increases the soil pH significantly. WARDA scientists studied the use of dolomite in improving rice cultivation in upland areas during 1988.

The trial was carried out at Man, Côte d'-Ivoire, on a highly acid soil (pH = 4.1, exchangeable aluminum = 2 meq/100). Dolomite with 28.3 percent CaO and 20 percent MgO was applied at six different levels. In addition, NPK was applied at the rate of 100 kg ha^{-1}, along with simple superphosphate (18 percent P_2O_5) and potassium chloride (60 percent K_2O). Two medium duration rice varieties (IDSA 6 and WABZI) were used in the trial.

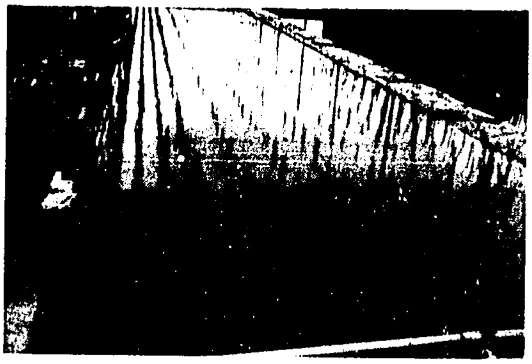
Trial results showed a significant positive effect of dolomite on rice yield. However, as the response was not linear there were no significant differences among the positive dosages applied. The trial is being conducted again in 1989 to verify this year's findings.

IRON TOXICITY SCREENING

Rice production in many inland valley swamps of West Africa is constrained by levels of ferrous iron that can be highly toxic to rice. Iron toxicity is usually associated with poor drainage and the presence of iron in the swamp's parent material or in the soils of adjacent slopes through which ground water flows laterally into the swamp. Because of the high costs of soil and water management approaches to relieve this problem, WARDA has made a major effort to develop improved rice varieties with high levels of tolerance to iron toxicity. Research on this problem is centered at Suakoko, Liberia, and is conducted in collaboration with the Central Agricultural Research Institute (CARI).

During 1988, a range of materials were screened in several trials to identify tolerance to iron toxicity. Materials in these trials included entries from the International Rice Testing Program (IRTP), promising fixed lines and segregating populations received from the International Institute of Tropical Agriculture (IITA), and promising varieties from WARDA breeders in other countries. Depending on the particular trial, screening for iron toxicity tolerance was carried out either in concrete beds in which uniformly high levels of ferrous iron had been created or in swamps on the CARI station where intense iron toxicity pressure was present.

Encouraging trial results have identified a number of cultivars that are as tolerant as the tolerant checks, Suakoko 8 and Gissi 27. These will be reconfirmed in subsequent trials and their agronomic traits will also be evaluated. Some of the more promising sources of tolerance have come from WARDA's international accessions. For example, the BW series from Sri Lanka, the variety Mat Candu from Malaysia, and CIAT 21528 from the Centro Internacional de Agricultura Tropical (CIAT) in Columbia, a well as several cultivars from IRRI and IITA.



Screening for iron toxicity tolerance at Suakoko, Liberia, is often conducted in concrete beds to maintain uniformly high levels of ferrous iron.

WARDA scientists are also studying how iron toxicity tolerance is inherited in order to accelerate and systematize their breeding efforts. Genetic studies were continued in 1988 to identify the number of genes responsible for tolerance, to identify new genes, to determine the mode of inheritance for different tolerant cultivars, and to understand the linkages between genes related to tolerance and other cultivar traits. Preliminary results show that tolerance in Suakoko 8 is controlled by a dominant gene, whereas the responsible gene in Gissi 27 is recessive. Both genes are non-allelic. Genetic studies on other cultivars will continue.

Weeds

IDENTIFICATION OF WEEDS

The identification of weed species and their distribution began in Côte d'Ivoire many years ago and several inventories now exist. However, these cover only limited parts of the country and are least comprehensive for the upland rice ecosystem. Past studies also made little effort to analyze and classify the weed species to determine the major characteristics of the weed flora. Thus further studies were needed.

A systematic field weed collection was started in 1986 and continued in 1988. Weed specimens having local names were brought to Bouaké for identification. Positive identification of some of the more difficult species was confirmed by the Botanical Garden of the University of Abidjan.

WARDA's study collected and identified 424 weed species from 76 plant families. These include all categories of weed vegetation except tree regrowth.

The largest number of weeds are broadleaf types (dicotyledons) that make up 77 percent of the collection. Grassy weeds (monocotyledons) account for another 21 percent. Ferns (pteridophytes) amount to only two percent of the weeds collected.

The most important weeds of upland rice in Côte d'Ivoire include:

- *Chlomolaena odorata* L.
- *Euphorbia heterophylla* L.
- *Imperata cylindrica* var *africana* (Anderss.)
- *Striga* species
- *Digitaria horizontalis*
- *Rottboellia cochinchinensis* (Lour.)
- *Cyperus rotundus* L.
- *Eleusine indica*
- *Pennisetum polystachion* L.
- *Ageratum conyzoides* L.

The distribution of weed species followed ecological conditions closely. Generally,

Euphorbia heterophylla **is quickly becoming a very serious weed for rice farmers in West Africa.**

Chlomolaena odorata is concentrated in the more humid forest zone with more limited infestation in the Baule Savanna. *Striga* species are restricted to the sub-humid savanna zone in the northern part of Côte d'Ivoire. The remaining species occur to some degree throughout most environments in Côte d'Ivoire. Further surveys will be conducted in 1989 to complete this study in the forest zone with an emphasis on perennial weeds, and in the savanna emphasizing *Striga* species.

CONTROL OF *EUPHORBIA HETEROPHYLLA*

Euphorbia heterophylla is becoming one of the most persistent and economically damaging weeds in upland rice in West Africa. Without effective controls, the weed can destroy the entire crop. WARDA scientists conducted a number of experiments to find ways of controlling this weed.

Determining Optimal Weeding Times

In the first experiment on *E. heterophylla*, scientists tried to identify critical periods of competition between rice and the weed to determine the most appropriate period and frequency of weeding.

Treatment plots were established and kept weed free for 1, 2, 3, 4 and 5 weeks while control plots were left unweeded for the same periods. Recommended fertilization practices were followed.

The plots were dominated by *E. heterophylla*. Keeping the plots free of weeds only for the first two weeks barely saved the rice crop as subsequent weed infestation was high enough to depress yields below 0.5 t ha^{-1}. Rice yields rose to 1.75 t ha^{-1} when plots were kept weed free for the first three weeks and to 2.6 t ha^{-1} when kept weed free for 4-5 weeks. Conversely, plots that were weeded only after the first two weeks of planting had yields of 2.3 t ha^{-1}. Grain yields dropped dramatically when the crop was left unweeded for longer periods, falling to almost zero when left for five weeks unweeded.

Thus, manual weeding earlier than three weeks may be useful only if a follow-up weeding is conducted. Weeding four weeks after rice emergence may be too late.

Influence of Cultural Practices

The effects of double cropping and mowing on *E. heterophylla* suppression were studied in the second experiment. Two main treatments were tested on an area heavily infested with *E. heterophylla*: (CP1) cowpea was grown during April-June followed by the rice crop during July-October; (CP2) three mowings at three week intervals conducted from April to June followed by rice in July-October. Both treatments were compared to the control (CP3) which consisted of no crop or mowing until July when the rice crop was planted following normal land preparation. The rice crop was further split into weeded and non-weeded subplots for both treatments and the control. A short duration rice (ITA 657) and a short duration cowpea (IT-84-1-108) were used in the experiment. No fertilizer was applied to the first season cowpea crop, but 10:18:18 NPK at 150 kg ha^{-1} was applied to the second season rice crop at seeding.

There was a significant effect of the cultural practices on weed biomass at harvest as well as on the number of weedings required. Cowpea followed by rice produced the lowest weed biomass. Moreover, the double cropping treatment only required one hand weeding; the treatment with three mowings required two hand weedings; and, the untreated control plots required three hand weedings. Yield results followed the same pattern.

Effects of Repeated Herbicide Application

WARDA researchers also evaluated the choice between repeated herbicide applications compared to improving the efficiency of herbicide on *E. heterophylla*. Several herbicides, each applied once, were compared to treatments in which the first application was followed by another application of herbicide several days later.

Table 7. Influence of double cropping and repeated mowing on the biomass of Euphorbia heterophylla and grain yields of rice (ITA 657), Bouake, Cote d'Ivoire, 1988

Treatment	Mean density of *E. heterophylla* before treatment (plants m^{-2})	Number of weedings affected	Mean biomass of *E. heterophylla* at harvest (t ha^{-1})		Mean grain yield (t ha^{-1}) Rice
			Weeding treatment means	Cultural practice means	
CP1 weeded	219	3	5.13	19.03	1.05
CP1 unweedea	228	0	32.93	19.03	0.76
CP2 weeded	208	2	1.53	8.45	1.67
CP2 unweeded	213	0	15.38	8.45	0.80
CP3 weeded	234	1	0.48	4.99	2.98
CP3 unweeded	217	0	9.50	4.99	1.44
C.V. (%)			19.2	19.1	15.8
S.E.			1.04	.73	.114

There were 12 herbicide treatments in total, each repeated four times. WABC 165 was the rice variety used. The fertilizer treatment was 10:18:18 NPK at 150 kg ha^{-1} for all the plots followed up with 75 kg ha^{-1} of urea at tillering. Phytotoxicity effects and weed density were assessed one week after each herbicide treatment.

The application of trichlopyr-propanil (Garil at 5 liters ha^{-1}) or oxadiazon (Ronstar 25 EC at 4 liters ha^{-1}) followed by picloram-2,4-D (Tordon 101 at 1.0 liters ha^{-1}) gave excellent weed control. Other effective combinations can be noted in Table 8.

Repeated herbicide application did not cause toxicity problems beyond those of a single application.

Results showed the financial advantages of herbicide use. Without herbicide the cost of labor required for four hand weedings to maintain weed free rice plots was approximately US \$430 ha^{-1}. This compares with the cost of a single application of herbicide which varied between US\$ 90-180 ha^{-1}, and with two applications at a cost of US\$160-225 ha^{-1}. Grain yields were highest and not significantly different (3.7-3.9 t ha^{-1}) for the hand weeded plots and for two of the double dose herbicide treatments. The investment in a second herbicide application was further justified economically since the risk of seed contamination was reduced such that weeds could eventually be entirely eliminated from treated fields.

Integrated Control of *Euphorbia heterophylla*

A final experiment measured the combined effects of tillage methods, herbicide application and supplementary hand weeding on control of *E. heterophylla*.

The tillage treatments were: (1) plowing followed by discing followed by harrowing and rice seeding (traditional method); (2) chiselling followed by two soil tilling operations followed by harrowing and rice seeding; and, (3) chiselling followed by one soil tillage followed by harrowing and rice seeding. To each of these soil preparation treatments, plots were divided into three sections. One section received no herbicide application, the second plot received oxadiazon at the rate of 1 kg a.i. ha^{-1}, and the third plot received oxadiazon followed by picloram-2,4-D at the rate of 1.0 litre ha^{-1} Each of the plots were further divided into sections receiving handweeding and no weeding. Fertilizer was applied at the rate of 200 kg ha^{-1} of 10:18:18 NPK at seeding followed by 50 kg ha^{-1} of urea at tillering.

E. heterophylla heavily infested the test plots. As the various tillage treatments stimulated weed germination, the population of *E. heterophylla* rose from an average of 40 plants

Table 8. Effect of repeated herbicide application on the control of *Euphorbia heterophylla*.

Treatment	Date of-application (DAE)	Herbicide rate (g m.a. ha^{-1})	Mean phytotoxicity rating (0 - 100)	Mean weed density (plants m^{-2})	Mean Rice grain yield (t ha^{-1})
Oxadiazon	0 - 1	1000	22.4	44.1	2.3
trichlopyr-propanil	21	2200	40.5	6.4	3.1
Thiobencarb-propanil + picloram- 2,4-D	21	2700 + 300	30.2	8.5	3.0
Pretilachlor-dimethametryn	0 - 1	2000	18.1	90.5	1.2
Pretilachlor-dimethametryn	21	2000	40.7	10.9	2.8
Trichlopyr-propanil fb picloram-2,4-D	21 fb 42	2200 fb 300	41.8	1.5	3.8
Oxadiazon fb picloram-2,4-D	1 fb 28	1000 fb 300	16.6	1.8	3.7
Pentazon-propanil fb picloram 2,4-D	21 fb 42	4000 fb 300	20.2	3.8	3.4
Thiobencarb-propanil fb picloram-2,4-D	21 fb 42	2700 fb 300	26.0	4.2	3.5
Weed free (4 hand weedings)	every 21 days	0	0	1.3	3.9
No weeding	none	0	0	184.6	0.2
C.V. (%)				6.0	7.2
S.E.				0.808	0.085

DAE = Days after rice and weed emergance except for herbicides marked (*).
fb = followed by

m^{-2} before tillage to 200 plants m^{-2} at final harrowing. None of the tillage methods had an effect on the required frequency of hand weeding. Each required two hand weedings to raise yields above 2.0 t ha^{-1}.

Best results were obtained for the herbicide oxidiazon. A first application oxadiazon followed by picloram-2,4-D required only one hand weeding. When oxadiazon alone was used in combination with the tillage practices manual weeding labor was reduced by 50 percent. And the application of oxidiazon followed by picloram-2,4-D reduced manual weeding labor by 90 percent.

By applying oxadiazon alone, weed biomass was reduced by between 30 and 75 percent for the various tillage treatments. Oxadiazon used in combination with picloram-2,4-D reduced weed biomass by between 40 and 98 percent.

An integrated approach to control of *Euphorbia heterophylla* has proven to be the most effective way to control this prolific weed.

Grain yields were greatly influenced by tillage method and the herbicide treatment used. The third tillage treatment was by far superior. The combination of oxadiazon with each of the respective tillage methods increased grain yields 30, 40 and 70 percent, respectively. Using tillage practices in combination with both oxadiazon and picloram-2,4-D raised yields by 70, 80 and 100 percent, respectively.

Financial analyses showed that it was profitable to use oxadiazon in combination with the third tillage treatment. It was also economical to apply oxadizaon in combination with picloram-2,4-D for all three tillage practices, with the highest returns achieved when these were used in combination with the third tillage practice.

WEED POPULATIONS IN BUSH-FALLOW FARMING

Upland rice in West Africa is often cultivated in shifting cultivation cropping systems. As land shortages emerge and cultivation is intensified, farmers will have to move towards shorter bush- and grass-fallow rotations within which weed infestation generally increases. WARDA is developing improved weed control practices for farmers to use in intensified land use systems.

Work in 1988 examined the effects of tillage and weeding methods. WARDA scientists tested hand hoeing versus power tillage, each conducted at three frequencies before planting (1, 2 and 3 cultivations spaced three weeks apart). Also tested were two weeding methods (no weeding and hand weeding at three week intervals throughout the season).

A wide spectrum of weeds were found in the original plots. During the first two months after rice seeding, *Pennisetum polystachyon, E. heterophylla, Digitaria horizontalis, Setaria pallide-fusca* and *Celosia trigyna* dominated. Gradually *P. polystachyon* covered the plots from the rice booting stage to harvest. In the weeded plots, weeding removed all of the dominant species, but this created a favorable environment for short statured weeds. Thus, a second weeding was needed.

There was no significant difference between hand or power tillage, nor among the tillage frequencies with respect to weed flora, weed biomass at the time of harvest, or grain yield. Each of the tillage methods and frequencies required two hand weedings in order to obtain over 2 t ha^{-1} of grain. One weeding was insufficient and three weedings found to be unnecessary.

Upland rice farmers often employ a slash and burn technique to develop land used in their shifting cultivation practices.

Insects

DYNAMICS OF INSECT PESTS

The incidence of pest species and in particular their occurrence relative to crop phenology influence the magnitude of crop losses and thus their economic importance.

Information on insect pests in upland rice ecosystems of Côte d'Ivoire has been gathered during the past three years. Because of the dynamic nature of insect pests, important temporal and spatial variations have been identified. During 1988 the distribution and occurrence of key insect pests was closely monitored, the ecology of the major species studied, and their natural enemies (parasites and predators) identified.

WARDA scientists worked in two Côte d'Ivoire sites, Bouaké in the forest-savanna zone and Toumbokro in the forest zone. Plots were established using planting dates staggered at two week intervals and treatments were replicated four times. Insects were sampled using sweep nets beginning 30 days after sowing and at 10 day intervals thereafter until harvest. Rice stems were dissected at 40, 70 and 100 days after sowing and observations taken on deadheart symptoms.

As observed in previous years, insect pest pressures were higher in diversity and abundance at Toumbokro than at the Bouaké site. Only stalk-eyed flies (*Diopsis* spp.) and lepidopterous stem borers were consistently present in the Bouaké trial while other pests occurred only erratically at that site.

At Bouaké, two major insect population peaks occurred at 40 and 60 days after sowing, irrespective of sowing date. Peaks were most pronounced for *D. apicalis*. There was a gradual and steady increase in the incidence of deadhearts with the age of the crop, but stem borer attack was low in all planting dates. The stem borers identified through dissections included the following distribution: *Maliarpha separatella* (59 percent), *Sesamia calamistis* (28 percent) and *Chilo zacconius* (13 percent).

At Toumbokro, there was only one population peak which occurred at 50 days after sowing. Stem borer infestation was low at that site with *Maliarpha separatella* making up 83 percent of the species collected. The leaf-feeding ladybird beetles (*Chnootriba similis*) and *Nephotettix* spp. occurred in large populations. These were present at the early vegetative stage and their population level was influenced by planting date.

Predators of rice insect pests identified in the study included spiders, praying mantis, dragon flies and assassin bugs. Among these, however, only the spiders appear to

Spiders may play a significant role in controlling rice pest populations in West Africa.

have a potential role in the management of pest populations. Because they co-exist with the pests, unlike other predators, migration out of the crop is very limited. They occurred throughout the growing season with their population levels peaking at the vegetative stage of plant growth, which coincides with the period of greatest diversity of pest species.

Parasites of rice stem borers were also collected. At Toumbokro parasitized larvae occurred as the crop developed towards maturity. This was the general trend observed in previous years as well. Parasitization in the Bouaké site began as early as 70 days after sowing, with the following parasitoides identified:

- *Apanteles sesamia* (*Braconidae*),
- *Rhaconotus concolor*,
- *Bracon* sp.,
- 4 species of *Ichneumonidae*,
- *Doryctes* sp. (*Braconidae*), and
- 1 species of *Tachinidae*.

VARIETAL EVALUATION FOR INSECT RESISTANCE

Screening for varietal resistance to insect pests has been carried out for some time by a number of research organizations working in West Africa. Several varieties have been reported as resistant to various insects. However, the exercise has stopped usually at the screening level. Because of the variable conditions under which varieties are screened, it is necessary to consolidate the available information to establish a better base for the development of new and improved resistant varieties.

To work toward this goal, a mass screening program was established in 1988 following an agreement between IITA and WARDA. Facilities located at IITA were used to screen for stalk-eyed flies (*Diopsis longicornis*) and the pink borer (*Sesamia calamistis*).

Stalk-Eyed Flies

A set of 163 rainfed lowland selections from IITA's advanced yield trials, preliminary yield trials, and observational nursery were screened in the stalk-eyed fly program. They were grown in screenhouses on one row plots consisting of 10 hills per entry. A large population of insects were released in the screenhouse, and observations on deadhearts were made 45 days after transplanting.

WARDA researchers also began working with a second set of elite varieties and lines from the IITA rice program that had already passed through several screenings and were ready for advancement. The 28 varieties and lines were sown inside the IITA screenhouse containing a high insect population in one row plots containing 10 hills per entry. This trial was replicated four times. Deadheart counts were taken at 45 and 65 days after transplanting. These entries were allowed to mature in order to determine tolerance.

In the first mass screening, the level of infestation ranged from 20-75 percent. Fifty-nine entries were more susceptible than the susceptible check variety, Suakoko 8. Only one entry, TOX 3052-46-E2-4-5, could be classified as highly tolerant. Because resistance to insect pests is very rare, it was not surprising that so few of the entries showed an acceptable level of resistance. Six additional lines showing some resistance were chosen for more intensive evaluation.

Among the 28 elite lines tested, the rate of attack by the stalk-eyed fly at 45 and 65 days after transplanting ranged from 33-54 percent and 26-62 percent, respectively. Five lines showed some resistance: A 21387-2, A 21403-2, TOX 3102-27, A 21389-2 and H 1042.

The stalk-eyed fly attacks the crop in the field usually at the early vegetative stage. Some lines react by producing compensatory tillers, a trait which is genetically determined, and which may contribute to increased grain yield under insect pressure. The number of productive tillers was also measured, and five lines showed considerable promise: TOX 3102-27, A 21387-2, A 21403-2, A 21358-3 and A 21367-1.

Pink Borers

WARDA entomologists also screened 30 plant varieties for resistance to pink borers in the IITA upland rice screenhouse. A susceptible variety, OS 6, was grown around the perimeter of test varieties and at 45 days after sowing they were infested with pink stem borer eggs at the blackhead stage. Supplementary infestations were made later. Test materials were planted inside the screenhouse in order to synchronize the appearance of adult moths with the test materials reaching 40-45 days of age. Upland varieties were planted in single rows consisting of 10 hills each and replicated three times. Observations were made on the number of deadhearts that appeared. In addition, five hills per variety were infested with egg masses containing 50 eggs and the stems from these were dissected 21 days later to recover the larvae.

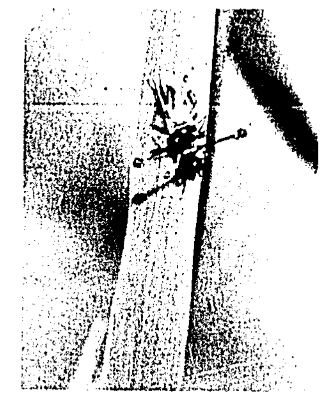
Percentage deadhearts ranged from 4-43 percent. This was lower than expected and suggests there may have been problems of escape which need to be reduced through further improvement in screening techniques. Four varieties, TOS 8980, TOS 9769, OB 677 and W 1263, had deadheart percentages of less than 10 percent. Considering tillering ability and the number of productive tillers 120 days after sowing, TOG 6632, TOG 6343 and TOG 6486 also appear promising. Percentage larval recovery ranged from a low of 28 percent for TOS 8883 to a high of 58 percent.

These studies will be continued using modified controlled conditions as well as in field tests in order to reappraise the 1988 results.

YIELD LOSS FROM INSECT DAMAGE

Several insect species are associated with rice, but within a particular location only a few may be regarded as major pests. Since grain yield is the ultimate measure of crop performance, it is important to determine to what extent insect damage reduces production.

WARDA scientists have conducted trials on upland rice in Côte d'Ivoire for the past three years to measure the economic importance



The stalk-eyed fly usually attacks the rice plant during the early vegetative stage of growth.

Table 9. Effects of stem borer damage following insecticidal applications of fenitrothion at different periods of crop growth, Toumbokro, Cote d'Ivoire, 1988.

Fenitrothion* treatment	Leaf damage** 45 DAS	Deadhearts 70 DAS	Bored stems		Borers/ 5 hills	Yield (t ha^{-1})	%Yield loss
			100 DAS	At maturity			
A	0.5	3.0	15.9	23.3	8.0	1.62	0.0
B	2.5	1.6	12.6	7.0	1.0	1.47	9.6
C	1.5	2.7	27.9	17.3	7.0	1.20	26.3
D	2.7	2.5	14.8	21.1	7.0	1.56	4.0
E	5.2	3.4	9.6	13.0	4.0	1.38	15.2
F	5.8	2.1	13.2	18.6	5.0	1.34	17.2
G	7.0	5.2	16.8	6.4	3.0	0.94	42.2
C.V. (%)		32.4	54.8	57.1	59.0	27.6	
S.E.		.48	4.35	4.36	1.44	.187	

* A = Applications at 25, 45 and 65 DAS
B = Applications at 35, 55 and 75 DAS
C = Applications at 25 and 45 DAS
D = Applications at 35 and 55 DAS
E = Applications at 45 and 65 DAS
F = Applications at 55 and 75 DAS
G = Untreated check

** Leaf damage by *Chnootriba* and *Chaetocnema* with 0-9 rating.; DAS = Days after sowing.

of several insect pests and to determine the most critical stage of growth for plant protection. A summary trial was conducted at Bouaké in 1988 to confirm earlier results.

WABC 165 was planted into plots and treated with insecticidal applications of Fenitrothion 60 EC at the rate of one liter ha^{-1}. Six different treatment schedules were used to protect the crop at different stages of growth. Observations were made on leaf damage at 45 days after sowing, deadhearts at 70 days after sowing, bored stems at 100 days after sowing, and the number of borer larvae during dissection.

Plots that were sprayed as early as 25 days after sowing had less damage by leaf feeding insects such as ladybird beetles and flea beetles. Application of insecticide significantly increased yield, with the time of application determining the magnitude of the increase. Plots sprayed at 25, 35 and 45 days after sowing had the highest grain yields, surpassing the untreated check by a maximum of 42 percent. This indicates that insecticidal applications for protection against defoliators during early growth stages are necessary for maximum yields. Later application, though increasing yields, gave less advantage.

There was no correlation between bored stems, measured either at 100 DAS or at maturity, and grain yield. Thus, the larger part of the yield reduction was attributable to early infestations by defoliators rather than the lepidopterous stem borers.

Varietal Development

Rice varietal improvement activities in 1988 included germplasm evaluation, evaluation of introduced varieties, varietal development through hybridization and selection, multilocational testing, and the production and supply of breeder seed to national agricultural research programs.

Crosses

A well focused crossing program is essential to any rice improvement effort. The rice breeder must clearly understand the traits and priorities that are most crucial at this stage in order to develop the varieties best suited for the farm. Ninety crosses were made in 1988. The parents used in the crosses came from 28 varieties and only single crosses were made.

F_1 Plants

Within six weeks of harvest, F_1 seed were germinated in petri dishes, planted into pots and then transplanted into beds in the screenhouse. Optimum conditions were maintained to produce maximum tillering. Plants were further ratooned to increase seed production. Forty-six crosses were retained and data was collected on new parents and the F_1s retained for advancement.

F_2 Plants

The F_2 generation is the most critical in rice breeding because many traits are fixed during this generation. In Bouake, 33 crosses were grown under upland conditions and selections were made for superior progeny. Eight of the tested crosses were advanced to F_3 pedigree lines.

Many of the traditional upland varieties grown in West Africa are tall, susceptible to lodging but easy to harvest.

F_3 Pedigree Lines

A pedigree nursery is where promising varieties are first assessed with any certainty. A total of 4601 F_3 upland rice pedigree lines were tested from 93 different crosses. Plant and bulk selections were made. From these, 59 crosses were discarded. ITA 257 was observed to combine well with most of the traditional upland rice varieties utilized and produced good early maturing progeny.

A total of 484 plants were selected for advancement and 41 lines were bulked for their superiority and homogeneity.

F_4 Upland Pedigree Lines

From 18 individual crosses 3662 pedigree lines were planted. Selections were made from only three crosses that produced distinctly superior progeny. Again ITA 257 showed superior combining ability. There were 567 plants selected for advancement and 66 superior lines were bulked for further observation.

F_4 Hydromorphic Pedigree Lines

Two hundred forty-two F_4 pedigree lines from eight crosses were grown under hydromorphic conditions in 1988. Out of these lines, 82 superior plants were selected from three crosses and only one line was bulked.

F_4 Upland Bulk Lines

One hundred forty-one F_4 bulk progenies from 10 crosses were planted under upland conditions. Selections were made on the basis of uniformity, yield potential, plant type, grain type, adaptability and disease resistance. Thirteen lines were selected from two crosses with ITA 257 for further evaluation.

F4 Hydromorphic Bulk Lines

Nine entries were selected from two crosses in the hydromorphic F_4 bulk line trials. A total of 141 lines from 10 crosses were evaluated.

Variety Trial

An exploratory trial was conducted at Bouaké to determine the performance of selected upland varieties in hydromorphic soil conditions where the water table ranged from 35 to 85 cm from the soil surface. An NPK fertilizer at 65:36:36 kg ha^{-1} was applied uniformly. IR 5931-110-1 produced the highest yield (2.24 t ha^{-1}) followed closely by Bouaké 189 (2.20 t ha^{-1}) and B 3623 (2.14 t ha^{-1}). In comparison, two varieties identified earlier as promising, IDSA 6 and WABC 165, yielded only 1.30 t ha^{-1} and 0.79 t ha^{-1}, respectively.

Parental Selection

Twenty-three varieties were selected for later use in the hybridization program during 1989. The selections were made from germplasm, popular traditional varieties, improved varieties, trial plots and from the International Rice Testing Program (IRTP).

INTERNATIONAL COLLABORATION

WARDA took part in the advanced variety trials, observational nursery trials and preliminary screening trials of IRTP-Africa during 1988. Entries in these tests come from introductions from various parts of the world as well as from WARDA's own upland materials.

Advanced Variety Trials

Fourteen upland varieties were tested but none showed superior yield performance compared to previously identified varieties.

Observational Trials

Among 100 entries tested, nine were retained for preliminary yield trials in 1989. These included ITA 118, ITA 130, ITA 162, ITA 183, ITA 187, ITA 225, TOX 1012-12-28, TOX 1857-3-2-201-1 and TOX 936-81-3-3-101.

Preliminary Screening Trials

Among 150 entries tested in the IRTP trials, eight were judged promising enough for advancement based on their plant type and reaction to diseases. These were IRAT 209, IRAT 222, IRAT 240, IRAT 288, IRAT 291, TOX 1879-8-101-1 and TOX 1889-8-14-1-2.

COLLABORATION WITH NARS

In 1988 a collaborative breeding program that aimed at developing improved upland varieties well adapted to specific West African environments was begun with plant breeders in Nigeria, Côte d'Ivoire, Sierra Leone, Liberia and Senegal.

One set of 141 F_6 elite lines was sent to Senegal for in place selection by national breeders in the Casamance. One set each of 500 F_5 pedigree lines from 31 crosses were sent to Côte d'Ivoire, Liberia, and Sierra Leone, and two sets of these lines were sent to Nigeria.

Breeders from these respective programs also visited WARDA's varietal improvement trials in Bouaké, Man and Odienne in August, 1988. This provided a valuable opportunity for WARDA and national program breeders to jointly evaluate the breeding materials and to exchange notes, ideas and experiences.

DEVELOPMENT OF DROUGHT SCREENING METHODS

Testing for drought tolerance in the field is not only time consuming, but tests often yield unreliable information. It is known that a deep and intensive root system is a major contributing factor for upland adaptability and drought tolerance. Consequently, WARDA scientists have begun to develop a method of screening for root depth whereby shoot characteristics could be correlated to rooting behavior. Once

Drought is always a threat to rice production in the West African region.

developed and verified, this procedure could greatly facilitate screening for drought tolerance.

Twenty-four varieties were used in the 1988 experiment. Each variety was grown in a black plastic tube 110 cm long and 21 cm diameter which was buried in the soil. Varieties were replicated three times. Following the tillering stage, only one plant was retained in each tube. At the emergence of the main panicles, tubes were removed from the soil, cut open and the root numbers counted and related measurements taken.

Root Length and Number

Root lengths were greater than expected. Moroberekan had the longest roots, averaging 123 cm in length. ROK 61 and IR 5931-110-1 had 117 cm roots and IDSA 6 produced roots 116 cm in length. A positive correlation was observed between root length and the number of roots at 50, 75 and 100 cm depths.

ROK 16 had the largest number of roots (22) at 50 cm depth, followed by Moroberekan (18) and LAC 23 (16).

ROK 16 had the highest number (15) at 75 cm depth, followed by IR 10068-11-1, Moroberekan, IR 5931-110-1, IDSA 6, WABIS 675 and LAC 23.

At a depth of 100 cm WAB 1-217, IDSA 6, and IR 10068-11-1 had the highest numbers of roots in that order.

Culm Diameter

Culm diameter was measured at 20 cm from the soil surface and three culms were measured for each entry. Moroberekan had the thickest culm (7.7 mm) which was significantly greater than the other entries. It was also observed that culm diameter is positively correlated with maximum root length, number of roots, and root intensity at different depths. Because each of these characteristics is directly related to drought tolerance, culm diameter appears to be the most important single character for assessing rooting behavior.

On-Farm Research

Some of WARDA's research directions have continued over an extended number of years, and 1988 served to conclude some of these efforts. One of the most important of these has been the Technology Assessment and Transfer program (TAT) which began in 1983 and which has since expanded to involve farmers from four countries. Although future WARDA programs will include on-farm research as an integral component, the purposes and methods will be modified to improve feedback to our station-based activities.

TECHNOLOGY ASSESSMENT AND TRANSFER

On-farm evaluation of improved varieties began in Côte d'Ivoire in 1984, and has subsequently expanded to cover Ghana, Liberia and Sierra Leone. In this program new upland rice varieties were assessed and farmers' acceptability of each variety was measured. During 1988, 56 on-farm trials of

WARDA's on-farm trials for improved upland rice varieties have been going on in Cote d'Ivoire since 1983.

both short and medium duration varieties were conducted in the four major agro-climatic zones of Côte d'Ivoire. In each trial three varieties were compared to a widely used check. Ten similar trials of two short duration and three medium duration varieties were conducted in Liberia, 15 trials in Sierra Leone and 20 in Ghana.

At each site varieties were tested for grain yield performance with and without application of fertilizers. The fertilized plots all received the dosages recommended in their respective countries.

In addition to these field tests, participating farmers were asked to give their opinions of each test variety and to indicate how they planned to dispose of the harvested seed. It was felt that the amount saved for seed would give a good indication as to how highly the farmers rated the variety.

Cote d'Ivoire

Among the short duration varieties tested in Côte d'Ivoire, IRAT 144 has been evaluated for three consecutive years; and IDSA 10 and WABC 165 for two years. The yield performance of these varieties in 1988 was similar to earlier test results, averaging 2.0 t ha^{-1} with or without fertilizer in all parts of the country, but did not exceed the check variety, IAC 164. Moreover, farmers did not indicate greater preference for one variety over another. In order to maintain a wide choice of short duration varieties, these varieties will continue to be tested as the search for superior varieties continues.

Among the medium duration varieties, IDSA 6 has been evaluated for four years, WABZI for two years, and WABIS 675 for one year. During 1988, IDSA 6 significantly out yielded both the check variety, Iguape Catete, and all other varieties tested at the Bongouanou and Gagnoa sites. At the other sites, no variety showed yield superiority with or without fertilization. Despite its high yield potential, farmers expressed strong reservations about adopting IDSA 6 because of their dislike for its short stature.

Liberia

Each of the short duration varieties tested in the Liberia TAT trials was in its second year of tests. Yields were poor in the 1988 tests, averaging below 1.0 t ha^{-1}. This was partly due to the fact that the short duration varieties tested, IAC 164 and WABC 165, matured 20 to 30 days earlier than farmers' traditional varieties and as a result suffered substantial bird and rodent damage before harvest. Due to the large field losses, these varieties did not perform significantly better than the local checks, either with or without fertilizer. Farmers were nonetheless impressed with the early maturity of both varieties because the earliest maturing variety presently grown in Liberia is LAC 23 (130-140 days).

WABZI, WABIS 675 and IDSA 6 were the medium duration varieties tested. IDSA 6 significantly out yielded all other varieties with or without fertilization and had an 80 percent yield response to the use of fertilizer. As observed elsewhere, however, Liberian farmers complained about the short stature and related harvesting problems associated with IDSA 6.

Sierra Leone

The same varieties were tested in Sierra Leone as in Liberia. Yields here were similar to those in Liberia and fertilizer response was low as well. Yields of short duration varieties varied from 1.2-1.4 t ha^{-1}, and for medium duration varieties between 0.9-1.2 t ha^{-1}.

Despite the low yields, farmers in Sierra Leone remarked that the short duration varieties reduced the number of weedings necessary from two to one. This has greatly increased farmers' interest in both IAC 164 and WABC 165. In Bo-Pujehun District, the farmers were so impressed with these two varieties that they initiated dry season multiplication in order to increase the number of trials for 1989 from 10 to 30.

Ghana

In Ghana, testing the same varieties as in Sierra Leone and Liberia, yields ranged from 1.4-2.7 t ha^{-1}. The test varieties out yielded the checks in every trial with or without fertilizer.

CROPPING SYSTEMS IN COTE d'IVOIRE

Rice in West Africa is often grown in relay cropping or in mixture with other crops. In 1988 an initial characterization of the major rice cropping systems was undertaken. The study was conducted in two broad zones of Côte d'Ivoire through farm visits and discussions with farmers during the cropping season.

In the forest zone, it was observed that mixed cropping is the most common system in both the monomodal rainfall and bimodal rainfall areas. Rice is usually grown intercropped with other crops such as maize, cassava, banana, or vegetables. Mixed cropping is practiced more in the plateau portion of the continuum than on hydromorphic land types, and not at all in the swamp areas. Mixed cropping is limited in the hydromorphic zone to the upslope margins. There was no apparent mixing of cash crops. Coffee and cocoa are grown as single crops on the plateau and middle slopes. Sometimes cocoa is grown in association with plantain or banana in the hydromorphic areas where flooding does not occur. And during the early planting and pruning of coffee and cocoa trees, rice is often grown in association with the young shoots.

Crop rotation and mixed cropping were practiced equally in the savanna zone. Crop rotation is very common in the upland areas but less so in the hydromorphic areas. The following were the most common rotations in the upland ecosystem:

- cotton - cereals (rice, maize and sorghum)
- cotton - cereals - groundnut
- groundnut - cereals.

In hydromorphic areas, rice followed by vegetables was the most common rotation.

A practice commonly observed in the savanna zone is rice as a base crop in a range of mixtures. There are also crop combinations that do not involve rice, such as cassava + yam and yam + maize. The most commonly grown rice types in the upland/hydromorphic area are short to medium duration varieties, whereas in the swamps, medium to long duration varieties are more common.

Following description of the major cropping systems, the survey data already collected will be analyzed further with the goal of defining more appropriate research objectives aimed at the development of improved varieties and resource management practices that fit into such local systems.

Mangrove Swamp

Introduction

The mangrove swamps of West Africa create a unique rice production environment, with a set of biological and soil related constraints quite different from those present in inland swamps and Sahel systems. An interdisciplinary team of WARDA scientists have characterized, in a preliminary set of studies, this environment and are working toward the development of improved technologies well adapted to farmers' needs. Past work has

Crabs are one of the most damaging pests of rice grown in the mangrove swamps of West Africa.

already achieved notable success, particularly in the development of cultivars well adapted to mangrove swamp conditions.

Work in 1988 continued these efforts in several areas. Varietal improvement research aimed at developing a new generation of high yielding varieties tolerant to acid sulphate and saline conditions and tolerant to crabs and stem borer. Crop and resource management research continues to investigate new practices to ameliorate these soil conditions, and to manage the pest and pathogen complex to minimize damage to the rice plant.

Improving Mangrove Swamp Soils

EVALUATING ALTERNATIVE PHOSPHORUS SOURCES

Phosphorus is a major limiting nutrient for rice grown on areas of limited flooding in mangrove swamps. Much of the response to phosphorus has been attributed to immobilization by iron and aluminum, particularly at early growth stages. Although regular applications of phosphorus in the form of superphosphate have been recommended to improve these soil conditions, the continued use of superphosphate is prohibitively expensive for most mangrove rice farmers.

WARDA scientists have been working to identify phosphorus fertilizers which give high first year response and good residual effectiveness for use in P deficient mangrove swamp soils. As alternative sources with low soluble phosphorus, rock phosphate fertilizers are less susceptible to P fixation and could have higher residual effectiveness than soluble phosphate fertilizers on highly weathered soils in mangrove swamps.

In 1988 a randomized complete block trial with three replications was conducted using two phosphate rock materials obtained from Senegal, Matam and Taiba rock phosphate. These were compared to single superphosphate applications at the 40, 80 and 120 kg

P_2O_5 ha^{-1} regimes. The treatments included a control without phosphorus and 80 kg N ha^{-1} applied as urea in two applications; one at two weeks after transplanting and a second four weeks later. Four week old ROK 5 rice seedlings were transplanted at a spacing of 20 x 20 cm. These treatments had been used for the same plots for the previous two years.

Phosphate rock fertilizers have performed inconsistently over the past three seasons, with earlier results showing that single superphosphate was more effective in increasing rice grain yields on P deficient soils. However, results in 1988 indicated that both rock phosphate sources were equally effective as superphosphate.

Moreover, while past results have shown that intensive use of phosphorus in excess of 40 kg P_2O_5 has not significantly improved rice yields, 1988 results showed that dose increments as high as 120 kg P_2O_5 ha^{-1} continued to give significant yield response. Response at these levels may reflect more intense soil leaching under high rainfall (2860 mm) experienced at Rokupr in 1988 relative to 1986 (2090) and 1987 (2380).

Further research is now required to evaluate the partially acidulated rock phosphate fertilizers in relation to more soluble P sources and the effect of incorporating crop residues on availability of phosphorus from different phosphate materials. Financial analyses will also be conducted to determine profit maximizing rates of application.

IMPROVING NURSERY FERTILITY AND MANAGEMENT

Seedling vigor is an important determinant in the survival of rice transplanted into mangrove swamps. Seedlings of low vigor are susceptible to destruction by crabs and tidal wash. Mangrove swamp rice farmers traditionally respond to the need for sturdy seedlings by growing them in nurseries for 10-12 weeks and transplanting 15 or more seedlings per stand. While assuring stand establishment, the yield potential of the crop is also reduced. The practice also requires high seeding rates, usually 100 kg ha^{-1} or more.

WARDA scientists in Rokupr established an experiment to test the effects of seedbed preparation method, seeding method, and nursery site fertility on seedling vigor. The nursery fertility regime consisted of: unfertilized plots; application of 25 g m^{-2} of 15:15:15 fertilizer at sowing; and 500 g m^{-2} of rice husk (including bran) applied two weeks prior to sowing. Nursery tillage practices included: plowing and harrowing or construction of raised beds. Seeds were broadcast or drilled in rows 15 cm apart. Treatments were placed in a randomized complete block design with four replications on both upland (freely drained) and hydromorphic sites. In all treatments seedlings were allowed to grow for six weeks. Plants were sampled weekly starting at two weeks after sowing to determine height, stem thickness and dry matter production.

Table 10. Yield response (t ha^{-1}) of ROK 5 to superphosphate and rock phosphate materials in acid sulphate soils, Rokupr, Sierra Leone, 1988.

Phosphorus fertilizers	P_2O_5 applied (kg ha^{-1}) 40	80	120	S.E.	Mean
Taiba rock phosphate	1.94	2.24	2.24		2.14
Matam rock phosphate	1.99	1.99	2.71		2.23
Single superphosphate	2.25	2.58	2.85		2.56
Mean	2.06	2.27	2.60	.134	
Control without P		1.69			
C.V. (%)		17.7			
S.E.		.231			.134

At the end of six weeks, seedlings from each nursery were transplanted into the tidal mangrove swamp in a split plot design with three replications. No fertilizer was applied to the transplants.

Chemical fertilizer applications consistently improved seedling vigor and growth compared to both unfertilized and rice husk treatments.

Seedling growth was generally higher in nursery stock raised on the hydromorphic site. On the other hand, seedlings in upland nurseries were more responsive to cultural practices. Sowing on raised beds gave higher vegetative growth on both upland and hydromorphic nurseries. This may be the result of better rooting and nutrient uptake. Broadcasted seed also produced better sized seedlings in comparison to drilled seed. This result is believed to be due to the more even spacing of broadcast seed, which reduced seedling competition, as compared to the clustering of seedlings typical of line drilling.

Poor nursery management on the part of mangrove swamp rice farmers leads to situations like this.

The source of seedlings (nursery sites) had little effect on the growth and yield of rice. However, raising seedlings on beds, and either fertilization or manuring of nurseries (fertilization being superior) did significantly improve grain yields of the mature rice plants.

Managing Mangrove Swamp Pests

The mangrove swamp environment supports a unique combination of pests which reduce rice grain yields. Principal among these are the rice stem borer and crabs. Either pest can drastically reduce yields, and in some cases completely destroy a crop.

RICE STEM BORER HABITS

Previous work has shown that yield losses due to the stem borer *Maliarpha separatella* frequently exceed 40 percent. When stem borers attack, they cause the crop to lodge more easily which makes the plant more susceptible to many rice diseases.

Information on the population dynamics of stem borer is essential to the development of efficient control measures. Previous research by WARDA, and collaborative work with the Overseas De.elopment Natural Resources Institute (ODNRI), has resulted in the development of a female sex pheromone that can be used to attract and monitor the habits of this insect. It has been shown that in Sierra Leone *Maliarpha* moths appear in a low peak in May at the beginning of the rainy season and reach their highest peak in November at the end of the season. The early peak coincides with the normal date of establishment of rice nurseries by most farmers. Thus, many rice farmers bring infested transplants to their fields when establishing their crop.

WARDA scientists set up experiments in 1988 to determine the level of crop infestation as related to date of nursery establishment and to the intensity of *Maliarpha* male moths at the nursery site. Starting June 1, six planting dates were used, each separated by two week intervals. On each sampling date, four random samples were taken and examined for eggs. After inspection for eggs, each rice stem was dissected and infestation of *Maliarpha* larvae was recorded. Levels of infestation were measured at 2, 4, 6 and 8 weeks after sowing in the nursery. Additionally, daily catches of the male *Maliarpha* moths were recorded throughout the trial period.

The male moth population in the nurseries was highest in mid-June and declined to zero by mid-August. Eggs of *Maliarpha* were found in the nurseries as early as two weeks after seeding. Although the incidence of *Maliarpha* larvae varied systematically with nursery planting date, differences among dates were not significant. However, there was a significant increase in the level of larval infestation the longer the seedlings stayed in the nursery.

It may be that the first brood of moths in the transplanted rice field originated from the nursery, however the current year's results are inconclusive. Further work is now required to establish with more precision the occurrence of infestation in the nursery to more accurately determine the appropriate time for uprooting seedlings in order to minimize *Maliarpha* carryover into the transplanted rice crop.

CULTURAL PRACTICES FOR STEM BORER CONTROL

WARDA-Rokupr scientists established trials in the associated mangrove swamp, using long and short duration varieties to assess the effects of planting date, fertilizer application, and crop density on stem borer infestation. Two fertilizer rates, three dates of transplanting and three crop densities were used. The level of infestation was determined by randomly selecting 40 rice hills from each plot and dissecting the plants for estimation of stem borer infestation.

Irrespective of varietal duration, the July and August transplanted crops were significantly less infested with stem borers (7 and 11 percent, respectively) than the crop transplanted in September (20 percent). Infestation was more than double for long duration varieties at all transplanting dates. Average grain yield losses due to stem borers was 30 percent for ROK 10, the long duration variety, compared to 9 percent for the short duration variety, ROK 5.

Fertilization significantly increased stem borer infestation in ROK 10, but less so in ROK 5.

Crop density did not have an effect on infestation levels for the short duration variety. However, in ROK 10 infestation was significantly lower at the highest density, 33 hills m^{-2}, compared to rice planted at 15 and 25 hills m^{-2}. Nevertheless, because grain yields were not significantly affected by plant density in either variety, these results suggest that low density transplanting may still be preferable to economize on rice seed.

Stem borers may inflict losses of up to 40 percent in rice grown in mangrove swamp areas.

CONTROL OF CRABS

The crab species *Sesarma huzardi* is the most prevalent and voracious species in mangrove swamp areas. These crabs live in burrows within the rice fields or along creeks and bunds where they feed on young rice seedlings and other plant debris.

To combat this pest, WARDA-Rokupr scientists studied the effects of two tillage practices (plowing alone and plowing followed by puddling) and four transplanting dates on minimizing crab damage to rice.

Table 11. Impact of date of transplanting on infestation by stem borers and rice grain yield, Rokupr, Sierra Leone, 1988.

Transplanting date	Stem infestation at harvest (%)		Grain yield loss (%)	
	ROK 5	ROK 10	ROK 5	ROK 10
Mid-July	2.2	11.3	---	---
Mid-August	6.1	15.1	0.0	27.9
Mid-September	12.2	28.6	17.1	31.7

Crab damage was evaluated at 4, 8 and 12 days after transplanting. Damage was assessed by counting the number of rice stems destroyed as a percentage of the total number of rice stems in a 1 meter x 1 meter quadrant.

WARDA scientists observed that where no weeds were present, tillage practice had no significant effect on infestation. However, at the site where a dense mat of salt tolerant *Paspalum vaginatum* weeds were present providing potential hiding places for crabs, crab infestation was significantly lower in plots that were plowed and puddled. Crab infestation levels at the dense weed site decreased with the delay in transplanting. At the site with no weeds, crab infestation remained generally high at all test dates.

WARDA-Rokupr scientists have found that mid-August is the best transplanting date for rice in order to escape major crab damage such as this.

These patterns may reflect habitat preference by crabs in tidal swamps as the season progresses. At the tidal mangrove site with no weed infestation, crab populations seemed to increase with time and nearly the entire trial crop was devastated by the end of the season. This suggests that the weed situation must be considered for effective control of crabs through cultural practices. Future research will focus on the manipulation of other cultural practices alone and in combination to check their suppressive effects on crab infestation.

SCREENING FOR CRAB TOLERANCE

Another means of fighting crab damage is by introducing varieties with resistance to crabs. Preliminary studies have indicated that the majority of mangrove swamp rices are susceptible to tidal swamp crabs. In earlier screening work, WARDA scientists found that out of more than 500 varieties tested only two percent, were highly tolerant. WARDA researchers also learned that the degree of heritability for tolerance was moderate (h^2_b = 61 percent) giving some hope for improving tolerance through breeding.

To continue this study in 1988, WARDA-Rokupr scientists tested 104 rice varieties from the breeding program at two sites under two levels of crab intensity. At each site 42 day old transplants were used with a spacing of 20 x 15 cm. The advanced line, WAR 72-2-1-1, was used as the resistant check. No fertilizers were applied in the nursery or the field. Crab damage was recorded at 4, 8, 12 and 16 days after transplanting.

Only six varieties, WAR 77-3-2-2, Raden Jawa, RD 15, RADEN MAS, Rohyb 1 and ROK 10, survived the crab attack at the high intensity site. The rest were completely destroyed by the middle of the season. If confirmed in subsequent trials these resistant varieties will be used as parents in WARDA's mangrove swamp hybridization program.

Management of Soil Salinity, Soil Acidity and Weed Levels

Depending on their distance from the ocean, mangrove swamps experience varying intensities of salinity, acidity and weed infestation. All of these factors contribute to current low levels of productivity in this rice growing environment. Recent periods of low rainfall have further increased soil salinity and acidity problems by reducing the volume and duration of fresh water flooding. Under these conditions soil toxicities, especially for iron and aluminum increase. Phosphorus also becomes more deficient. These constraints, coupled with ineffective weed control, necessitate the development of new management techniques to improve rice productivity in this environment.

AMELIORATION OF ACID SULPHATE SOIL CONDITIONS

Acid sulphate conditions are prevalent on soils in mangrove swamps that are subject to seasonal drying and aeration. Trials conducted over the last three cropping seasons have shown that incorporation of 5 to 10 tons ha^{-1} of rice husks (plus bran) helped to overcome these nutritional disorders. Incorporation of organic matter in acid soil reduces aluminum activity through the formation of complexes, creating a more suitable medium for crop growth. The high silica and potassium content of rice husk and straw also serve to increase oxidizing power of rice roots and minimize uptake of iron.

The trial was continued in 1988 using rice husk and straw to verify earlier findings and to determine the nature of interactions with chemical nitrogen and phosphorus. Applications of both crop residues were tested in combination with two fertilizer treatments, 60 kg N ha^{-1} and 60 kg N ha^{-1} plus 40 kg P_2O_5 ha^{-1}.

Incorporation of five tons of rice husk or straw resulted in grain yields of 3.2 t ha^{-1} and 3.1 t ha^{-1}., respectively, compared to yields of 2.7 t ha^{-1} without the application of

Use of rice husks as a soil amendment helps create a more favorable growing environment for rice in acid sulphate soils.

residues. The combined application of nitrogen with rice husks out yielded the corresponding nitrogen treatment with straw by 400 kg ha^{-1}. However, with the addition of phosphorus rice straw was equally as effective as using rice husks which suggests that rice husk application may be more beneficial and desirable as a soil amendment in conditions where phosphorus is limiting. Because of abnormally high flooding that partially alleviated acidity at the trial site in 1988, this experiment will be repeated under more intensive acid sulphate conditions, and to determine the residual effectiveness of these measures in sustaining productivity over time.

Table 12. Mean rice yield response (t ha^{-1}) from application of crop residues under different fertility regimes in acid sulphate soils, Rokupr, Sierra Leone, 1988.

Soil fertility treatments	Soil Amendments			S.E.	Mean
	Untreated	Rice husk 5 t ha^{-1}	Rice straw 5 t ha^{-1}		
Without N or P	2.17	2.76	2.80		2.58
60 kg N ha^{-1}	2.95	3.51	3.14		3.20
60 kg N ha^{-1} + 40 kg P_2O_5 ha^{-1}	3.10	3.33	3.34		3.25
Mean	2.74	3.20	3.09	.056	
C.V. (%)		9.1			
S.E.		.097			.056

Table 13. Effect of plant spacing on weed growth and grain yield of ROK 5 in a non-tidal mangrove swamp, Rokupr, Sierra Leone, 1988.

Distance of planting (cm)	Dry weight ($g\ m^{-2}$) Weeded	Dry weight ($g\ m^{-2}$) Unweeded	S.E.	Grain yield ($t\ ha^{-1}$) Weeded	Grain yield ($t\ ha^{-1}$) Unweeded	S.E	%Reduction
20 x 15	7.1	31.2		1.83	1.44		21.6
20 x 20	7.4	21.0		2.01	1.87		6.9
25 x 25	7.9	34.7		1.67	1.41		15.8
30 x 30	11.2	42.9		1.91	1.32		31.0
Mean	8.4	32.5	2.03	151		.094	
S.E.	4.06			.188			

C.V. (%) 39.0% for dry weight; and 22.3 for grain yield.

CROP DENSITY AND WEED GROWTH

Weeds severely limit rice production in associated mangrove swamps. Previous research at Rokupr has shown that timely and thorough land preparation, followed by two hand weedings within 40 days after transplanting can suppress weed growth and increase rice yields substantially.

Use of closer crop spacing than traditionally practiced by farmers in West Africa helps to reduce the level of weed infestation in rice grown in mangrove swamps.

Experiments carried out in 1988 showed that by varying crop density, farmers can also influence weed infestation levels. Most farmers grow varieties with poor tillering ability and transplant at wide spacings, both factors favoring weed growth as well as reducing yield potential. WARDA scientists hypothesized that planting materials with high tillering ability at closer spacing would serve to suppress weed growth.

To test this scientists employed four crop densities (20 x 15 cm, 25 x 25 cm, 20 x 20 cm and 30 x 30 cm) to observe the effect on weed growth. Weeding treatments included hand weeding once at 30 days after transplanting and a treatment with no weed control. Uniform fertilizer treatments were applied to all plots. Treatments were replicated four times. Dry weed weight was taken at 50 days after transplanting. Plant height, tillers m^{-2}, and grain yield were noted at harvest.

Best results were obtained for the 20 x 20 cm crop density, both with respect to yields and weed suppression. Compared to the lowest crop density (30 x 30 cm) weed dry matter in the optimum density was reduced by 34 and 51 percent, respectively, under weeded and unweeded conditions.

This trial is being continued in 1989 to evaluate the density effect of other promising varieties. Results will be used to develop alternative integrated weed control packages.

HERBICIDE CONTROL

Herbicides are costly and not easily available to farmers in the mangrove swamp rice region. However, as rice production intensifies and more herbicides become available, it is necessary that practices are not only effective but safe to protect both the rice crop and the environment. Mangrove swamps are used not only for rice production, but also for drinking water, washing, bathing and fishing.

Several herbicides were screened in trials conducted at Rokupr in 1988. The herbicides

Table 14. Effects of herbicides on weed control and yield of ROK 5 in an associated mangrove swamp, Rokupr, Sierra Leone, 1988.

Treatment*	Application**		Weed weight	Yield
	Rate ($l\ ha^{-1}$)	Time (DAT)	($g\ m^{-2}$)	($t\ ha^{-1}$)
Tamariz	9.0	20 fb 1 hw at 35	1.9	3.01
Arozin D	2.5	10 fb 1 hw at 30	2.2	1.88
Ronstar 25 EC	3.0	6	24.1	2.93
Ronstar 25 EC	5.0	6	23.8	2.74
Basagran PL 2	8.0	20	30.6	2.58
Stam F34T	9.0	21	18.0	2.61
Stam F34T	9.0	21 fb 1 hw at 35	1.7	3.17
Stam 7221	13.0	21	20.6	2.73
Machete EC	3.3	10	28.7	2.67
Machete EC	3.3	10 fb 1 hw at 30	1.7	2.85
Handweeding	Twice	21 + 35	1.3	3.34
Untreated check	---	---	54.8	2.22
C.V.%			53.4	12.6
S.E.			4.65	.172

* All herbicides were liquid formulation; EC = emulsifiable concentrate.

** DAT = Days after transplanting; fb = Followed by; and 1 hw = One handweeding.

were applied at low concentrations to determine their weed control effectiveness.

All the herbicides tested controlled weeds significantly better than the untreated check. Use of Machete EC followed by one hand weeding at 30 days after transplanting; Tamariz; Arozin D; and Stam F34T followed by one hand weeding 30 days after transplanting provided as effective weed control as two hand weedings. Although Arozin D provided good weed control, it was very toxic to rice and reduced the number of tillers m^{-2} even more than the untreated check. The other herbicides tested were not toxic to rice.

The results indicate that herbicides could be effectively used for weed control and that they are not toxic to rice in most instances. However, one timely hand weeding may be necessary to prevent build-up of herbicide resistant weed species and to maximize rice yields. Further work is needed to develop optimum combinations of manual and chemical control practices.

Varietal Improvement

One of the major on-going activities carried out at WARDA-Rokupr is the varietal testing program. WARDA breeders' objectives are to improve the levels of genetic resistance to diseases and insects, tolerance for adverse soil conditions, and higher yield potential. Effort is concentrated on developing materials in three maturity ranges to fit areas with varying salt-free periods caused by seasonal tidal movements.

Improved varieties developed so far are only suited for cultivation in medium duration (160-170 days) areas. Suitable early maturing varieties (100 -120 days) with intermediate stature (90 - 125 cm) for cultivation in short season swamps are still lacking.

To identify more promising varieties, several observational yield trials (OYTS) and replicated yield trials (RYTS) were conducted. In each of the trials, seeds were sown in early June in upland nurseries and fertilized with 15:15:15 chemical fertilizer at the rate of 25 g m^{-2}. Six-week old seedlings were transplanted at 15 x 20 cm spacing with 2-3 seedlings/hill into plowed and puddled plots. At two weeks after transplanting, 60 kg N ha^{-1} was applied. At panicle initiation an additional 20 kg N ha^{-1} was applied. On the associated mangrove swamp sites, a basal application of 60 kg N ha^{-1} and 40 kg P_2O_5 ha^{-1} was given. Weeds were controlled by hand weeding at three and six weeks after transplanting. Weight and grain yield were recorded at harvest. Seedling vigor in the nursery, time to 50 percent flowering, time to maturity and plant height were also recorded for each entry.

Future varieties grown in Guniea-Bissau must allow for mechanical harvesting.

OBSERVATIONAL YIELD TRIALS

Three OYTS were conducted in 1988. One tested short duration varieties in the associated mangrove swamp and two others tested medium and long duration varieties in the tidal swamps. Results were encouraging and confirmed earlier indications of progress.

In the short duration trials eight Rokupr bred lines and 30 promising varieties were tested against IR 10781-143-2-3. The plots were located on low fertility soil with mild iron toxicity problems. Thirteen varieties, including all eight Rokupr bred varieties, outyielded the check. WAR 115-1-2-11-4 (4.47 t ha^{-1}), WAR 115-1-2-11-2, WAR 115-1-2-10-5 and IR 25912-63-2-2 were the top ranking materials with respect to yield performance. The latter three varieties were also among the top yielding varieties in the 1987 trials. The growth duration and plant height of the selected lines ranged from 120-135 days and 70-90 cm, respectively. These selections have considerable potential for use in tidal limits in short rainy season parts of Guinea-Bissau and Southern Senegal.

The medium duration trial tested 43 promising varieties and five Rokupr bred advanced lines. ROK 5 was used as the check variety. Only BW 295-5 (3.15 t ha^{-1}) and BW 293-2 (2.46 t ha^{-1}) out yielded the adjacent check plot. BW 295-5 has been the top yielder in this trial for the past two seasons. Both varieties are of intermediate stature (110 and 90 cm, respectively) and resist lodging.

The long duration trial had 18 varieties that out yielded the check, Kuatik Kundur (1.61 t ha^{-1}). The very low check variety yield may have been due to severe acid sulphate soil conditions affecting the site. Four of the varieties: BR 111-140-1-1, SPR 7419-1-2, BR 20-3B-17 and WAR 73-1-M4-2 out yielded the best Kuatik Kundur plot by margins of 37-107 percent.

REPLICATED YIELD TRIALS

In the short duration associated tidal swamp trials, seven varieties significantly out yielded the check variety. Three, WAR 115-1-2-10-5, IR 21855-53-2-1-2-2-1 and WAR 115-1-2-11-2, gave yields in excess of 4.0 t ha^{-1}.

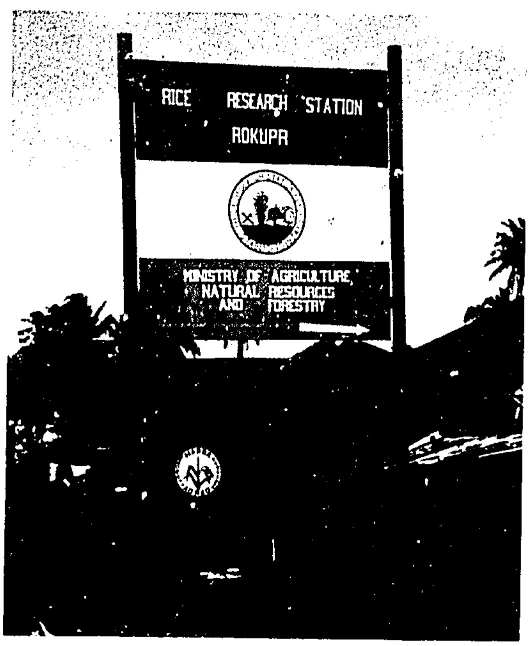
For the medium duration RYTS, 18 varieties were tested against ROK 5. Only WAR 1 significantly out yielded the check with 5.72 t ha^{-1}. However, each of the top seven varieties had yields over 5.0 t ha^{-1}.

The long duration RYTS performed poorly due to very poor soil conditions and crab attack. The check variety, Kuatik Kundur, gave average yields of 2.1 t ha^{-1}. Even at this level, only three varieties out yielded the check significantly.

Collaboration with NARS

WARDA-Rokupr has established a wide network of contacts and collaborators in the national programs to aid in its research efforts. In 1988, scientists from Sierra Leone, The Gambia, Guinea and Guinea-Bissau took part in these activities.

Previous studies have shown that new technologies developed at Rokupr have been adopted throughout the region, particularly in Sierra Leone, Guinea, Guinea-Bissau and The Gambia. In northwest Sierra Leone along the Great Scarcies River and in southwest Sierra Leone along the Bumpeh River, 53 percent of the farmers raising short duration varieties are now growing WARDA-Rokupr bred or introduced varieties. WAR 1, ROK 5 and Rohyb 6 are the most commonly adopted ones.



WARDA's collaboration with the national program in Sierra Leone has produced beneficial results for several countries within West Africa.

On-farm trials continued to be conducted during 1988 to test new technologies under realistic conditions, but which also helped to gain the confidence of farmers in the region and expose them to some newly improved rice varieties. WARDA-Rokupr staff also continued to help farmers in the region through the production and multiplication of seed to national programs.

Sierra Leone

In Sierra Leone, in collaboration with the Northwestern Integrated Agricultural Development Project (NWIADP) and the FAO Inland Valley Swamp Rice Development Project, 147 mangrove swamp rice farmers took part in on-farm trials. They evaluated the yield potential and quality of WARDA-bred varieties.

During crop growth and after harvest, questionnaires were administered to sample farmers in order to get their feedback.

In the southern area, results from 30 farmers showed that WARDA-Rokupr varieties yielded more than the traditional varieties in 57 percent of the cases. Fifty-two percent of the farmers rated the new varieties equally or better than the traditional varieties in terms of shattering, threshing, milling, keeping ability and taste. Many of the farmers sampled were already growing earlier WARDA-Rokupr released varieties. Thus, the average yield difference was only 20 kg ha^{-1} in favor of the WARDA rices.

In the northwestern area, 23 farmers were interviewed. Sixty percent of the farmers here rated the new WARDA-Rokupr varieties higher in terms of shattering, threshing, milling, keeping ability and taste. However, only 20 percent of those tested had yields higher than the traditional rice grown. Part of the reason for this was that the area had unprecedented floods in 1988 that devastated rice fields and caused severe damage to newly transplanted rice.

Also, WARDA continued its cooperative arrangement with the national Rice Research Station (RRS) in Rokupr. Occasional joint seminars were held and WARDA scientists took part in planning and research reviews of the Sierra Leone program. On the research side, WARDA and RRS continued their efforts at identifying controls for the Rice Yellow Mottle Virus (RYMV). Finally, WARDA scientists helped to set up exhibits and displays for the annual field day organized by RRS.

The Gambia

In The Gambia three sets of varieties (ROK 5, Rohyb 6 and Kuatik Kundur) were tested on-farm through the cooperation of the Ministry of Agriculture. Two zones were used. The first zone was along the south bank of the Gambia River and the second was on the north bank of the river.

Results from farms on the northern side indicated that average yields were 3.13 t/ha^{-1} for Rohyb 6; 3.01 for Kuatik Kundur; and 2.71 t ha^{-1} for ROK 5. Locally grown rice averaged 2.61 t ha^{-1}.

Farmers preferred Rohyb 6 and Kuatik Kundur to ROK 5 because of their lateness in maturity and thus they fit more comfortably into their normal farming patterns. The earlier maturing ROK 5 was damaged by birds and bird scaring is not normally practiced by farmers in this area.

On the southern bank, yields for all varieties were low at all three sites because of high acid sulphate soil problems and extensive fish damage to new transplants at one site. Yields were only 0.4 - 2.1 t ha^{-1}. However, Rohyb 6 yielded over 4.0 t ha^{-1} at one site.

Guinea

WARDA's collaboration in 1988 with the Ministry of Agriculture involved several review and planning meetings and the conduct of advanced yield trials on Kaback Island, just west of the mainland. Five of the varieties tested yielded more than 4.0 t/ha^{-1}.

Guinea-Bissau

Collaborative activities with scientists in Guinea-Bissau have extended for a period of years. These efforts have resulted in the release of several WARDA-Rokupr bred varieties. In 1988, foundation seed were made available to the Ministry of Agriculture for BG 400-1 and RD 15.

Trials were established using 15 promising varieties and tested at the Caboxanque Research Station. Scientists there also took part in testing the synthetic pheromone used to attract male *Maliarpha* moths and testing of other controls for the rice stemborer.

Seed Production

WARDA-Rokupr has been multiplying and purifying seed for distribution to national researchers, extension agencies and farmers since 1985. In 1988, four hectares were devoted to the production of seed from 57 rice varieties. These seed are maintained in a cold room and distributed upon request to the groups mentioned above. ROK 5, WAR 1, Rohyb 6, ADNY 301, CP 4, ROK 10 and Kuatik Kundur are the most widely requested varieties.

Training and Communications

Training

GROUP TRAINING

WARDA's group training program remains productive by enhancing the rice knowledge in the region. In 1988 there were five group training programs conducted for member states as a whole at WARDA's Training Center located in Fendall, Liberia. There were 92 participants from 15 of the member states of West Africa involved in the five courses.

In addition to the region-wide group training courses, a special two-week, intensive rice production course was given for 13 members of the Liberian agricultural research program; and a two-week orientation course on mangrove swamp rice research for three field assistants each from Guinea-Bissau and Sierra Leone.

INDIVIDUAL TRAINING

Staff at WARDA-Rokupr also assisted and supervised one student from Njala University College in Sierra Leone obtain his B.Sc. by allowing him to work with the staff in completing his dissertation on "Factors affecting the adoption/diffusion of WARDA-Rokupr recommended technologies among farmers in the mangrove swamp rice areas along the Great Scarcies River of Northwest Sierra Leone."

Since 1975 there have been a total of 34 students and scientists who have conducted their research at the WARDA-Rokupr station.

TRAINEE FOLLOW-UP

A follow-up study of former trainees was completed in 1988 in which over 400 former

Country	Farm machinery management	Post harvest technology	Rice Production research & extension	Audio visual & extension communication	Seed production
Benin	2	1	1	1	1
Burkina-Faso	1	2		2	
Cote d'Ivoire				1	
The Gambia	1		2		1
Ghana	1	2	1		2
Guinea	3	2	2	2	1
Guinea-Bissau	1		2	2	1
Liberia	1	4	1		1
Mali	1	4	2	3	
Niger	1	2	1	1	1
Nigeria		3	2		1
Senegal	2		1	2	1
Sierra Leone	2	1	2		2
Tchad	2		1		
Togo	1	2	2	3	1

Table 15. Member state participation in WARDA group training courses, 1988.

trainees from 14 member states evaluated WARDA's group training efforts and gave feedback on ways to improve the program and also to identify the positive aspects of the program. Of the respondents, 76 percent said they were satisfied with the topics, methods and content of WARDA's group training courses; 53 percent were satisfied with the schedules, organization and social aspects of the courses; and more than 70 percent felt that the training they had received was relevant to their work. Some of the major points the former trainees indicated needed strengthening included: more extensive contact between trainees and scientists during and after the training period; further provision of opportunities for continued post-training learning; and continued collaboration with WARDA in its programs. The study also pointed out the limited emphasis in WARDA's research-related training in the past. This input helped WARDA frame the training component of its Medium-Term Plan for the next five-year period.

FUTURE DIRECTION

The training staff was heavily involved in preparing the Medium-Term Plan during 1988. Several activities were undertaken to provide a basis for future activities. With funding from UNDP, a manpower assessment and training needs study was begun to provide benchmark data on manpower supply and needs, training and research institutions, national plans, capabilities and priorities. Further input is planned for 1989 when a training conference of NARS representatives will be held to crystalize data concerning future directions and resource allocations.

A review began of all earlier WARDA training materials with a view to the early production of training manuals for regional use. Topics for short courses, seminars and conferences were identified and planning initiated for university linkages for an enhanced program of degree-related training.

PHYSICAL IMPROVEMENT

On the physical side, the Training Center acquired new simultaneous interpretation equipment that will allow the Training Center to host two bilingual courses simultaneously. Also, the recreational area for students was expanded and the offices of staff rearranged to more economically serve WARDA's course participants.

Communications

COMMUNICATIONS CENTER

With the help of consultants and the hiring of some new staff, WARDA took a number of steps to upgrade its communication efforts to donors and the scientific community in West Africa.

During 1988 WARDA established an effective communications center that links it with many other research centers and outside agencies. WARDA joined the CGNET in 1988. This provides better and more cost efficient communications with respondents. The internal telephone system for the temporary headquarters in Bouake was streamlined and radio and telex facilities were put in place for the outstations in Monrovia, Liberia; Saint Louis, Senegal; and Rokupr, Sierra Leone. Additionally a fax machine was installed at the Bouake headquarters.

A consultant from IITA reviewed the short and long-term computer needs of WARDA and made major recommendations for installing an effective and efficient computer network. Computers were ordered and installed in all the WARDA locations during 1988. A standardized word processing program has been agreed upon and will reduce many of the problems of internal communications.

PUBLICATIONS

A number of documents, including the Highlights, Annual Report, Strategic Plan, Medium-Term Implementation Plan, the Director General's Newsletter, and a Mangrove Rice publication were produced in 1988. The Mangrove Rice publication was selected as the "Outstanding Professional Skill Award " winner from among 82 publications entered in the competition held annually by the Agricultural Communicators in Education, an international professional agricultural journalism organization.

A publications specialist was hired to initiate WARDA's desk-top publishing efforts and to develop more effective communications procedures. A set of publications policies were drafted, new desk-top publishing equipment ordered and partially installed, and the review of backlogged publications was started. It is anticipated that many of WARDA's publications will be produced in-house in the future, including: research reports, conference proceedings, monographs, newsletters, brochures, and internal forms. The installation of the new publishing equipment will facilitate the expansion of WARDA's copublishing activities with the NARS in the region and with other CG centers.

TRANSLATION AND INTERPRETATION

A new translator was hired to increase WARDA's ability to meet its bilingual mandate for publishing in both French and English. New translation and interpretation equipment was also purchased for WARDA's headquarters in 1988 and will be used for small group meetings, seminars and short courses. WARDA's interpreter has begun compilation of a glossary of rice related terms to aid other interpreters in making the necessary interpretation of English into French and vice versa.

DOCUMENTATION

The WARDA documentation unit had a major job in just setting up shop in the new location in Bouake. The work for the temporary library has been completed and additions have already been made to the original temporary facilities to expand the reading room and provide more space for books and periodicals.

The WARDA librarian has expanded the holdings of the library and is adding further options to its holdings by the use of CD-ROM disks that allow WARDA to link up with databases such as AGRICOLA. WARDA's documentalist has also begun issuing a monthly update of new acquisitions and a bibliographic listing of WARDA holdings by subject matter.

With funding from the Canadian research organization, IDRC, a consultant completed a study for the establishment at WARDA of a West Africa Rice Information Service. It is anticipated that funding of this project will help WARDA to make a major impact on the provision of much needed rice information to WARDA scientists and NARS scientists within West Africa.

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* Completed term April, 1988
** Assumed chairmanship April, 1988

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S. Camara, MS, internal auditor

Adminstration and Finance

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D. Sindiren, PhD., interim director of administration and finance****
K. Akuffo-Akoto, BSc., FCCA, chief accountant
D. Amanu, FCCA., financial controller*
B. Andrews, MA, administrative officer
U. Konan, ML., CFB., personnel officer

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D. Hill, MSc., head of publications
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G. Paku, PhD., agro-statistician

Post-Harvest Technology

Fendall, Liberia

A. Adewusi, MS, processing engineer
M. Takeda, agricultural engineer*-

Seed and Germplasm Laboratory
Fendall, Liberia
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A. Abifarin, PhD., senior breeder, IITA liaison assistant/Director general's representative

Regional Upland Rice Research Station

Bouake, Cote d'Ivoire

K. Miezan, PhD., geneticist, station director

E. Akinsola, PhD., senior entomologist
M. Briat, agronomist (mechanization)**+
M. Choudhury, PhD., senior breeder
J. Dallard, breeder**+
R. Diallo, MS, extension agronomist
S. Diatta, DEA., agronomist
G. Nyoka, PhD., weed scientist

Regional Mangrove Swamp Rice Research Station

Rokupr, Sierra Leone

M. Agyen-sampong, PhD., entomologist, station director
H. Bernard, BS, weed scientist+
W. Cole, MS, extension agronomist+
C. Dixon, MS, soil scientist+
S. Fannah, MS, entomologist+
S. Fomba, MS, pathologist+
M. Jones, PhD., breeder+*

Regional Irrigated Rice Research Station

St. Louis, Senegal

A. Coly, PhD., physiologist, station director
H. Diara, biologist
M. Diop, PhD., associate weed scientist
T. Diop, associate entomologist
B. Fall, sociologist
J. Faucher, agronomist**+
F. Huibers, PhD., water management specialist***
J. Olufowote, MS, breeder

Training Center
Fendall, Liberia
K. Conteh, MS, MA, head, training center
A Akintayo, PhD., trainer
A. Maiga, PhD., trainer

* left during the year
** French cooperants
*** Dutch cooperants
**** Died during the year
**- USAID
*- Japanese cooperant
\+ National program staff based at WARDA

West Africa Rice Development Association

BALANCE SHEET AT 31 DECEMBER 1988

CURRENT ASSETS	1988 US$	1987 US$
Inventory	58 341	32 763
Accounts Receivable - Donors	925 342	1 429 600
Accounts Receivable - Others	348 871	115 833
Fixed Deposits	1 262 664	255 594
Cash and Bank Balances	731 570	360 803
Total Current Assets	3 326 788	2 194 593
CURRENT LIABILITIES		
Bank Overdraft	2 797	------
Accounts Payable	84 843	128 813
Provisions and Accruals	1 112 440	725 255
Contributions in Advance	1 426 491	64 234
Project Fund Balance	86 849	179 660
Total Current Liabilities	2 713 420	1 097 962
Net Current Assets	613 368	1 096 631
Property, Plant and Equipment	3 200 684	2 880 568
NET ASSETS	3 814 052	3 977 199
REPRESENTED BY:		
Capital Fund	3 200 684	2 880 568
Training Fund	92 801	85 883
Working Capital	400 000	400 000
Operating Fund	120 567	610 748
Fund Balances	3 814 052	3 977 199