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RICE IMPROVEMENT IN EASTERN, CENTRAL, AND SOUTHERN AFRICA

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FOREWORD

Present indications are that the potential for increasing the yield and area under rice in Africa is enormous. However, in most of the countries in eastern, central, and southern Africa, the present rice-growing area is quite modest. Many governments now have plans to dramatically increase rice production in response to the accelerating demand for rice by rural and urban consumers throughout the region.

The International Rice Workshop held in Lusaka, Zambia, from 9-19 Apr 1984 brought together the rice scientists from the eastern and southern African region for the first time, in order to jointly assess their problems and formulate common strategies for rice research and development. The workshop and subsequent monitoring tour was organized by the Department of Agriculture of Zambia and was jointly sponsored by IRRI and IITA. Scientists participated from Kenya, Tanzania, Zimbabwe, Zambia, and Madagascar.

The papers in these proceedings document the status and achievements of rice research in each national program and the directions by which future progress can be made. A thorough set of recommendations emerged from the scientific discussions which provide a blueprint for building a base of regional collaboration in rice research among all the countries in the region.

I want to extend my sincere thanks to the Hon. Minister of Agriculture and Water Development, General Chinkuli, for formally hosting this workshop in Lusaka. Many staff of the ministry worked very hard to make the proceedings a success. Dr. Kaung Zan, IRRI liaison scientist for Africa, organized the conference on the part of IRRI and IITA. The technical and general editing for this volume was done by Dr. Dennis P. Garrity and Mrs. Ann Zimdahl, respectively.

We hope these proceedings will serve to somewhat alleviate the great information gap that exists regarding rice in eastern and southern Africa, and that the international cooperation so necessary to making big strides in rice improvement will be stimulated.

M. S. Swaminathan

KEYNOTE ADDRESS

J. N. R. KASEMBE

The Honorable Minister of Agriculture and Water Development, honorable members of the Government of Zambia, distinguished participants of this Rice Workshop, ladies and gentlemen, I would like to join the Honorable Minister of Agriculture and Water Development, General Chinkuli, in thanking the International Rice Research Institute (IRRI) and the International Institute for Tropical Agriculture (IITA) who have jointly sponsored this first Rice Workshop for the east, central, and southern African region. This is an indication that IRRI and IITA have recognized the importance of our region in the production of rice.

Within the region, land in rice has increased from 1970 to 1980 in Comoro, Kenya, Malagasy, Malawi, Mozambique, Tanzania, and Uganda, while in Burundi, Sudan, and Zimbabwe there has been no change in area under rice. Yields have increased steadily in three countries of the region (Kenya, Sudan, and Uganda), while there was no change in yields in Comoro, Malawi, and Zimbabwe, and a decreasing yield trend in Burundi, Malagasy, and Tanzania.

On the average, yields in the major rice-growing countries in tropical Africa have remained low in the last decade. Therefore, total production shows an upward trend mainly because of expansion of rice land in our region.

Both IRRI and IITA are under the Consultative Group for International Agricultural Research (CGIAR) system. IRRI has the global responsibility for rice research, while IITA has the mandate for agricultural research in tropical Africa, and in cooperation with IRRI, has the responsibility for rice development in Africa. Thus, the recognition of our region is of utmost importance in this workshop.

The main functions of IRRI and IITA are as follows:

- Germplasm collection, conservation, evaluation, and characterization, at IRRI for the benefit of all world rice programs, and at IITA for African programs.
- Breeding varieties for use by national programs. Since the breeding objectives vary with the ecology and the prevailing production constraints, these international centers help in defining research goals, priorities, and activities on a multidisciplinary basis for regional and national programs. Our region has been behind other regions of Asia, West Africa, and Latin America

Director general, Tanzania Agricultural Research Organization and representative from Africa, Consultative Group for International Agricultural Research.

mainly because we have only recently started producing reasonable amounts of rice. Because the demand for rice is rising in our region, imports have been increasing. This workshop offers the opportunity to set goals, priorities, and a work plan for immediate and future activities.

- Offering consultancy: in rice technology and its transfer to needy areas; in establishing procedures for conducting research on grain yield and plant type, drought resistance, adverse soils tolerance, low temperature tolerance, disease and insect resistance; and in the more general area of rice cultural management. The best example of this function is the High Yielding Varieties Technology Project (HYVT) which started in 1980 at IITA.
- Training of manpower at all levels for rice research and development. Here I stress the short-term training courses offered by IRRI, mainly in rice production, especially for our east, central, and southern African region where rice cultivation is not traditional. Imported technology from Asia is very important in this aspect. The most important rice ecologies in our region that need appropriate technologies are: upland rice (freely drained), rainfed lowland rice (hydromorphic), swamp rice (*dambos* in Zambia, *vlei*s in Zimbabwe, *fadamas* in Nigeria, *bolis* in Sierra Leone, *bonde* in Tanzania), and irrigated rice. Training in research, such as the Genetic Evaluation and Utilization (GEU) Training Course, is also offered.

Following this lengthy account of the main functions of IRRI and IITA, let me address the objectives of this workshop. This workshop will review the status of rice production in Africa in general and in the different countries of the region in detail. It will also examine the efforts already made in improving rice production as well as identify the constraints that affect production. The main constraints may be grouped into four categories: 1) environmental, 2) biotic, 3) management, and 4) socioeconomic. Lastly, but most importantly, if we are to use this opportunity given us by IRRI and IITA, the workshop must discuss ways and means of improving rice production in our region. This, I suggest, we should do in the following ways:

- Examine the prospects for rice production in the region.
- Review the problems of rice production in the region and the priorities in trying to solve them, emphasizing the major thrust in each problem.
- Draw up recommendations and a plan of work to implement these recommendations. The recommendations should emphasize the interactions between the international centers (IRRI and IITA) and the region, not excluding the formation of a regional center for that function. In West Africa, there are already two regional centers, the West African Rice Development Association (WARDA) in Liberia and the Institute for Tropical Agronomic Research (IRAT) in Ivory Coast, and not mentioning the proximity of IITA to most West African countries.

It is my personal conviction that, although the international centers are there to provide assistance, each region and country must understand its own constraints and develop its own research capability to arrive at appropriate solutions. International center scientists with the necessary skills can be placed at strategic

locations in our region or at a proposed regional location. This workshop can recommend action and decide on a possible location in the region.

It is also important that each country deploy its scientists to ensure maximum productivity, to encourage creative ability, and yet operate in areas where rice has shown potential for cultivation. This is sometimes difficult when few staff are available, so a well planned strategy should be followed carefully and consistently, guided by the experience of IRRI and IITA and possibly incorporating the activities of other countries in the region to avoid unnecessary duplication.

Because training is imperative to success and because IRRI and IITA run excellent courses for technical and scientific personnel, it is the responsibility of the countries in the region to utilize these resources and seek the assistance of IRRI and IITA. There should also be opportunities for training within the region because closer cooperation among the scientists in the region is very important and must be initiated immediately. *Tiende pamodzi.*

Lastly, ladies and gentlemen, I hope everyone will contribute effectively to the objectives of the workshop and that all of our countries will benefit in some way. May I take this opportunity to thank the Zambian government for initiating and hosting this workshop. I wish the workshop participants success in this challenging task.

REGIONAL PERSPECTIVE

RICE PRODUCTION IN AFRICA: AN OVERVIEW

KAUNG ZAN, V.T. JOHN, AND M. S. ALAM

INTRODUCTION

Rice production in Africa has been engaging the attention of national and international agricultural policy makers recently. Rice is a strategic component of food security and a crucial element in the staple food economies of several African countries. Demand for rice in Sub-Saharan Africa is becoming more acute as a result of a general dietary shift from traditional foods, and this demand will likely continue to rise. Production must be stepped up to avert a serious economic drain of the foreign exchange reserves in most countries.

In 1982, Africa had about 3.5% of the world's total rice area and nearly 2.2% of total production. The ecologies under which rice is cultivated vary considerably. About 50% of the area is classified as upland, in many respects unfavorable for rice production. The remainder is subjected to varied water regimes and nutrient imbalances. Only 11% of the entire area is irrigated. Production needs to be increased in 89% of the total rice area if self-sufficiency is to be achieved.

Toward this goal, the World Bank loaned the various rice projects in Africa US$199 million (12) in 1982. The 1985 total estimated land-use for rice in Africa is 5.7 million ha. The estimate for 1990 is 6.8 million ha. During the next 15 yr, an additional 3 million ha are expected to be placed under irrigation, half of which will be in northern Africa. Sahelian, western, and eastern and southern Africa will each bring 500 000 ha under assured irrigation (13). If these goals are met, the import bills of most African countries will be reduced considerably, if not eliminated.

RICE SITUATION IN AFRICA

Rice area

The total rice area in Africa between 1961-65 and 1982 is given in Table 1. The regional patterns for 1970, 1975, and 1980 are given in Table 2.

Rice area increased 62.7% from 1961-65 to 1982. West African rice land forms nearly 50% of the entire rice area in Africa and shows a 28% increase from 1970 to 1980. On the other hand, the northern region shows a 15% decrease while central,

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Table 1. Rice area in Africa (11).

	1961-65	1969-71	1975	1980	1981	1982
			(Area in 1000 ha)			
World	124112	130673	142668	143843	143761	144621
% increase over 1961-65		5.9	14.9	15.9	15.8	16.5
Africa	3097	4010	4275	4754	4909	5039
% increase over 1961-65		29.4	38.0	53.5	58.5	62.7
% of area in Africa compared to World	2.4	3.0	2.9	3.3	3.4	3.5

Table 2. Regional break-up of rice area in Africa (8, 10).

Regions	1970	1975	1980
		(Area in 1000 ha)	
North Africa	485	442	412
% increase/decrease over 1970		−8.8	−15.0
West Africa (WARDA countries)	1977	2073	2527
% increase over 1970		+4.8	+27.8
Central, East, and South Africa	1635	1760	1815
% increase/decrease over 1970		+7.6	−11.0
Total Africa	4097	4275	4754
% increase over 1970		+4.3	+16.0

Table 3. Rice area in African countries (8, 10). (Only countries with more than 40,000 ha are listed.)

Region/country	Area in 1000 ha			
	1970	% of total	1980	% of total
Egypt	480	11.71	408	8.29
Ghana	55	1.34	80	1.62
Guinea	408	9.95	400	8.13
Guinea Bissau	42	1.02	40	9.81
Ivory Coast	289	7.05	450	9.15
Liberia	182	4.44	197	4.00
Malagasy	935	22.82	1216	24.72
Mali	166	4.05	190	3.86
Mozambique	65	1.58	75	1.52
Nigeria	300	7.32	550	11.18
Senegal	88	2.14	85	1.72
Sierra Leone	332	8.10	425	8.64
Tanzania	151	3.68	190	3.86
Upper Volta	40	0.97	40	0.81
Zaire	258	6.29	280	5.69

east, and southern Africa show an 11% increase over 1970. Table 3 shows the rice area in 15 major rice-growing countries (out of a total of 31) in Africa during 1970 and 1980. Summarizing the trends, Table 4 lists countries which have increased their rice area, countries with no change in rice area, and those with decreased area.

Out of 31 countries listed, 18 increased in rice area from 1970 to 1980 with a total area of 3 789 000 ha in 1980. Substantial increase in area has been noted in Ivory Coast, Nigeria, Sierra Leone, and Malagasy. Seven countries with a total area of 1 011 000 ha in 1980 decreased area; prominent among these were Guinea and Egypt. Six countries with a total area of 75 000 ha did not show any change.

Production

Rice production in Africa increased steadily from 1961-65 to 1982, paralleling the world trend. Compared with the 1961-65 figure for Africa, the production level for 1982 was 64.6% higher. Table 5 summarizes rice production trends in Africa between 1961-65 and 1982, and Table 6 gives rice production by regions.

The increase in production of rice in Africa from 1970 to 1980 was contributed by two regions — West Africa and central and eastern Africa. On the other hand, the

Table 4. Rice land in Africa: Changing trends from 1970 to 1980.

Increased area in 1980 compared with 1970		No change in area in 1980 compared with 1970	Decreased area in 1980 compared with 1970
Benin	Mali	Burundi	Angola
Central African Republic	Mauritania	Cameroon	Egypt
Comoros	Mozambique	Congo	Gambia
Ghana	Niger	Sudan	Guinea
Ivory Coast	Nigeria	Upper Volta	Guinea Bissau
Kenya	Sierra Leone	Zimbabwe	Senegal
Liberia	Tanzania		Togo
Malagasy	Uganda		
Malawi	Zaire		

Table 5. Rice production trends in Africa (11).

	1961-65	1969-71	1975	1980	1981	1982
			(in 1000 t)			
Africa	5 425	7 336	7 729	8 445	8 562	8 930
% change over 1961-65		35.2	42.5	49.6	50.6	64.6
World	253 013	311 536	359 693	397 444	412 166	408 759
% change over 1961-65		23.1	42.2	57 1	62.9	61.2
% of world	2.1	2.4	2.1	2.0	2.0	2.2

Table 6. Rice production in different regions of Africa (8, 10).

Region	1970	1975	1980
		(in 1000 t)	
Africa	7388	7729	8445
% increase over 1970		4.6	14.3
North Africa	2611	2423	2355
% increase/decrease over 1970		−7.2	−9.8
West Africa (WARDA countries)	2234	2633	3001
% increase over 1970		15.2	34.3
Central, East, and South Africa	2543	2673	3089
% increase over 1970		5.1	21.47

decreased production of northern Africa is symbolized by the drastic fall in hectarage of rice land in Egypt (Table 3). Table 7 shows the productivity level of rice and the total production in 15 major rice-growing countries.

The per hectare yields in the major rice-growing countries in tropical Africa, excluding Egypt, generally remained low from 1969-71 to 1980. The low yields are a serious constraint. The major reason for the increase in total rice production in Africa is the increase in area under cultivation, pointing to the need to increase the per hectare yields in individual countries.

Based on the per hectare productivity recorded in 1970 and 1980, Table 8 summarizes each country's production trend over the 10-yr period. Fourteen countries show an increase in per hectare yields of rice, whereas 11 countries show a decrease and 5 no change.

Combining the information in Tables 4 and 8, Table 9 summarizes rice production trends in African countries.

Table 7. Rice production in African countries (8, 10).

Region/country	Yield (kg/ha)		Production in 1000 t	
	1970	1980	1970	1980
Egypt	5.4	5.8	2605	2348
Ghana	1.3	0.8	69	62
Guinea	0.9	0.9	350	350
Guinea Bissau	1.7	1.0	67	40
Ivory Coast	1.1	1.2	316	550
Liberia	0.8	1.2	138	243
Malagasy	2.0	1.9	1869	2327
Mali	0.8	1.1	138	200
Mozambique	1.6	–	102	75
Nigeria	1.6	1.3	490	725
Senegal	1.0	1.5	91	130
Sierra Leone	1.4	1.3	458	565
Tanzania	1.2	0.9	182	180
Upper Volta	0.9	0.8	34	30
Zaire	0.7	0.8	188	230

Table 8. Per hectare productivity of rice in African countries.

Increase in kg/ha	Decrease in kg/ha	No change in kg/ha
Cameroon	Angola	Central African Republic
Congo	Benin	Comoros
Egypt	Burundi	Guinea
Kenya	Gambia	Malawi
Liberia	Ghana	Zimbabwe
Mali	Guinea Bissau	
Mauritania	Ivory Coast	
Niger	Malagasy	
Senegal	Nigeria	
Sudan	Sierra Leone	
Togo	Tanzania	
Uganda		
Upper Volta		
Zaire		

Table 9. Rice production – trends in different African countries.

Production status	Countries
1. Increased production with increased area and increased per hectare productivity	Liberia, Mali, Mauritania, Niger, Uganda, and Zaire
2. Increased production with increased area and no change or lower productivity per hectare	Benin, Central African Republic, Comoros, Ivory Coast, Kenya, Malagasy, Malawi, Nigeria, and Sierra Leone
3. Increased production with same or decreased area but with higher productivity per hectare	Cameroon, Congo, Senegal, and Togo
4. Decreased production with same or decreased area but higher productivity per hectare	Egypt, Sudan, and Upper Volta
5. Decreased production with same or decreased area and low productivity per hectare	Angola, Burundi, Gambia, Guinea, and Guinea Bissau
6. Decreased or no change in production but with increased area and low productivity per hectare	Ghana, Mozambique, and Tanzania

Self-sufficiency - Supply versus Demand

Second only to Far Eastern countries, Africa is the world's major importer of rice. However, unlike the Far East, Africa steadily increased importation of rice between 1979 and 1982 (Table 10).

Although the main rice exporting country in Africa is Egypt, the quantity exported from that country has steadily decreased from 178 000 t in 1976-78 to 25 000 t in 1982 (12). The major rice importing countries are listed in Table 11.

Table 10. World rice trade in relation to Africa (12).

	(in million)							
	1979	1980	1981	1982	1979	1980	1981	1982
	Export				Import			
Africa	–	–	–	–	2.2	2.4	2.7	3.3
Far East	7.8	7.6	7.9	7.3	4.4	4.6	4.4	2.7
Near East	0.1	0.1	0.1	0.0	1.8	2.0	2.0	2.2
Others	3.6	4.2	4.4	3.9	3.1	2.9	3.3	2.8
World	11.5	11.9	12.4	11.1	11.5	11.9	12.4	11.1

Table 11. Rice importing countries in Africa (12).

Country	Average				
	1976-78	1979	1980	1981	1982
	(in 1000 t)				
Africa	1617	2330	2424	2741	3273
Cameroon	17	41	29	35	35[a]
Ghana	42	40	31[a]	38[a]	35[a]
Guinea	45	70	70	78	80[a]
Ivory Coast	97	218	257	336	350[a]
Liberia	47	74	87	96	95[a]
Malagasy	104	175	193	193	360
Mauritania	38	50	45	48	75
Mauritius	73	72	88	80	78
Nigeria	342	440	450	600	600[a]
Senegal	244	352	280	322	350[a]
Sierra Leone	10	91	57	45	87
South Africa	101	137	126	150	150[a]
Others	458	570	723	722	938

[a]Unofficial estimates.

Table 11 shows the almost constant or sometimes increasing trends in rice imports in several rice-growing countries of Africa. The increased demand for importation stems from the fact that the self-sufficiency level, as reflected in WARDA countries, has been decreased while the per capita consumption has been increased (Table 12).

While the local supply for consumption has remained at about 1.5 million t in the WARDA countries, the per capita consumption has increased since 1975 and, probably as a result of increased population, has led to higher import levels and lowered self-sufficiency.

PROBLEMS AND PROSPECTS OF RICE PRODUCTION

This section discusses the main environmental, biotic, management, and socio-economic constraints in the rice production systems in Africa.

Table 12. Self-sufficiency levels per capita consumption of rice by WARDA countries (26).

Year	Local supply (1000 t)	Self sufficiency (%)	Per capita consumption (kg)	Import (%)
1975	1690	84	15.2	13
1976	1663	74	16.2	21
1977	1490	57	18.7	43
1978	1473	51	20.4	48
1979	1601	54	20.3	45
1980	1519	48	21.4	52
1981	1502	47	20.9	53
1982	1716	48	22.7	52
1983	1693	49	21.7	51

Systems of rice culture

Experts attending conferences and workshops on systems of rice culture in Africa have generally agreed that rice-growing systems (ecosystems) in the region should be grouped as follows:

- *Dryland rice* (upland rice) is grown on naturally freely-drained soils, where the water table is always below the rice roots. Therefore, the moisture supply is entirely dependent on rainfall.
- *Hydromorphic rice* (rainfed lowland rice) is grown on the soils where rice roots are periodically saturated by a fluctuating water table, in addition to rainfall.
- *Mangrove swamp rice* (tidal swamp rice) is grown in swamps along the coastal regions with tidal intrusion.
- *Inland swamp rice* (rainfed medium-deep waterlogged rice) is grown on flat or V-shaped valley bottoms and flooded to different degrees, which sometimes leads to floating conditions.
- *Paddy rice* (irrigated rice) is grown on bunded paddies, either under rainfed or irrigated conditions.

Although reliable statistics on areas under different ecosystems are difficult to obtain, reasonable estimates have been made for West Africa. Dryland and hydromorphic rice systems have been combined under the upland rice category, and the remaining three (mangrove, inland swamp, and paddy) make up the lowland rice category (25). Recent estimates of area in upland, lowland rainfed, deep water, and irrigated ecologies for all of Sub-Sahara Africa are listed in Table 13. In this classification also, hydromorphic rice is combined with the true upland rice ecology.

Climatic resources and constraints

Climatic factors, such as rainfall, temperature, solar radiation, and photoperiod, influence the physiological expression of the genetic potential of rice varieties. Climate also influences the incidence of pests and diseases, which in turn reduce grain yields.

Table 13. Rice ecologies in sub-Sahara Africa (14).

Ecologies	West Africa		Central and East Africa		Total Africa	
	Area in 1000 ha	Percentage of total	Area in 1000 ha	Percentage of total	Area in 1000 ha	Percentage of total
Upland	1437[a]	62.5	610	33.7	2047	49.8
Lowland						
Rainfed	408	17.5	850	47.0	1258	30.6
Deep water	340	15.0	--	--	340	8.3
Irrigated	115	5.0	350	19.3	465	11.3

[a] Including hydromorphic phreatic rice, considered upland in Senegal.

Rainfall is crucial to successful rainfed rice cultivation. The quantity, reliability, duration, and frequency of rains affect the suitability of the area and also attainable yields. In the high rainfall humid zone of West Africa, where upland rice is grown extensively, drought is not a major problem. Other areas have low mean annual precipitation and or unreliable rainfall, so moisture supply becomes the most limiting factor for upland rice. This is especially true in transition and savanna regions of West Africa and also in rainfed rice areas of central and eastern Africa, such as Tanzania and Malagasy. In addition, most upland rice soils, especially in West Africa, have low water-holding capacity. This, coupled with the relatively shallow-rooting habit of the rice plant, limits the soil volume the plant exploits for moisture (3). This situation justifies breeding rice varieties for drought resistance.

Rainfall patterns in major parts of central Africa, such as Angola, Cameroon, Gabon, and Zaire, are more favorable for rice production. Yet, the full potential of rainfed rice production in these countries remains to be fully assessed, including the social factors and food preferences.

Temperature greatly influences the growth pattern, duration, and yield of rice. Critical temperatures for different growth stages of the rice plant have been identified (Table 14). Air temperatures normally below 20 C and above 30 C markedly affect the growth and yield of rice (27). The mean minimum temperatures in several rice areas of central and eastern Africa and Malagasy drop below 25 C and at times much lower during the rice-growing season.

Two types of cold, cold weather and cold water, can injure rice. The common symptoms caused by low temperature are: poor germination, slow growth and discoloration of seedlings, stunted vegetative growth, delayed heading and incomplete panicle exsertion, prolonged flowering period because of irregular heading, degeneration of spikelets, sterility, and formation of abnormal grains (15). Delay in flowering and delayed maturity duration are especially marked in MV. For example, the growth duration of IRAT8 and IRAT13 is extended to about 160 d in cold-prone Rwanda, whereas they mature in 120-130 d in various parts of West Africa.

The effect of high temperature is more pronounced at the heading stage when the fertility of spikelets is adversely affected by temperatures above 35°C, as in Sahelian countries.

Table 14. Response of rice plants to varying temperature at different growth stages (27).

Growth stage	Critical temperature (°C)		
	Low	High	Optimum
Germination	10	45	20-35
Seedling emergence and establishment	12-13	35	25-30
Rooting	16	35	25-28
Leaf elongation	7-12	45	31
Tillering	9-16	33	25-31
Initiation of panicle primordia	15	--	--
Panicle differentiation	15-20	38	--
Anthesis	22	35	30-33
Ripening	12-18	30	20-25

Solar radiation in the tropics is higher in the DS than in the WS. Consequently, the DS yield is higher. Low solar radiation, particularly during the reproductive stage, can greatly reduce spikelet number. During the ripening stage, it reduces grain yield by decreasing the percentage of filled spikelets.

During August, usually coincidental with the critical reproductive stage in rainfed rice in the forest belt of West Africa, low solar radiation lessens chance of obtaining high yield (22). Under good water and fertilizer management, as with irrigated rice, too little light can easily limits yields in the humid zone of Africa.

Soil resources and constraints

The world's most productive rice land consists mostly of young alluvial soils in river deltas and inland valleys. Soils in such rice areas are predominantly hydromorphic. Entisols and Inceptisols are of fine medium texture with montmorillonitic and vermiculitic clay mineralogy. The reserve of nutrients of these soils and their ability to supply them are generally high because of their high cation exchange capacity and weatherable mineral contents. The distribution of such fertile land in the wetter regions of tropical Africa is limited, thus limiting any rapid expansion of rice production there. According to FAO (9), the total area of Aquepts and Aquents in tropical Africa is estimated at about 55 and 48 million ha in the forest and savanna, respectively.

Well drained upland soils. The well-weathered Alfisols, Ultisols, and Oxisols in the tropical wet-dry region are marginally suitable for upland rice because of their low available water-holding capacity, resulting from a sandy surface horizon and kaolinitic mineralogy. On such soils, even relatively short dry spells hurt upland rice. Hence, the performance of upland rice on such soils depends largely on available soil moisture reserve and tolerance of the rice variety to drought stress.

Nitrogen (N) is the most limiting plant nutrient for upland rice. The behavior of available N in soils with a seasonally fluctuating ground-water table may cause severe N deficiency. This is particularly true in soils situated at the intermediate zone between the well-drained and wetter parts at the lower relief on a rolling and undulating topography.

Phosphorus and sulfur deficiencies have been observed in rainfed upland rice grown in the savanna. On Alfisols in the dry-wet region, with continuous cultivation or after burning following land clearing, iron (Fe) deficiency may be observed.

Leaching losses, soil acidity, and multiple nutrient deficiencies in high rainfall regions may severely hurt yields on strongly leached Ultisols and Oxisols. This is particularly true for high yielding rice varieties with high nutrient demand.

Hydromorphic and swamp soils. In the Pre-Cambrian basement complex areas of West Africa, the rolling topography has small V-shaped or U-shaped valleys. In such valleys the quality of interflow spring or seepage water is important. During most of the year, seepage water contains a high level of Fe^{++} and Mn^{++} ions. Hence, Fe toxicity in rice grown in the inland valleys or swamps is common, especially in Liberia, Sierra Leone, and Nigeria. The terrain may also produce poor drainage, resulting in unfavorable reduced soil conditions.

Lowland coastal soils. Most mangrove swamp soils along the West African coast are potential or actual acid sulfate soils (7). In their original swampy conditions, these soils contain variable amounts of pyrite (FeS) which, upon aeration of the soil, will oxidize, leading to soil acidification. This also can form high levels of Fe^{++} and Al^{+3}, which can reduce rice growth and yield.

Marine salinity from sea water intrusion limits rice in some lowland coastal areas of West Africa. During the WS, with the higher flow volume of the river, gradual washing reduces salinity.

Considerable research on the development of acid sulfate soils for rice production has been carried out at the Rokupr Station in Sierra Leone. It has been shown that by proper poldering, salt water from the tidal intrusion can be prevented from entering the rice-growing areas in Gambia, Senegal, and Nigeria.

Assessment and evaluation of potential rice land in Africa

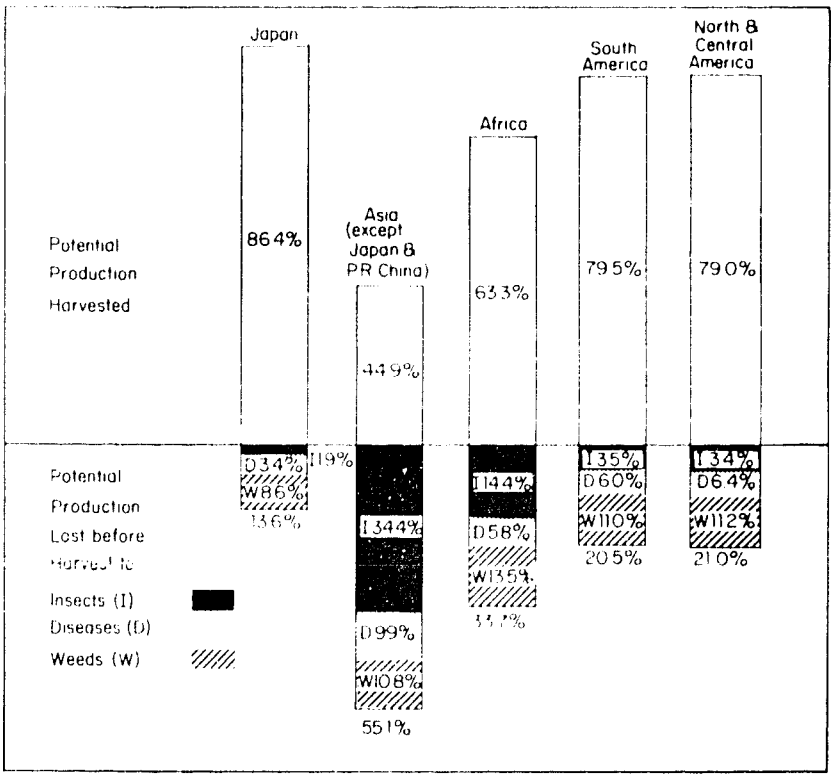
Soil conditions and land characteristics for the various types of rice cultivation in Africa have not yet been systematically assessed. A brief assessment of West African rice growing areas was made by Moormann (16). Information on east and central Africa is particularly scarce. Lack of more detailed soil and land-use surveys in most African countries limits rapid expansion of rice areas in Africa. According to recent IRAT and FAO land resources survey reports, Cameroon has substantial areas of potential rice land yet to be fully developed and evaluated. In Malagasy and Tanzania (Zanzibar and Pemba Islands), most of the rice land is irrigated and includes a wide range of soils and land types. Even where rainfall is adequate in mainland Tanzania, rice is less likely to be grown than any other food crop. However, the country could rapidly expand rice in such areas as the Kilombero valley, the swamp land in Kimba and Shinyanga regions, and the Rufiji valley in the coastal region.

Yet to be explored is the use of the three large hydromorphic lowlands, the lower Niger river delta, the Congo river basin, and the upper White Nile swamps, for rice cultivation. Although the area of inland hydromorphic soils is modest, compared to the well-drained upland, it offers higher potential for intensified rice production.

The total area of hydromorphic swamp soil is believed to amount to 2 million ha in Sub-Saharan Africa.

Biological constraints. Lack of high-yielding improved varieties, disease and insect pests, weed and vertebrate pests are the major biological constraints. For raising the yield per unit area, African farmers, especially the small farmers, need varieties with reasonable but stable yield levels, appropriate growth duration, and tolerance or resistance to environmental stresses and devastating diseases and insects. Cramer (5) estimated the world's average yield loss at about one-third of the value of the rice crop: 13.8% is caused by insect pests, 11.6% by diseases, and 9.5% by weeds. According to Barr et al (4), the yield loss attributable to insects, disease, and weeds in Africa was 33.7% of the potential production (Fig. 1).

Superior varieties. The so-called new plant type, or IR8 plant type, developed by IRRI in the Philippines, has several attributes needed for high-yield potential. The MVs have stature and sturdy stems, essential for lodging resistance; short and erect leaves to utilize solar energy efficiently; and they respond to high levels of management. The rice varieties from IRRI are further reinforced with multiple resistance to major insects, diseases, soil, and environmental stresses. In 1973, an interdisciplinary and problem-oriented rice breeding program, GEU, started with



1. Estimated percent potential rice production and percent loss to various pests.

the goal of incorporating the best characteristics into rice varieties. The major GEU problem areas include: agronomic characteristics, diseases and insects, drought, adverse soils, deep water and extreme temperature, and grain quality and nutritional value.

High-yielding varieties, such as IR8, IR5, IR20, IR30, IR36, IR42, IR46, IR1529-680-3, and IR1416-131-5, are being grown in several African countries under lowland rainfed or irrigated conditions. However, African rice ecologies are complex, with many species of insect pests, plant pathogens, and weed species different from those of Asia. Varieties best adapted to the complex African ecologies are still to be identified.

The rice research program of IITA is developing rice varieties adapted to free-drained upland, hydromorphic, irrigated, and shallow swamp ecologies of Africa and to associated stresses. The strategy is genetic improvement by breeding specific adaptational attributes of local African varieties into more productive genotypes from IRRI and elsewhere. As a result, superior upland rice varieties developed at IITA, such as ITA117, ITA141, ITA235 and 257, have resistance to drought, BL and grain discoloration. They are also superior to traditional varieties in their resistance to lodging and hence respond positively to higher management.

Under hydromorphics without excessive waterlogging and with good management, the intermediate-statured varieties, such as the IR5 plant type, can yield as well as in irrigated paddies. However, tolerance to Fe toxicity is also important for hydromorphic as well as shallow swamps. ITA247, developed at IITA (IR5/Suakoko 8), combines adaptability to fluctuating water tables, tolerance to Fe toxicity, and resistance to BL. For irrigated conditions, varieties such as ITA212, ITA121, ITA123, and ITA230 gave yields of 6 t/ha or higher. Varieties including IR42 and ITA121 have been found suitable for low fertility management.

The major achievement of IRAT in Ivory Coast is the development of upland rice varieties highly tolerant to drought and BL. IRAT109, IRAT110, IRAT142, with short growth duration (about 100 d), and IRAT104, IRAT156, with medium growth duration (120-130 d), appear promising.

WARDA is an inter-governmental organization of 15 West African countries, formed mainly for research, development, and training. The primary sources of entries for WARDA trials are IRRI, IITA, and IRAT. The special research project of WARDA at Rokupr is the only center in Africa working on the improvement of mangrove rice. Among the varieties developed at that station, BD2, ROK4, ROK5, ROK8, and ROK9 are being used in Sierra Leone, Guinea, and Guinea Bissau. IR2797-125-3-2-2-2, IR4707-140-3, IR4712-13-3-1-2, and IR5677-47-3-1-1, with improved plant type and medium growth duration, also showed high yield potential in this ecology.

Insect pests. More than 80 species of insects have been reported to attack rice in Africa (14), but between 10 and 15 species are considered major pests (1). Among the insect pests, stalk-eyed fly is indigenous to Africa and is more prevalent in irrigated and hydromorphic ecologies. Species of lepidopterous SBs and GM differ from those of Asia. The major insect pests of major importance to rice are

Table 15. Insect pests of major importance to rice in Africa.

Common name	Scientific name
White stem borer	*Maharpha separatella* Rag.
Striped borer	*Chilo zacconius, C. diffusilineus, C. partellus*
Pink borer	*Sesamia calamistis, S. botanephaga*
Stalk-eyed fly	*Diopsis (thoracica) macrophthalma* Dalman
Armyworm	*Spodoptera* sp.
Grain sucking bugs	*Aspavia* spp.
	Stenocoris spp
Caseworm	*Nymphula depunctalis* Zell
Gall midge	*Orseolia oryzivora* Harris & Gagne
Whorl maggot	*Hydrellia* sp.
Lady beetle	*Epilachna similis* (Muls)
Termites	

listed in Table 15. In addition, the BPH (*Nilaparvata meander* Fennah,) and GLH are considered potential pests (23).

Insects can be controlled by a number of methods, but the use of R varieties is most effective. This inexpensive method of insect control is also compatible with other control methods in the IPM approach. Several rice varieties that are R to insects have been developed by IRRI; however, Africa has some insect pests Asia does not have. At IITA, researchers are trying to identify the sources of resistance to SBs, stalk-eyed fly, GM, CW, and RWM, and at present 48 varieties have been identified as R/MR. Recently, an integrated pest management (IPM) program was initiated by WARDA in its member states.

Diseases. Fungal, bacterial, and viral diseases often strike African rice. Rice Bl caused by *Pyricularia oryzae* is the most widespread and devastating disease in Africa. The causal fungus of Bl varies greatly in pathogenicity. Many lines from crosses in African land varieties such as Moroberekan, LAC23, 63-68, and OS6, with high yielding exotic semidwarf varieties at IITA, are resistant to leaf Bl. However, the relationship between leaf Bl and neck Bl is not yet well understood. Recently, an intercenter collaborative task force on Bl was formed with IRRI, IITA, WARDA, CIAT, and IRAT. IITA has major responsibility for this task force in Africa. RYMV is a potential threat to rice. The presence of RYMV has been confirmed in Kenya, Ghana, Ivory Coast, Nigeria, Senegal, Upper Volta, and Niger. The virology unit of IITA has developed a technique for detecting the virus using the Enzyme-linked Immunosorbent Assay. IITA investigators identified several plants resistant to this virus, and a breeding program has already been started to develop varieties R/tolerant to this virus.

Other diseases are HLS caused by *Helminthosporium oryzae*, leaf scald caused by *Rhynchosporium oryzae*, ShB caused by *Rhizoctonia solani*, sheath rot caused by *Acrocylindrium oryzae*, and glume discoloration. In addition, BLB caused by *Xanthomonas oryzae* has been reported recently in Mali, Niger, Senegal, Sierra Leone, Upper Volta, Cameroon, and Tanzania. BLS caused by

Xanthomonas translucens f. sp. *oryzicola* has also been reported in some African countries. Screening for resistance to glume discoloration and leaf scald has been emphasized in IITA's research program.

Weeds. Weed control is one of the most labor-intensive operations in rice production. The yield reduction estimates due to weeds in Nigerian rice production are given in Table 16.

In upland and hydromorphic rice ecosystems, certain upland weed species (*Rottboellia exaltata* L., *Commelina* spp., *Digitaria* spp., *Echinochloa* spp., *Cyperus* spp., and *Imperata cylindrica*) and certain hydromorphic aquatic weed species (*Fimbristylis* spp., *Alternantera* spp., and wild rice, *Oryza* spp.) are problems. They often resist a range of herbicides. Among the aquatic weeds, wild rice and *Ischaemus rugossum* are the most difficult to control (2).

Hand weeding in many rice areas of West Africa can require 250-780 h/ha, depending on the ecosystems, frequency of weeding, and environmental conditions during cropping. Poor land preparation at planting time can greatly increase weed infestation. In paddy rice, water management helps control weeds. In lowland bunded rices, flooding the field to a depth of 7.6-10.2 cm also suppresses weed growth after transplanting. Burning the stubble after rice harvest is practiced in several Asian countries. In several countries of Asia and Africa, hand weeding is the most common practice among small farmers. Time of first weeding is important; in direct-seeded rice, weeding should begin before the crop is 3-4 wk old.

For upland, hydromorphic, irrigated, and deep water rice ecosystems, removal of weeds before seeding largely depends on the area of rice grown and availability of family labor. Herbicide use is still limited, and the cost-benefit ratio is crucial.

Management

Yield is the expression of interaction between the genotype and the environment; management creates a favorable or unfavorable environment. Major management factors that determine the crop yield are discussed in the sections which follow.

Growing season. Except in irrigated rice, the growing season is crucial for all rainfed rices. Depending on the onset of rains, length of rainy season, and maturity growth duration of the variety, the time of seeding or raising of seedlings should be adjusted. In direct-seeded culture, rice is usually seeded after one or two good showers when soil moisture is sufficient to start germination and to establish the crop.

Table 16. Losses in rice yield due to weeds (20).

Rice culture type	% reduction in yield
Upland rice	70 - 100
Lowland rice	33 - 75
Direct seeded rice	46 - 84

Land preparation. Proper land preparation is essential for good stands and crop growth. In several rice-growing countries, land preparation commences soon after harvest of the preceding crop while the soil is still moist enough to be worked easily. In general, land preparation in lowland rice consists of two to three alternate plowings and harrowing, depending on soil texture and weeds. Longer intervals between tillage operations allow weed seeds to germinate and be killed by subsequent tilling.

In Africa, land is mainly prepared by manual labor using a short-handled hoe. In tsetse-free areas, draught animals are being introduced, and their use is increasing slowly. Both the cultivated area and yields could be increased with more draught animal power and improved animal draught implements.

In large rice production parastatals, such as the River Basin Development Project in Nigeria, Cameroon, and Tanzania, machines are clearing and tilling the land. Small power tillers have been introduced in Sierra Leone. However, mechanization requires an infrastructure for maintenance and repairs, including availability of spare parts.

For the fragile upland soils of West Africa, conventional tillage leads to soil erosion. Hence, minimal or zero tillage, using a rolling injection planter developed by IITA, minimizes soil erosion.

Plant density. Planting rice closer than necessary increases cost and chances of lodging. On the other hand, spacing wider than necessary means fewer plants per unit area and this may reduce the optimum yield. Random planting is quite common in rainfed rice in Asia and Africa, particularly for traditional varieties. The advantages of straight row plantings are: 1) they are easier to weed, and a rotary weeder can be used, 2) optimum plant population is possible, and 3) it is easier to apply insecticides and topdress fertilizers.

Plant density also affects tillering. The tiller number is positively or negatively correlated with grain yield, depending on the variety and management, especially the fertilizer application.

For upland rice culture in Africa, planting methods range from random dibbling to broadcasting and drilling in rows.

The effect of plant density on grain yield of rice grown with various levels of soil N in irrigated rice has been reported. The yield of two early-maturing rices increased by 1.3 t when the plant density was increased from 0.67×10^5 (40 × 40 cm) to 106 (20 × 5 cm) hills per hectare (19).

No single spacing is best suited for all varieties. In general, short, lodging-resistant and photoperiod-insensitive varieties, such as IR8, IR36, IR42, and IR50, should be spaced 20 × 25 cm in the WS, regardless of soil fertility. In the WS, tall and leafy, heavy tillering varieties, such as Peta, are spaced 25 × 25 cm in relatively poor soil and 30 × 30 cm in fertile soils. In the WS, the tall varieties are spaced 30 × 30 cm in poor soils and 35 × 35 cm in fertile soils (7).

Fertilizer management. Fertilizer is a very effective input for rice production but an expensive one. Fertilizer use in African rice culture is still very low for many reasons. For example, in Malagasy, only about 9000 ha of rice land, or some 0.77% of the total rice area, receives fertilizer. The rates of application average

about 10 kg/ha. In the traditional cultivation of rice under upland, hydromorphic, and swamp conditions, fertility is restored through the bush fallow system. Soil fertility is usually not a serious problem for the first and only rice crop following bush fallow. However, there is little data on fertility management and fertilizer formulations for continuous hydromorphic, swamp, and upland rice cultivation, particularly for the Ultisols under high rainfall conditions. Better information is also needed on the nutrient requirement for the major soils used for rice production. Recent studies have shown that, besides N, P, and K, zinc and sulfur are also deficient on certain soil types in the savanna region. The problem of Fe and Al toxicity in hydromorphic and swamp rice cultivation also requires closer assessments.

Nitrogen (N). N-use experiments have shown that normally less than 30 to 40% of the N applied to irrigated rice is recovered. N losses occur in the soil mainly through nitrification and denitrification, ammonia volatilization, immobilization, leaching, and ammonia fixation. Hence, method and time of application are important for increasing N efficiency. Urea and sulfate of ammonia are the two most common sources of N. Split application of N, one at transplanting and the other at panicle initiation, are best for high grain yields in the case of medium and long duration varieties. However, upland rice grown on coarse-textured and naturally well-drained soils needs a minimum of three split applications — just before seeding, when the crop begins tillering, and at panicle initiation.

In transplanted rice, preplant N fertilizer should be thoroughly incorporated into the soil and kept flooded. The second dose may be broadcast, but it is preferable to incorporate it into the soil by rotary weeders. Fertilizer utilization and grain yield in irrigated rice are highest when fertilizer is placed at a soil depth of 10 cm (Table 17).

Phosphorus (P). P deficiency is a widespread nutritional disorder in rice, second only to N, and Africa is no exception. P deficiency invariably occurs on acid sulfate soils, Vertisols, and certain Inceptisols (21). The P-fixing capacity of soils is an important consideration for recommending adequate levels of P for the

Table 17. Effect of placement of N and other methods of application on grain yield and efficiency of fertilizer N (6).

Method of application	Grain yield[a] (t/ha) Nitrogen sources (N labelled)			Efficiency kg rough rate per kg N
	Urea	Ammonium sulfate	Mean	
Fertilizer incorpprated at planting	6.8	6.8	6.8	14
Placed at 10 cm soil depth	8.6	8.3	8.4	43
Split application[b]	7.1	7.6	7.3	23
Mean sources	7.3	7.6		

[a]Check (with fertilizer N) yield was 5.9 t/ha. LSD (5%) .67 t/ha.
[b]30 kg N/ha at planting and 30 kg N/ha at panicle initiation.

desired fertilizer response. The two major sources of P are superphosphate and rock phosphate. In general, P is applied at planting. Later application can be made but not later than the active tillering time.

Potassium (K). Generally, rice does not respond to K as markedly as to N and P. However, K response is higher in sandy and coarse-textured soils. K should be applied during the final land preparation.

Zinc (Zn). Zn is a minor nutrient element likely to be deficient in alkaline soils of Africa. In Zn-deficient soils, a seedling dip of 2% Zn oxide prior to transplanting produced higher yields in rainfed lowland rice. Incorporation of 10 kg Zn sulfate per hectare in chronically Zn-deficient areas is also recommended.

Water management. Water management for African rice culture should include moisture conservation in upland soils, drainage in valley bottoms and swamps, and control of the water supply in irrigated rice. Research at IITA on reduced tillage with mulch showed that the system is effective with water conservation of upland soils.

Many African countries are expanding their irrigation projects where land consolidation, leveling, and layout for maximum efficiency of water use is imperative. Large irrigation schemes are located in Malagasy, Nigeria, Mali, Ivory Coast, Sierra Leone, Senegal, Tanzania, Cameroon, and Kenya. Major reasons for the decline of irrigation efficiency are frequent breakdowns of machinery and earth-moving equipment, improper maintenance, and lack of spare parts.

Water requirements vary with the growth stage of the rice plant. In lowland rice, a depth of 3-5 cm of water is needed during the vegetative stage. However, short spells of drought stress may not harm the crop during the vegetative stage.

Rice is most sensitive to water stress at the reproductive stage. Water stress during flowering increases spikelet sterility and decreases grain weight.

In the African rice-growing system, drainage in inland swamps and impounding water by bunding in rainfed rice are the primary needs for increased production.

Harvesting and postharvest management. Timely harvesting and appropriate postharvest management are needed to minimize losses. Appropriate harvest time is more important with traditional varieties that are susceptible to lodging or grain shattering. Optimum harvesting time for lowland paddy crops is from 28 to 34 d after heading in the DS (18). Overripening of grains increases sun cracking, especially in long grain rice, thereby reducing the head rice recovery. Alternate wetting and drying of paddy, either in the field or after harvest, also increases sun cracking. Paddy must be dried to about 14% MC for prolonged storage.

In most countries of Asia and Africa, harvesting is by manual labor. Use of appropriate hand tools, usually the sickle, can increase labor efficiency. Use of combines or power harvesters is suitable for lodging-resistant varieties planted in rows.

Socio-economic constraints

Africa can increase rice production by expanding the area grown in rice and increasing the yield per unit area. Africa is land rich, and rice production is labor-intensive; therefore, both options should be properly balanced increasing production.

Investment. This is the primary need for both options. Increasing the irrigated rice area would be the most assured way of increasing rice production in Africa. The existing irrigated rice technology of Asia could be adapted in Africa with appropriate modifications. Currently, large sums of money are being invested in developing irrigation projects in Nigeria, Senegal, Mali, Ivory Coast, and Cameroon, to name but a few. Several thousand hectares of inland swamps or flooded plains could be developed and grown in rice by application of proper drainage systems. All these development projects need capital investment and yearly expenditures for maintenance.

Africa particularly lacks trained manpower for research and extension services. To build up trained manpower also requires long-term investment. Similarly, the development of infrastructure, such as storage facilities and transport systems for input and produce, should not be ignored.

Price policies, input supply, and marketing. Effective marketing, timely input supply, credit management, and price policies are essential to provide farmers with assured incentives and the means of using improved technology.

Profitability is the main incentive for a farmer to do his utmost for high yield. For each country, this requires that the government fix and guarantee the price that will give an income per hectare comparable to that from related crops. The price fixed by the government must also be aimed at protecting local rice producers against competition from imported rice. Unfortunately, the cheaper price of imported rice, with which locally produced rice cannot compete in consumer acceptance, has discouraged increased production in certain African countries.

Subsidy is a means of promoting production. Purchased inputs such as fertilizers, pesticides, seeds, tools, and implements may be subsidized to encourage the farmer to use them in improved production packages. The problem with subsidies is that they are difficult to remove once introduced. Under such circumstances, the government could aim at a balance between the guaranteed price of paddy and subsidized input prices.

Credit. In Africa, rice has been promoted in many countries by permitting farmers to purchase essential services and inputs on credit and to repay the debt after harvest. In the Masagana 99 Program in the Philippines, loans are issued to rice growers according to the area of rice they are growing and the need for purchased inputs. Farm credit systems vary from one country to another, but the main objective — inducing the rice farmer to adopt improved technology — is always common. However, as in the case of subsidy, repayment of debts and loans has several problems.

Improved seeds. A coordinated seed program covering production, inspection, certification, collection, and distribution is essential. Some African governments have begun such programs with seed distribution handled by marketing boards. Several countries are yet to strengthen this essential aspect of their rice improvement system.

Research and extension. Increased rice production in Asian countries is achieved by improving the research and extension services. In the past decade, national research programs have been strengthened by providing trained

personnel, research institutions, experiment stations, and outreach research sites, plus corresponding extension networks. Africa needs improvement in its research and extension services. High priority must be given to research areas and disciplines according to the need of each country. The basic need for strengthening research and extension services must be met through training within the country as well as at advanced institutions abroad. Refresher courses at all levels should be offered continuously.

Role of women. Women's role in traditional farming is unquestionably important since, as mothers and housewives, they are often vested with responsibility for the family's nutrition. In typical small-scale peasant families, they are involved in most of the agricultural operations, particularly during and after harvest. Women are invariably denied educational opportunities and access to technological advances and scientific innovations. Women and society will benefit from access to all of the technical advances, credit, and research and to reduce mechanization in small-scale farming. The achievement of food self-sufficiency and better nutrition will depend greatly on removing of barriers that impede the contribution of women to agricultural development.

AREAS OF FUTURE EMPHASIS

Despite a long history of rice cultivation in tropical Africa, rice research in the continent is relatively young compared to that in Asia. Until recently, genetic improvement of rice in Africa was mainly focused on the upland ecology, which contributes 40 to 45% of total rice production, though it covers about 50% of the total area under rice. However, the production potential for upland rice in Africa is much below that of the other ecologies, such as hydromorphic, inland swamps, and irrigated paddy. This clearly indicates the need for a change in the emphasis of genetic improvement to more productive ecosystems.

During the last two decades, some of the major insect pests and diseases in Asia have appeared in parts of Africa. However, none has caused damage in Africa as severe as in Asia. Conversely, some insect pests and diseases prevalent in Africa are unknown in Asia. This situation emphasizes the need for research on specific problems of rice in Africa.

Considering the differences in species of insect pests and disease pathosystems, genetic improvement must be geared toward breeding resistance to these pests and diseases. More information on insect pests and diseases is still much needed, especially for central and east African countries. WARDA has been monitoring the pests and diseases in its member states in West Africa; however, in-depth studies are still lacking on the biology and epidemiology of pathogens and on the biology and ecology of important insect pests. Such information provides the base for a good resistance breeding program and integrated control approach.

Technicians also need to monitor closely and continuously potentially destructive diseases, such as BLB and virus diseases. Virus vectors, such as BPHs and GLHs are established in Africa.

Among the climatic constraints, cool temperature and drought in rainfed rice, when compounded with diseases such as BI, become serious problems. Much systematic research needs to be done on climate-disease complexes.

Nutritional imbalances, such as Fe toxicity, salinity, alkalinity, and acid sulfate soils are localized, yet they call for more research and screening for R sources under specific conditions. Agronomic research in Africa can benefit from the Asian experience if Asian cultural practices are adapted to suit African conditions. Independent research has been focused on upland rice, yet more work is needed on hydromorphic valley bottoms and mangrove swamps, where the growing conditions are somewhat different from those in Asia.

Rice has a high demand in Africa as a staple food, and the demand will continue to rise, but production levels at present are still low. However, if research addresses the major problems, with emphasis on genetic improvement, the potential for significant increase in production appears very good.

One can safely conclude that the need for more in-depth research on rice in Africa is imperative. As mentioned previously, the research capabilities of African countries are much more limited than in other rice-growing countries. Thus, the international and regional research centers, such as IITA, IRRI, IRAT, and WARDA, need to help African national programs, independently and in collaboration with one another, in their respective areas of competency and mandate.

Production projects operated by governments with financing and technical assistance from abroad have proven to be practical and economically viable. Many governments are keenly interested in rice production projects as a way to reach self-sufficiency in rice and as an alternative to dependence on small farmer production. Resolving the problem will require a two-pronged attack, involving millions of small farmers as well as government projects.

Finally, the overriding factor is the policy of the national governments. The national economic goals and priorities must favor rice production in Africa.

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RICE IN EASTERN AND SOUTHERN AFRICA: THE ROLE OF INTERNATIONAL TESTING

D. P. GARRITY

INTRODUCTION

The systematic international exchange and evaluation of elite rice genetic resources is a very recent phenomenon. Only within the past decade has this activity become an established force in global rice improvement.

Rice germplasm exchange on an informal level has, of course, been pursued since the dawn of rice cultivation. Traders, travellers, and settlers introduced and reintroduced many varieties of *Oryza sativa* into eastern Africa through various routes over the centuries, particularly via Malagasy, India, Sri Lanka, and Egypt. Nevertheless, only a tiny fraction of the enormous genetic diversity of rice has been introduced and utilized through these various informal contacts. African rice production systems have been characterized by relatively small and isolated zones of production (Fig. 1). This has effectively limited the efficient exchange and use of new genetic materials.

Local germplasm is no longer the sole resource for exchange. Within the past 20 yr we have witnessed the development of numerous powerful engines of directed evolution which have greatly accelerated the rate of progress in new rice varieties. Here I am referring to the rice breeding programs on the national and international level. At present, three of the international agricultural research centers (IRRI, IITA, and CIAT) as well as a regional center (WARDA) have rice improvement teams. In addition, most of the major rice-growing countries have developed or are now developing strong breeding programs at the state or national level.

Major new products of breeding and selection are being released annually from these programs around the world. The basic objective of international testing is to make this valuable and diverse material available to rice workers everywhere for unrestricted use in their rice improvement programs.

The small rice production base in most eastern and southern African countries poses great difficulties in the development of a national rice research capability. A major objective of this workshop is to explore ways by which the national programs can be strengthened through international cooperative efforts in the

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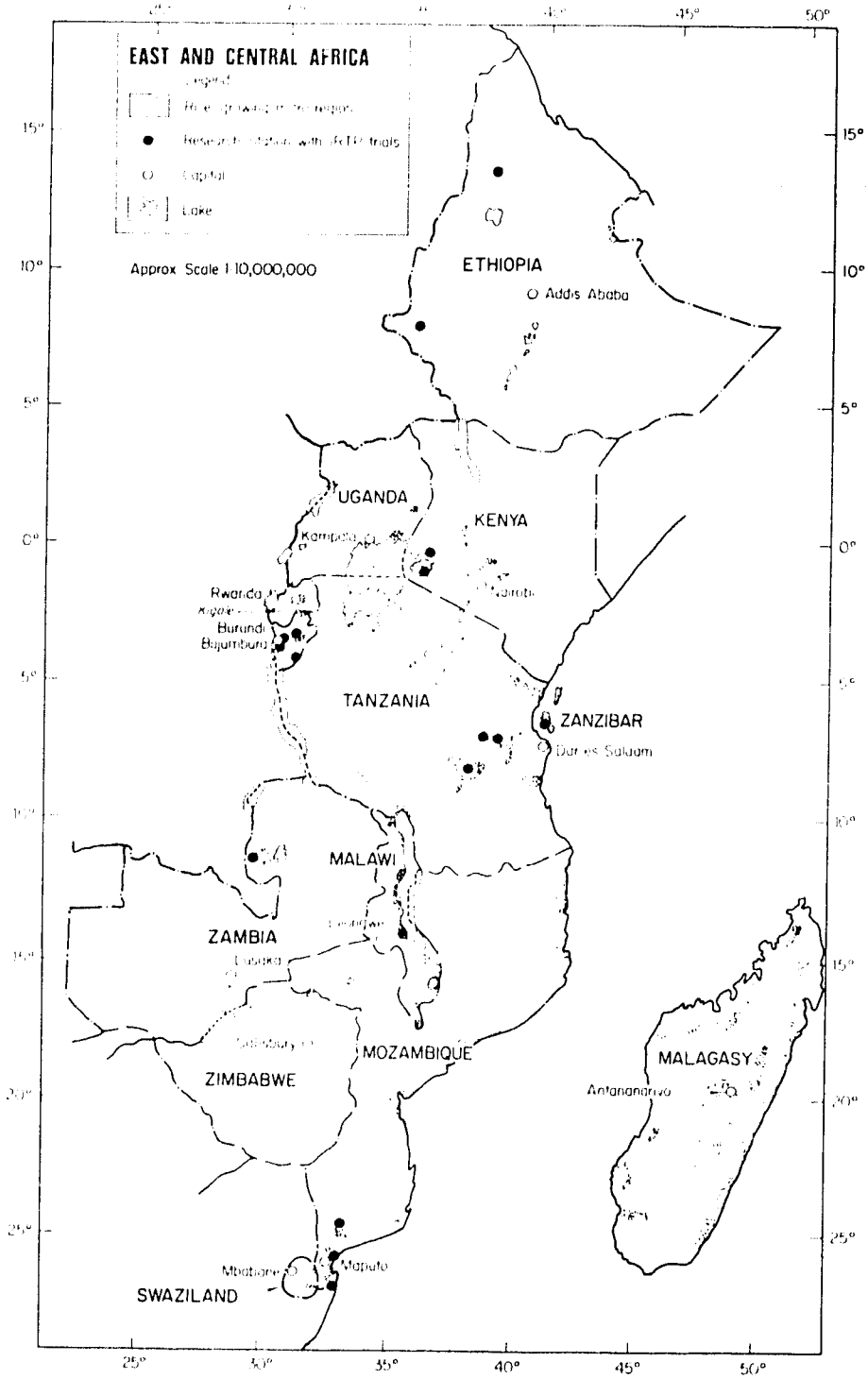

1. Tentative spatial distribution of rice-growing microregions in several eastern and southern African countries.

exchange of ideas, technology, and elite rice germplasm. This paper will examine the role of the International Rice Testing Program (IRTP) as a resource in the introduction and identification of superior varieties for the diverse rice-growing situations in eastern, central, and southern Africa.

FUTURE POTENTIAL OF RICE IN AFRICA

Indications are that the potential for future rice production in Africa is truly enormous. In a recent study, Sanchez and Buol (3) used the FAO Soil Map of the World to estimate the area of wetland soils in the three developing regions of Africa, Asia, and Latin America. Wetland soils are soils mapped as having a moisture regime suited to rice. For Africa the area of wetland soils was estimated to be 203 million ha (Table 1). This exceeds the current harvested rice area of 4.9 million ha by a factor of 40.

South and Southeast Asia, the region in which rice culture has developed to a remarkable intensity and sophistication on its many great river floodplains, has only 121 million ha of wetland soils, less than two-thirds the area that Africa has (Table 1). In addition, Sanchez and Buol's (3) survey showed that the area of wetland soils with no major soil constraint, physical or chemical, is higher in Africa than in Asia.

One example of the potential for rice expansion is the situation here in Zambia, host country for this workshop. Zambia had, as of 1981, about 5000 ha of rice area (1), yet it is estimated (2) that 12% of this large country is swamp and marsh, suggesting that tens of millions of hectares of potential riceland might be developed in Zambia alone.

Some long-range vision is needed to foresee the realization of this vast rice production potential. In eastern and southern Africa, the governments of most countries have plans for dramatically increasing the area under rice. At present, however, the rice area is quite small in most countries in the region (Table 2). Of the 15 rice-producing countries, only three cultivate more than 100,000 ha of rice (Malagasy, Zaire, and Tanzania). Six countries have less than 5000 ha each.

Africa and Latin America are the global frontiers for rice expansion. The world will not soon exhaust land resources for rice production to feed the approximately three billion rice-eating people who will be alive in the next two decades.

But as we all know, there may be a great gap between the availability of a basic land resource and its productive utilization. In terms of the skills and cultural

Table 1. The extent of wetland soils and rice area harvested in three developing regions (3, 1).

Region	Wetland soil (m ha)	Rice area harvested (m ha)
South and Southeast Asia	121	90.3
Africa	203	4.9
Latin America	231	8.2

Table 2. Rice area, yield, and production in the eastern and southern African countries, 1981.

Country	Area harvested (ha)	Yield[a] (kg/ha)	Production (1000 t)
Africa (Total)	4887	1752	8562
Eastern and Southern Africa	1771	1499	2655
Madagascar	1175	1701	1999
Zaire	290	862	250
Tanzania	150	1333	200
Mozambique	60	1033	62
Malawi	43	930	40
Central African Rep.	14	1071	15
Uganda	12	1167	14
Kenya	9	4706	40
Zambia	5	1276	6
Congo	4	1000	4
Burundi	2	4000	8
Somalia	2	2970	5
Rwanda	2	2667	4
Swaziland	2	2632	5
South Africa	1	2308	3

[a]Paddy.

requirements which must be given attention, rice is a unique crop and numerous complex constraints to rice development exist in most African countries.

A BASIS FOR COOPERATIVE EFFORT

The mid-60s witnessed a significant milestone in rice research when tropically-adapted semidwarf rice varieties were developed. They have been a catalyst for rice improvement programs around the world during the past two decades. Rice production in irrigated and favorable rainfed areas has increased substantially in many countries.

Irrigated ecosystems are fortunately characterized by a remarkable environmental uniformity at the global level. This has enhanced the wide adaptability of semidwarf varieties bred in irrigated environments. Ecosystem uniformity under irrigated conditions should not be over-emphasized, however. There are notable differences in the rice genetic background needed for adaptation to the wide variation in temperature and climatic patterns at different elevations and latitudes, to the diversity of adverse soils, and to the variations in local pathosystems.

Rainfed rice occupies another one-half of total world rice area, and efficient varieties with higher productivity in these ecosystems must be found. Modern semidwarf varieties generally have not made a wide impact in areas with poor water control and adverse soil conditions. There are relatively fewer varietal improvement programs to exploit the genetic potential of rice for such problem areas. Serious emphasis is now being extended to the rainfed rice ecosystems at the international level and in many national research programs. Research investment has increased rapidly in the last decade.

Ecosystem diversity in rice cultivation where water control is lacking is a baffling problem. Hydrologic conditions of these ricelands vary from perennial dryland on steep slopes to areas with water depths exceeding 2 m. Many areas are unpredictably subjected to drought stress, to submergence by flash flooding, or to both.

Because of the diversity and magnitude of problems involved in increasing rice production through the selection of improved varieties for widely varying ecosystems, it is generally recognized that intercountry cooperative efforts are imperative. Multilocation national and international testing of varieties has been a logical outgrowth of this awareness.

THE INTERNATIONAL RICE TESTING PROGRAM

Within an international testing network, each researcher continues to concentrate his efforts on the identification of materials that will have practical value in increasing yields under his existing adversity complex. However, through the sharing of the best materials and performance data with all other interested researchers, a basis for rapid progress in varietal development is created.

A worldwide IRTP network is being implemented in cooperation with several hundred rice research stations in about 70 countries. In Latin America, the network activites are coordinated in partnership with CIAT. In Africa, the activities are carried out in cooperation with IITA. WARDA helps coordinate IRTP activities in the West African countries. The fundamental purpose of this network is to make available to rice scientists around the world the best of advanced breeding materials on a convenient and systematic basis. The program seeks to provide the facility for individual rice scientists to test their breeding materials under a wide range of agroclimatic conditions and thereby reduce the time and investment required to develop and identify superior rice varieties.

International testing has been found to be useful in the identification of genetic variation (i.e. biotypes and races) in the major insect and disease pests of rice through the analysis of data on the differential varietal reactions across locations. Because of such genetic variation in the organisms attacking the rice plant, intercountry tests provide a mechanism by which genetic donors with wide-scale resistance are identified.

At present, 24 different nurseries are being composed (Table 3). Thirteen of these trials are targeted to specific rice environments covering the range of rainfed and irrigated ecosystems. An additional 11 nurseries are being composed to identify specific resistance to a range of individual stresses including diseases, insects, adverse soils, and adverse temperatures.

Currently, about 1,200 trials are requested by cooperating scientists and dispatched from IRRI each year. Participation by the eastern and southern African countries in IRTP nursery evaluation is shown in Table 4. Sub-Sahara Africa as a whole currently receives about 250 trials per year, the majority of which are requested by the West African countries.

The nurseries currently consist of a total of about 3,000 breeding lines and varieties. Originally, the majority of lines came from the breeding program at IRRI.

Table 3. Range of International Rice Testing Program nurseries composed in 1984.

Nursery				Entries (no.)
Nurseries for target environments				
			IRRIGATED	
Yield	–	IRYN-VE	International Rice Yield Nursery-Very Early	30
		IRYN-E	International Rice Yield Nursery-Early	30
		IRYN-M	International Rice Yield Nursery-Medium	30
Observational	–	IRON	International Rice Observational Nursery	400
			RAINFED	
UPLAND				
Yield	–	IURYN-E	International Upland Rice Yield Nursery-Early	25
		IURYN-M	International Upland Rice Yield Nursery-Medium	27
Observational	–	IURON	International Upland Rice Observational Nursery	211
LOWLAND				
Yield	–	IRRSWYN	International Rainfed Rice Shallow Water Yield Nursery	29
Observational	–	IRRSWON	International Rainfed Rice Shallow Water Observational Nursery	231
		IRDWON	International Rice Deep Water Observational Nursery	129
		IFRON	International Floating Rice Observational Nursery	33
		ITPRON	International Tide-Prone Observational Nursery	71
Nurseries for specific stresses				
Temperature	–	IRCTN	International Rice Cold Tolerance Nursery	175
Soil	–	IRSATON	International Rice Salinity and Alkalinity Tolerance Observational Nursery	150[a]
		Acid Upland	Acid Upland Screening Set	66
		Acid Lowland	Acid Lowland Screening Set	99
Diseases	–	IRBN	International Rice Blast Nursery	350[a]
		IRBBN	International Rice Bacterial Blight Nursery	200[a]
		IRTN	International Rice Tungro Nursery	250[a]
Insects	–	IRBPHN	International Rice Brown Planthopper Nursery	300[a]
		IRWBPHN	International Rice Whitebacked Planthopper Nursery	200[a]
		IRSBN	International Rice Stemborer Nursery	150[a]
		Rice thrips	Rice Thrips Screening Set	100[a]

[a]Estimated maximum number of entries.

A welcome sign of the increased strength of rice improvement programs in many countries is that at present 65% of the entries nominated to IRTP are derived from national programs.

Information from the network indicates that, up to the present, 70 entries identified thru IRTP testing have been released to farmers in 32 countries. A large proportion of these represent entries that were bred in one national program and through network exchange were eventually released in another country. Table 5 shows the IRTP entries that have been released in Sub-Sahara Africa, of which 22 have been reported.

Direct release of IRTP entries is particularly important in countries without rice breeding programs of their own, but in countries with a breeding program, IRTP

Table 4. Participation by eastern and southern African countries in the International Rice Testing Program.

Country	No. of nurseries dispatched							Types of nurseries
	1978	1979	1980	1981	1982	1983	1984[a]	
Malagasy			5		3			Rainfed, temperature, disease, irrigated
Zaire	–	10	–	–	5	5	4	Rainfed, disease, irrigated
Tanzania	12	15	12	9	12	17	5	Irrigated, rainfed, soils, disease, insect, temperature
Mozambique	2	3	–	–	27	–	–	Irrigated, rainfed, soils
Malawi	3	4	3	2	3	6	2	Irrigated, temperature, rainfed, disease
Cent. African Republic	–	–	–	–	–	–	–	
Uganda	1	2	–	–	9	9	4	Rainfed, irrigated
Kenya	3	–	4	6	6	5	2	Rainfed, irrigated, temperature, soils, disease
Zambia	–	–	1	1	11	14	8	Rainfed, irrigated, soils, temperature, disease
Congo	–	–	–	–	–	–	–	
Burundi	5	–	–	–	1	1	1	Irrigated, rainfed, temperature
Somalia	3	–	3	–	–	–	–	Rainfed, disease, irrigated, soils
Rwanda	–	–	2	–	–	–	–	Irrigated
Swaziland	–	–	–	–	–	–	–	
South Africa	–	1	–	–	4	4	2	Irrigated, temperature
Total	29	40	31	19	83	61	30	

[a]Requested as of 30 Mar 1984.

Table 5. IRTP entries which have been named as varieties in the Sub-Saharan African countries.

Country	Designation	Origin	Name given	Year released
Cameroon	IR42	IRRI	*	*
	IR46	IRRI	IR46	1981
Ghana	IR1820-210-2	IRRI	Tamale 1	1978
Ivory Coast	Jaya	India	*	*
	IR46	IRRI	*	*
Liberia	IR1416-131-5	IRRI	Suakoko 12	1981
Mali	IR1529-680-3	IRRI	*	*
	Jaya	India	*	*
Mauritania	IR1561-228-3-3	IRRI	IR1561	1981
Niger	IR1529-680-3-2	IRRI	IR1529	1979
Nigeria	IR30	IRRI	IR30	1981
	IR42	IRRI	IR42	1981
	IR46	IRRI	IR46	1981
Senegal	Jaya	India	*	*
Upper Volta	IR1529-680-3-2	IRRI	IR1529	1979
	Vijaya	India	*	*
Kenya	IR1561-228-3-3	IRRI	*	1981
Tanzania	BG90-2	Sri Lanka	*	*
	Pinulot 330	Sri Lanka	*	*
	IET1444	India	*	*
	ITA212**	IITA	*	*
	ITA233**	IITA	*	*

* = available, ** = to be confirmed.

entries are more frequently used as parents in crosses with the best locally adapted varieties. Over 5,000 entries have been used as donors in the hybridization programs in many countries and at IRRI for the improvement of yield and other specific agronomic traits, or for the incorporation of resistance to specific stresses into superior local varieties.

Information exchange is an element, in addition to germplasm exchange, that is given strong emphasis. The results of each year's yield, observational, and screening performance trials are published and distributed in a series of preliminary and final nursery reports. Through this information, sources of truly broad adaptation and stress resistance can be efficiently identified and used for further testing or as parental sources. The publication *IRTP in Africa* summarizes the nursery results obtained in Sub-Saharan African countries on a biennial basis.

TESTING RESULTS FROM EASTERN AND SOUTHERN AFRICA

Figure 1 shows the distribution of research stations in the eastern and southern African countries where results of IRTP trials have been reported. An attempt is made to indicate the rice growing micro-regions in each country. Given the inadequate information available, some mistakes in this map are possible. As a result of the knowledge gained through this workshop, we hope that we will be able to better define the spatial distribution of rice production and rice research in the region as a basis for future cooperative effort.

Rice researchers in most African countries work under difficult conditions. Trials that are planned often cannot be carried out or are lost due to uncontrollable circumstances. Researchers in nearly all eastern and southern African countries have evaluated IRTP nurseries (Table 4). However, the percentage of trials for which data have been reported is low. Thus, the picture of varietal response to eastern and southern African ecosystems is incomplete.

Irrigated rice

Expansion of irrigated rice area is desired in nearly all countries in the region. Thus, varietal trials for irrigated ecosystems have been those most frequently requested by cooperators, particularly the yield nurseries for the different growth-duration groups.

Table 6 shows the best-performing entries in the yield nursery trials of rices for medium duration (IRYN-M) conducted in the region during the past 3 yr. At Ahero, Kenya, the most outstanding entry during the 1980 trial was IR8, which yielded 5.8 t/ha. The local check in that trial, IR1561-228-3-3, yielded 3.7 t/ha.

At Gambella, Ethiopia, high yields were obtained in the 1982 IRYN-M. Two lines from India, RPII25-15-48-1-4-3 and RPII25-1526-2-2-3, yielded between 7.7 and 8.0 t/ha. In Mozambique, the 1982 IRYN-M was extensively tested. In the two tests at Chokwe, the two RPII25 lines mentioned above were the best performers in both tests. Eight out of the top 10 lines ranked best in both planting dates at that site, suggesting good repeatability between the two trials.

Varietal response at Marraluene was quite different from that at Chokwe. In Marraluene, the RPII25 lines were not among the top ten. RNR74802, BR-IRGA-40,

and IR54 were most outstanding in mean yield over both trials. RNR74802 and RPI125-1526-2-2-3, both from India, had the highest mean yield over all sites in Mozambique, followed by IRI9670-263-2-2-1, BR51-282-8, BG400-1, and IR54.

Data for the International Rice Yield Nursery-Early (IRYN-E) trials at Ahero, Kenya and in Mozambique are presented in Table 7.

Tests of the IRYN-VE (Very Early) were conducted at the same sites (Table 8). Yield potential for the very early maturing lines was as high as or higher than that for those of the early and medium groups at the Mozambique sites. However, the very early materials averaged only 91 d to flowering, compared to 105 d for the early set, and 126 d for the medium set. The very early materials are of interest to many programs due to their ability to maintain high yield potential and mature 15 to 40 d earlier than the prevalent varieties. The top five ranking very early entries in mean yields across the five Mozambique trials were TKM9, RPI899-1481-78-1, ORI65-28-1-1, RPI674-4038-78-3, and UPRI03-80-1-2, all originating at stations in India.

The International Rice Observational Nursery includes 300-400 entries of all maturity groups grown at two locations in Burundi in 1978. Among the best performing entries, the only variety that was outstanding at both locations was BR7 from Bangladesh (Table 9).

Rainfed and stress screening nurseries

Cold tolerance varietal tests were requested by several countries indicating that rice production at higher elevation may become important in a number of countries in the future. Data on cold tolerance screening have so far been reported only from the NAFCO Mbarali rice farm in Tanzania (Table 9). Also, data from the International Upland Rice Observational Nursery of 1978 were reported from Zanzibar, Tanzania (Table 9). Considering disease and insect nurseries, data have been reported for the International Rice Blast Nursery at Zanzibar. Entries scoring zero for BI infection are shown in Table 9.

FUTURE DIRECTIONS

At this time there are no strong self-sustaining rice-breeding programs in the eastern and southern African region. All of the countries except Malagasy have relatively small rice areas, making it quite difficult to justify support for a breeding program. Thus, for the forseeable future most national programs will be relying upon the direct introduction of new materials as their source of varietal release.

How can a small program make optimum use of the available resources in the international rice testing network? Of first priority, I think, is the need to focus clearly and realistically on the constraints and potentials of the agroecosystem into which new varietal technology is to be introduced. A straight-forward observation of the characteristics of the physical, biological, and cultural environment in which rice is or will be grown should provide the basis for ranking the constraints or defects in present varieties that should be overcome to elevate farm yields. This information should be communicated to colleagues on the international level to establish the type of materials with the most promise for introduction. Also, awareness by the researcher of what environments in other

Table 6. Best performing entries in the International Rice Yield Nursery-Medium (IRYN-M) at eastern and southern African sites.

Year	Site	Entry	Yield by rank (t/ha)	Grand mean of trial	CV (%)	LSD (0.5)	Elevation (m)	Crop season	Date seeded	Soil pH	Soil texture
1980	Ahero, Kenya	IR8	5.8	4.0	26.9	1.7	1153		8-30-80	5.5-6.4	clay (black cotton soils)
		PAU143-B-4-2-PR505	5.4								
		RP825-24-7-1	5.3								
		B3753-7-Pn-4-1	4.9								
		RNR52147	4.9								
		IR13540-56-3-2-1	4.7								
		BIET300 (RAU14-28-1-1)	4.5								
		IR4568-86-1-3-2	4.5								
		B2714C-Pn-1-107	4.4								
		MR1	4.3								
1982	Gambella, Ethiopia	RP1125-1548-1-4-3	8.0	4.6	36.8	2.7	500	wet	6-18-82	6.4	silty loam
		RP1125-1426-2-2-3	7.7								
		Cisadane	6.8								
		IR17494-32-1-1-3-2	6.7								
		IR15314-45-2-3-3	5.7								
		IR22082-41-2	5.7								
		MR24	5.7								
		PAU269-1-9-1-3	5.3								
		Chianung sen yu 23	5.2								
		IR13540-56-3-2-1	5.2								
1982	Salamanga, Mozambique	BG400-1	5.6	3.4	21.1	1.2	25		11-25-82	5.1	clay
		RP1125-1526-2-2-3	4.6								
		IR13540-56-3-2-1	4.5								
		IR19670-263-3-2-2-1	4.5								
		BR51-282-8	4.4								
		RP1125-1548-1-4-3	4.4								
		IR22082-41-2	4.3								
		MR24	4.3								
		RP1082-24-1-1-1	4.1								
		RNR29692	3.9								
1982	Chokwe, Mozambique	RP1125-1526-2-2-3	4.8	2.8	44.8		33		9-10-82	6.1-7.0	clay
		RP1125-1548-1-4-3	4.7								
		BR40-300-2-1	4.3								
		RNR74802	4.3								
		BG400-1	4.2								
		IR19670-263-3-2-2-1	3.5								

		IR13540-56-3-2-1	3.3								
		IR22082-41-2	3.2								
		Chianung sen yu 23	3.1								
		Taichung sen 10	2.5								
	Comments: Severe drought occurred during tillering, reproductive, and ripening stages.										
1982	Chokwe, Mozambique	RP1125-1526-2-2-3	4.4	2.9	25.5	1.2	33	wet	12-4-82	6.1-7.0	clay
		Chianung sen yu 23	4.0								
		BR-IRGA-409	3.9								
		BR51-282-8	3.6								
		RP1125-1548-1-4-3	3.6								
		RNR74802	3.5								
		Taichung sen 10	3.5								
		IR19670-263-3-2-2-1	3.4								
		IR22082-41-2	3.2								
		IR13540-56-3-2-1	3.1								
	Comments: Severe drought occurred during all rice growth stages.										
1982	Marraluene, Mozambique	BR-IRGA-409	3.3	2.3	41.7		15		11-23-82	5.5	clay
		RP1082-24-1-1-1	3.3								
		Taichung sen 10	3.2								
		BR51-282-8	3.1								
		IR17494-32-1-1-3-2	3.0								
		KMP 41	3.0								
		RNR74802	3.0								
		BG400-1	2.7								
		BG40-300-2-1	2.6								
		IR54	2.5								
	Comments: Severe drought occurred during tillering, reproductive, and ripening stages.										
1982	Marraluene, Mozambique	RNR74802	6.7	3.0	42.2	2.1	15		9-3-82	5.5	clay
		IR54	5.3								
		IR13525-43-2-3-1-3-2	5.0								
		BR-IRGA-409	4.9								
		KMP 41	4.9								
		IR17494-32-1-1-3-2	4.7								
		Taichung sen 10	4.6								
		IR19670-263-3-2-2-1	4.4								
		BR51-282-8	4.1								
		IR13540-56-3-2-1	4.1								
	Comments: Severe drought occurred during tillering, reproductive, and ripening stages.										

Table 7. Best performing entries in the International Rice Yield Nursery-Early (IRYN-E) at eastern and southern African sites.

Year	Site	Entry	Yield by rank (t/ha)	Grand mean of trial	CV (%)	LSD (0.5)	Elevation (m)	Crop season	Date seeded	Soil pH	Soil texture
1980	Ahero, Kenya	IR9209-48-3-2	6.2	4.6	21.2	1.6	1153		4-9-80	5.5-6.4	clay (black cotton soil)
		IR13429-196-1	5.7								
		MTU3419	5.7								
		BR169-1-1	5.6								
		UPR251-101-2	5.5								
		IR13427-40-2-3-3	5.4								
		Kaohsiung 139	5.4								
		IR50	5.2								
		R7-2-3-1	5.1								
		TNAU1756	5.0								
1982	Salamanga, Mozambique	UPR254-24-1	3.5	2.5	25.6	1.0	25		11-25-82	5.1	clay
		IR13429-196-1	3.3								
		RP1158-85-1	3.3								
		UPR238-42-2-3-TCA1	3.2								
		IR13429-109-2-2-1 (IR56)	3.1								
		SKL9-31-7	3.1								
		Chianung sen yu 30	3.0								
		HPU734	2.9								
		TNAU(AD) 103	2.8								
		PK95-29-2-1-1-2	2.7								
		T[illegible]ung sen yu 285	2.7								
1982	Chokwe, Mozambique	R[illegible]8-85-1	4.6	2.4	33.4	1.3	33		9-10-82	6.1-7.0	clay
		ADT30	3.3								
		HPU734	3.2								
		IR21015-80-3-3-1-2	3.2								
		IR13427-60-1-3-2-2	3.1								
		Chianung sen yu 13	2.9								
		Taichung sen yu 285	2.8								
		UPR82-1-7	2.8								
		UPR307-7-1-1	2.7								
		IR36	2.6								

Comments: Drought at tillering to ripening stages.

1982	Chokwe, Mozambique	IR13429-196-1	3.6	2.4	32.5	1.3	33	wet	12-4-82	6.1-7.0	clay
		IR13427-60-1-3-2-2	3.4								
		IR21015-80-3-3-1-2	3.2								
		TNAU(AD) 103	3.0								
		Chianung sen yu 13	2.9								
		HPU734	2.7								
		IR13240-82-2 3-2-3-1	2.7								
		IR13429-109-2-2-1 (IR56)	2.7								
		RP1140-27-3-2	2.7								
		RP1158-85-1	2.7								
		UPR254-24-1	2.7								
	Comments: Severe drought intermittently occurred during tillering, reproductive, and ripening stages.										
1982	Marraluene, Mozambique	IR13420-82-2-3-2-3-1	1.9	3.5	36.2	–	15		3-9-82	5.5	clay
		IR13429-109-2-2-1 (IR56	.6								
		Chianung sen yu 13	4.5								
		HPU734	4.5								
		IR21015-80-3-3-1-2	4.4								
		Chianung sen yu 30	4.1								
		CR155-5029-216	4.1								
		IR13427-60-1-3-2-2	4.1								
		BR220-1-1	3.9								
		UPR238-42-2-3-TCA1	3.8								
		IR36	3.8								
	Comments: Severe drought conditions occurred intermittently during the tillering, reproductive, and ripening stages.										
1982	Marraluene, Mozambique	Local check (Milyang 49)	4.3	2.2	31.7	1.1			11-23-82	5.5	clay
		UPR238-42-2-3-TCA1	3.8								
		IR13429-109-2-2-1 (IR56)	3.7								
		Chianung sen yu 30	3.6								
		RP1158-85-1	2.8								
		Taichung sen yu 85	2.8								
		RP1140-27-3-2	2.7								
		IR13427-60-1-3-2-2	2.5								
		IR13240-82-2-3-2-3-1	2.4								
		IR13429-196-1	2.3								
		Tainung sen 12	2.3								
	Comments: Severe drought conditions occurred intermittently during the tillering, reproductive, and ripening stages.										

Table 8. Best performing entries in the International Rice Yield Nursery-Very Early (IRYN-VE) at eastern and southern African sites.

Year	Site	Entry	Yield by rank (t/ha)	Grand mean of trial	CV (%)	LSD (0.5)	Elevation (m)	Crop season	Date seeded	Soil pH	Soil texture
1980	Wanguru, Kenya	IR19746-28-2-2	5.4	3.7	9.3	0.6	1159		9-22-80	6.0	clay
		RNR7306	4.8								
		IR19743-25-2-2	4.5								
		IR10179-2-3-1	4.3								
		IR19762-2-3-3	4.0								
		BG367-7	3.8								
		BKNBR75091-CNT-B3-RST-40-1-3	3.8								
		IR9708-51-1-1	3.8								
		BKNLR75091-CNT-B3-RST-40-2-2	3.7								
		BKNLR75091-CNT-B3-RST-48-2-2	3.7								
1982	Marraluene, Mozambique	IR50	6.1	4.2	26.2	1.8	15		9-3-82	5.5	clay
		RP1899-1481-78-1	5.9								
		UPR103-80-1-2	5.8								
		TKM9	5.7								
		BG367-7	5.3								
		IR19743-25-2-2-3-1	5.3								
		RP1674-4038-78-3	5.2								
		OR165-28-14	4.9								
		IR15429-268-1-2-1	4.8								
	Comments: Severe drought occurred during tillering, reproductive, and ripening stages.										
1982	Marraluene, Mozambique	TKM9	2.9	1.8	21.7	0.6	15		11-23-82	5.5	clay
		UPR103-80-1-2	2.9								
		OR165-28-14	2.5								
		RP1674-4038-78-3	2.4								
		IR19743-25-2-2-3-1	2.3								
		RAU4045-2A	2.1								
		RP1899-1481-78-1	2.1								

		CO39	2.0								
		Zhu xi-26	2.0								
	Comments: Severe drought occurred during tillering, reproductive, and ripening stages.										
1982	Chokwe, Mozambique	IR15429-268-1-2-1	4.9	3.2	27.3	1.4	33		9-10-82	6.1-7.0	clay (fine alluvial)
		TKM9	4.8								
		IR19774-23-2-2-1-3	4.2								
		IR19735-5-2-3-2-1	4.1								
		OR165-28-14	3.8								
		RP1674-4038-78-3	3.8								
		RP1899-1481-78-1	3.8								
		Kaohsiung sen yu 252	3.7								
		BG367-7	3.4								
		IR19791-12-1-2-2-2	3.4								
	Comments: Severe drought occurred during tillering, reproductive, and ripening stages.										
1982	Chokwe, Mozambique	RP1899-1481-78-1	4.8	3.0	29.5	1.4	33	wet	12-4-82	6.1-7.0	clay
		Kaohsiung sen yu 252	4.2								
		OR165-28-14	4.1								
		RP1674-4033-78-3	3.9								
		RAU4045-2A	3.8								
		UPR103-80-1-2	3.8								
		TKM9	3.6								
		PY2	3.5								
		CO39	3.4								
		DR92	3.4								
	Comments: Severe drought occurred during tillering, reproductive, and ripening stages.										
1982	Salamanga, Mozambique	Local check (RPKN-2)	4.3	2.3	33.2	1.2	25		11-25-82	5.1	clay
		OR165-28-14	3.3								
		TKM9	3.3								
		Kaohsiung sen yu 252	3.2								
		BG367-7	3.0								
		OR63-252	3.0								
		IR19735-5-2-3-2-1	2.9								
		IR19791-12-1-2-2-2	2.8								
		PY2	2.8								
		UPR103-80-1-2	2.8								

Table 9. Best performing entries in IRTP observational nurseries and screening sets reported from eastern and southern African countries.

International Rice Observational Nursery (IRON) – 1978

Mosso, Burundi

Elevation (m): 1200 Date seeded: Nov. 27, 1978
Weather conditions: favorable Fertilizer: NPK

Best performing entries:

BR7	S39F-254
BR51-26-1	MR22
Mala/J11	75-4830
4440 Sel. #10	RP919-24-7-1
B2362C/15-SI-8-2	IR4427-58-5-2

Mugerero, Burundi

Elevation (m): 780 Date seeded: Oct. 31, 1978
Weather conditions: favorable Fertilizer: NPK

Best performing entries:

BR7	CR1016
Local check (6044)	Kaohsiung 139
CR199-1	IET5122
IR2797-125-3-2-2-2	IR2797-105-2-2-3
IR4227-240-3-2	IR36
B541B-PN-58-5-3-1	IR1820-52-2-4-1
IR4432-52-6-4	Local check (C18)
CR1002	Taichung sen yu 285
CR1009	

International Rice Cold Tolerance Nursery (IRCTN) – 1981

NAFCO, Mbarali Rice Farm, Tanzania

Elevation (m): 1050 Date seeded: Sept. 7, 1981
Weather conditions: favorable Fertilizer: P
Min. temp: 10°C (vegetative stage)
Max temp: 31°C (reproductive stage)

Best performing entries:

K143-1-2	IR3941-8-1-PLP1B
K31-163-3 (Khudwani)	IR9202-36-3-2
HPU-129	IR9747-23-3-2
IR15924-265-3	K443-105
IR19746-26-2-3	

International Upland Rice Observational Nursery (IURON) – 1978

Zanzibar, Tanzania

Elevation (m): 30 Season: Vuli Date seeded: August 30, 1978
Weather conditions: Vuli Fertilizer: NPK

Best performing entries:

Kinandang Patong	IR5409-1
IR9690-1-1-1-7	IR2061-522-6-9
SMN74-170-39-1	B44B-50-2-2-5-1-1
Pinkot 330	IRAT105
AG-10-37	Seratus Malam
IRAT 110	Azucena
KN361-1-8-6	B733C-67-3-2
IR3880-13	IET2775
IR5179-2	IR1695-PP33-151-873
B57C-MD-10-2	IR1909-1-3-3

Continued on opposite page

Table 9 continued

International Rice Blast Nursery (IRBN) – 1982
Zanzibar, Tanzania

Elevation (m): 30 Season: Vuli Date seeded: August 27, 1982
Weather conditions: favorable Fertilizer: NP

Best performing entries:

Tetep	ITA116
5719	ITA118
Akishino Mochi	ITA132
IRAT 119	ITA142
IRAT 123	ITA175

countries may be ecologically homologous to his own may be extremely useful in building the bridges for efficient exchange of genetic material on an intercountry basis.

Second, a national testing program with continuity needs to be established. Careful testing of introduced and local materials is a continuous process. An important element in this work is to give serious attention to testing the materials under realistic conditions. This is most critical for rainfed rice. If the target environment is rainfed with frequent problems of drought or other stresses, testing under optimum irrigation management may have little applicability in the optimum choice of variety for farmer adoption.

At the international level, our continual challenge is how to make germplasm exchange more efficient, given that rice ecosystem diversity from country to country is very great. The identification of superior genotypes for each ecosystem is an effort requiring large numbers of materials. The numbers are so great, in fact, that we must learn how to target them better on the basis of specific environments.

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VARIETAL IMPROVEMENT RESEARCH IN RICE FOR AFRICA

K. ALLURI

INTRODUCTION

Rice is indigenous to Africa. The African continent is the place of origin for 6 of the 20 identified species of the genus *Oryza*, and African landraces of Asian rice have evolved there. The natural selection pressures of the African environment on Asian rices have resulted in distinctly different cultivars from those grown in Asia. The predominant species under cultivation in Africa is *Oryza sativa*, an Asian species that has been rapidly replacing the African *Oryza glaberrima*. There are also differences in the species of insects and pathogens that affect rice in Africa and Asia.

The importance of rice in Africa is not reflected by the area covered (about 3.5% of world rice area) or by production (about 2.2% of global rice production). Its importance to Africans is shown by the fact that rice imports to Africa have been increasing (6) in most countries. In the eastern and southern regions of Africa, the major rice-producing countries are Malagasy Republic (about 2.3 million t), Tanzania and Zaire (about 0.2 million t) (5), while Malawi, Kenya, Mozambique, and Uganda annually produce 10 000-20 000 t.

The average farm grain yields in the region are low (about 1.0 t/ha), but in some irrigated rice projects high yields of 8-10 t/ha have been recorded.

The important rice ecologies in the region are irrigated, rainfed shallow swamps (hydromorphs or dambos), and to some extent, rainfed upland.

Dambos are prevalent in Malawi, Zambia, and neighboring countries. This ecology has been characterized as extremely variable (A. J. Prior, personal communication). They are low-lying flat to saucer-shaped depressions usually with grassland vegetation, where water drains from the adjacent uplands to varying depths. Rice cultivation is often limited to the lands with shallow water depths. There is usually a drainage way leading to a river. The soil types vary from black clay to sandy. Dambos are termed *fadamas* in Nigeria and *bolis* in Sierra Leone.

IITA researchers seek solutions for important African problems in upland, hydromorphic, irrigated, and shallow-swamp rice ecologies, through varietal improvement. IITA actively collaborates with international centers, such as IRRI

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which has a worldwide mandate for rice research, regional institutes, such as WARDA and IRAT, and various national rice programs. This paper presents the research focus on the varietal improvement in rice at IRRI and IITA that could benefit the region.

Research process

The strategy for increasing rice production is to ameliorate production constraints mainly through genetic improvement at both IRRI and IITA. During the last decade, IRRI has systematized its co-ordinated rice improvement program into a multidisciplinary approach called the Genetic Evaluation and Utilization (GEU) Program (12). This approach has enabled IRRI to stay ahead of potential problems by developing insect- and disease-resistant varieties (16).

The strategy at IITA is similar though the emphasis has been particularly on upland rice because the production problems specific to Africa are more serious in upland than in lowland rice. In the past, varietal improvement for high yield potential and better grain quality received more emphasis than resistance/tolerance to insects and diseases. However, increased importance of BI, RYMV, and ShB diseases, and insects such as SBs, including *Diopsis* and GM in recent years, have made it necessary to concentrate on multiple resistance to diseases and insects. The major approaches for testing have been multilocational screening and evaluation in "hot spots" and controlled stress screening in the greenhouses and fields.

The multilocational research process has been organized through the IRTP and the African Rice Program, the details of which are presented in Alluri (this workshop).

Genetic resources

More than 60 000 cultivars including about 4000 accessions from Africa have been registered in the germplasm bank at IRRI (16). The gene bank of the IITA's Genetic Resources Unit has about 1500 accessions of African rice and 4500 of Asian rice (11). The germplasm collections are conserved, evaluated, and characterized, and the data is computerized at IRRI and IITA to benefit various rice programs.

Several important traits, such as tolerance/resistance to various stresses, aromatic types, and semi-dwarfs, have been observed among the germplasm collections (4, 9, 10, 11, 15, 16). Some African rices have been observed to have high levels of resistance to drought (8), BI and RYMV (11) and also Asian green leafhopper (25). Breeding programs of IRRI, IITA, and several national programs are benefitting from these genetic resources.

Breeding objectives and approaches

Breeding objectives vary with the ecology and the prevailing production constraints. However, the goal of any breeder is always to develop superior varieties for farmers. For success in a breeding program, it is necessary to clearly define the research goals, priorities, and activities and to execute these on a multidisciplinary basis.

Grain yield and plant type

A major objective for rice improvement is to obtain high yield potential coupled with stable yields. The deficiency of tall leafy traditional plant types is essentially lodging susceptibility that makes them respond poorly to improved management.

The semidwarf (IR8) plant type developed at IRRI by utilizing the Dee-geo-woo-gen dwarfing gene has been generally accepted as the ideotype for irrigated rice. Most plant breeding programs for irrigated rice have been utilizing the Dee-geo-woo-gen gene to develop semidwarfs; several superior cultivars for irrigated conditions have resulted (Table 1).

Observations at IITA indicate that in the absence of significant water stress, the high-yielding irrigated rices do well in hydromorphic conditions. However, under fluctuating water regimes, where weed and nutrient (particularly N) management is difficult, intermediate-statured cultivars of IR5 plant type were found to perform better. For varietal adaptation to deep water areas entirely different traits are needed.

IITA took up the challenge to improve the plant type for upland rice and thereby increase the management-responsiveness of the cultivars by an imaginative hybridization program and by irradiation of the well-adapted tall varieties. Techniques for selection of short-statured plants with thick roots at the seedling stage have been developed in support of this breeding strategy (1). The products of this breeding program are of short to intermediate stature (Table 2). We believe that it should be possible to develop short-statured upland types having moderate numbers of panicles (150-200 panicles/m^2), thicker roots, droopy lower leaves, erect upper leaves, and well-exserted panicles with good grain filling (1). The major emphasis at IITA in upland breeding is to incorporate the deep, thick root system of the adapted landraces. The benefits of such short types are initially being directed to the humid zone with the prospect of extending it to sub-humid tropical Africa.

Table 1. Promising irrigated lowland rice selections developed/evaluated at IITA.

Selection	Maturity (d)	Height (cm)	Grain length (1-7)	Grain chalkiness (0-9)
ITA123	124	100	3	1
ITA212	128	106	5	3
ITA222	127	97	5	3
ITA230	123	110	3	2
ITA232	123	113	3	3
ITA249	137	121	3	1
TOX725-1-8-201-1	125	101	3	1
IR13240-82-2-3-2-3-1	114	85	5	1
IR19670-263-3-2-2-1	127	107	3	5
IR21015-80-3-3-1-2	114	106	3	0
IR4422-98-3-6-1	137	113	3	1
IR42	135	122	5	1
IR46	127	115	3	0
IR54	125	113	3	0

Table 2. Performance of selected IITA upland rice lines.

Line	Yield (t/ha)	Maturity (d)	Height (cm)	Grain length (1-7)	Grain chalkiness (0-9)
ITA235	3.0	121	115	3	2
ITA135	2.3	118	127	3	1
ITA257	2.7	104	89	3	1
ITA128	3.2	125	136	3	1
TOX936-8-4-2-1	3.2	127	96	3	5
TOX1768-3-1-1	2.9	120	115	3	1
TOX1871-19-1	2.8	125	113	3	5

Breeding for drought resistance

Evaluation of rice cultivars in the uplands has demonstrated the importance of selecting for drought resistance. Among the phenotypic traits of the cereals, rice root depth and thickness seem to be strikingly different from the drought-resistant species such as sorghum. The value of a thick deep root system for drought resistance in rice has been non-controversial (2, 24, 27) and the results are encouraging (Fig. 1).

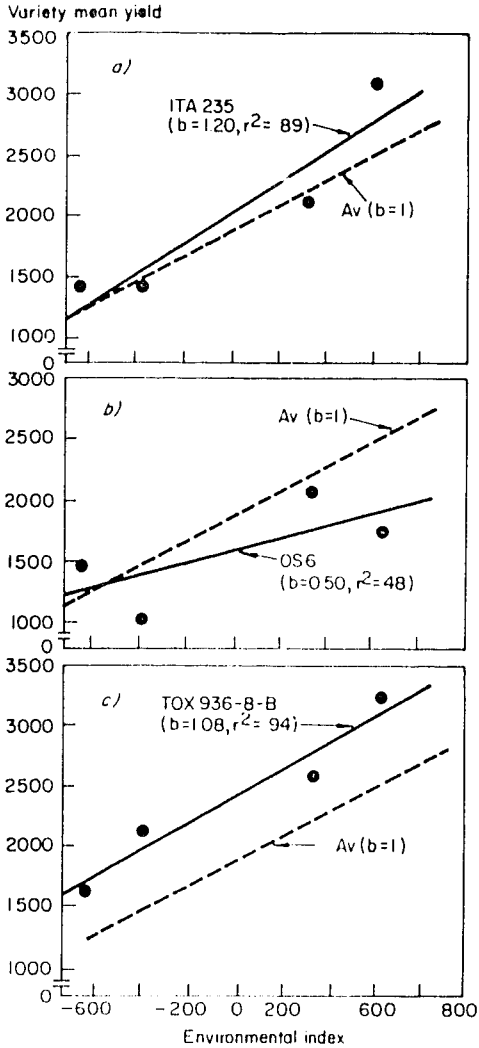
Aeroponic culture studies at IRRI (16) confirmed that among the root characteristics studied, root diameter appeared to be the least affected by environment. Root length was highly and positively correlated with root diameter. The studies confirmed our observation that most varieties with deep root systems generally have thick roots, and these characteristics could be useful criteria in selecting for drought resistance, emphasizing a drought avoidance program. Selection for early maturity to escape drought is another approach for the areas with a monomodal rainfall pattern. Other screening techniques, both at IRRI and IITA, are based on dry and rainy season field screening and evaluation.

At IRRI, the 1983 drought screening of different cultivars at reproductive stage, using a line-source sprinkler system followed by whole-plot sprinkler irrigation system, indicated that the best data to take for drought screening at reproductive stage are grain yields of both stressed and non-stressed environments (16). Also at IRRI, field screening of germplasm and breeding lines indicated that a large percentage of TOX lines from IITA were drought resistant (16).

Tolerance to adverse soils

At IRRI (16), greenhouse and concrete bed techniques for mass screening have been developed and are being used satisfactorily for various adverse soil problems, such as salinity, alkalinity, acid sulfate soils, Fe and boron toxicity, and Zn and P deficiencies. These studies enable researchers to identify sources of resistance to a specific problem; consequently, these sources could be used in breeding programs.

Emphasis on screening work at IITA to date is on field screening *in situ* for Fe-toxicity problems in acid lowlands and Al toxicity coupled with P deficiency in acid uplands. In the humid tropics, where upland rice is not stressed by drought, it



1. Performance of TOx 935-8-B (Selected from thick, deep roots and short stature at seedling stage) in multilocational trials, Nigeria, 1983.

suffers from other problems, including soil acidity and intense leaching of nutrients in sandy textured soils of low base exchange status; these problems culminate in low inherent soil fertility and low productivity. IITA's Onne station is representative of the above problems. An analytical field-screening technique for acid tolerance has been developed at Onne by judicious fertilizer management. Acid (no applied lime or P with a pH range of 3.8 to 4.0) and control (applied 0.5 t dolomite lime/ha and 60 kg P/ha with a pH range of 4.6 to 4.8) strip treatments have been developed covering 1 ha for field screening of rice cultivars. Yields, panicle number, and general vigor tended to be lower and the flowering delayed in the acid strips. Improved cultivars (Table 3) have been developed utilizing such techniques.

Screening for Fe-toxicity tolerance at IITA is also based on field screening done in "hot spots" at Bende (Nigeria) and Suakoko (Liberia). These areas are being

Table 3. Grain yield and agronomic characteristics of varieties found promising in acid upland soils screening, Onne, 1983.

Variety/line	Grain yield (t/ha)		Plant height (cm)	Days to flowering	Plant[b] vigor	Disease[c]			
	Control plot[a]	Acid				Leaf blast	Neck blast	Grain discolo-ration	Sheath blight
TOX 1753-1-24	4.3	3.7	110	80	1	1	–	3	3
TOX 954-203-2-101	3.8	3.0	105	90	1	1	–	3	3
TOX 1012-12-2-1	3.6	3.7	110	95	1	1	–	3	5
ITA 117	3.0	2.8	115	85	1	1	1	1	3
ITA 235	2.4	2.3	130	85	3	3	1	2	2
LAC 23 (check)	2.1	1.9	158	104	1	0	1	1	3
IR 8192-166-2-2-3	3.3	2.7	92	112	5	2	2	5	–
UPLR 1-5	3.1	2.7	109	116	3	4	2	1	–

[a]Plot treated with lime. [b]Based on a scale of 1-9. Score of 1 indicates very vigorous and 9 very weak plants. [c]Based on a scale of 0-9. Score of 0 means no incidence and 9 very susceptible reactions.

monitored constantly for fluctuations in the concentration of Fe in the inter-flow water to confidently rate varietal performance. From such an approach, superior cultivars have been identified (Table 4). Initial attempts to simulate Fe toxicity in pots have been encouraging, and this technique will be refined in the future (A. O. Abifarin, personal communication).

Low temperature tolerance

IRRI conducts screening for tolerance to low air and water temperatures in Korea, Nepal, India, and at IRRI, Philippines. The segregating populations are multiplied through the Rapid Generation Advance technique and the bulk populations and fixed lines are screened at test sites. The superior selections enter the International Rice Cold Tolerance Nursery (IRCTN) and are available for international testing.

Table 4. Performance of selected ITA lines on Fe-toxic soils at Bende and under non-stress conditions at Ibadan, Nigeria.

Cultivar	Plant height (cm)	Growth duration (d)	Bende, 1983		Grain yields at Ibadan (t/ha)			
			Tolerance[a] score	Yield (t/ha)	1983	1982	1981	Average
Tolerant								
ITA245	125	140	2.8	2.4	4.0	4.8	4.4	4.4
ITA239	135	145	3.0	2.8	4.7	6.2	4.1	5.0
ITA247	140	150	3.8	1.9	4.5	5.1	4.9	4.9
Suakoko 8 (check)	150	145	2.5	2.6	4.3	–	–	–
Susceptible								
ITA123	110	120	5.2	0.2	3.7	5.2	4.8	4.6
ITA121	110	125	5.3	0.6	3.8	5.3	4.7	4.6
ITA 212	110	130	5.5	0.5	4.4	6.4	5.1	5.3
IR26 (check)	95	120	5.8	0.1	3.5	–	–	–

[a]Mean of the scores taken at 30, 60, and 75 DT. Score 1 indicates tolerance and 9 susceptibility.

The low-temperature problem in Africa is due to differences in altitude and latitude causing seasonal variation. However, at present, most rice in eastern and southern Africa is grown at altitudes lower than 1000 m, only occasionally up to 1500 m above sea level. Considerable potential seems to exist in the regions where altitudes are higher than 1000 m.

In the present rice-growing areas, low temperatures (less than 15°C) can usually be avoided by adjusting the planting time where a single crop of rice is grown. The problem, however, is serious for delayed planting and for dry-season irrigated rice.

Most research in Africa is limited to varietal screening with little or no emphasis on breeding for low-temperature tolerance. Intensive research on varietal improvement for low temperature was initiated by the National Cereals Research and Extension Project supported by IITA as a Cameroon national program activity 3 yr ago. Some superior cultivars have been identified (Table 5). The problems associated with low temperatures in Cameroon include delayed growth duration and spikelet sterility and the diseases Bl and sheath rot. There is a need for more research to develop varieties tolerant to low temperature for altitudes of about 1500 m and above.

Grain quality

Grain quality requirements vary considerably in the region. For example, long slender translucent grain types for export are preferred in Malawi (21), red grain rice in Malagasy (26), long grain types such as Afaa Nwanza, Kihogo (22) and Supa India in Tanzania. There is a need to understand the local preferences more clearly to appropriately tune breeding objectives. In Malawi (Mr. Mambwe, personal communication) the program will promote high-yielding cultivars that are not superior to Blue Bonnet in grain quality since the demands from the importing countries have been relaxed.

Research on grain quality at IRRI (17, 18, 20) has resulted in improving the various rice quality tests. The various components (storage, milling, marketing, cooking, eating and nutritive quality) of grain are being determined at IRRI and also initiated at IITA (18, 20).

Disease and insect resistance

Breeding for resistance to diseases and insects is given high priority at both IRRI and IITA. As one would expect, a greater proportion of African rices and African

Table 5. Performance of some cold tolerant genotypes at Ndop plain under irrigated conditions, 1983.

Genotype	Yield (kg/ha)	Height (cm)	Days to 50% flowering	Leaf blast (0-9)	Sheath rot (0-9)	Grain discoloration (0-9)
B2161-C-MR-57-1-3-1	6380	105	110	1	3	3
IR7187-33-2-3	5890	98	103	3	3	1
B29838-SR-51-1-2-1	5880	96	109	3	3	3
IR2061-522-6-9	4820	91	110	1	3	3

land races of *O. sativa* have been found to be resistant to African specific insects (3) and diseases (7, 8, 9, 10, 11), but there are exceptions (25). IRRI has made progress in developing varieties for Asia that are resistant to many insects and diseases (13, 14, 15, 19).

Screening studies at IITA (3, 8, 9, 10, 11) have identified donors and superior resistant cultivars for BI, RYMV, and glume discoloration diseases and stalk-eyed fly. African SBs and GM. Genes for resistance to various African diseases are being incorporated into high-yield materials at IITA.

Collaborative research

At present, production problems and the potential threats that are likely to develop under intensive and/or extensive rice cultivation need to be addressed collectively by the varietal improvement programs involved in the region.

A collaborative approach has proven to be rewarding elsewhere to monitor and control various pests and diseases efficiently. This approach needs to be considered in this Workshop for Africa because there is much that could be gained in rice improvement from national and international institute research.

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POTENTIAL RICE VARIETIES FOR EAST AFRICA

B. B. SHAHI

INTRODUCTION

Of 15 countries in the East African region, 2 are major rice producers, and only Malagasy uses rice as a staple food: in the other countries rice ranks third to fifth in production when compared with cereal crops. Although the area under rice is small in these countries, quality rice is grown for consumption or export. In Kenya, a large area of the total 8000 ha is under Basmati and Sindano varieties. In Malawi, rice is a cash crop: mainly Bluebonnet 50 is grown for export and Faya 14M-69 is grown for home consumption. Similarly, Tanzania grows around 279 600 ha with a total production of 268 000 t, and an average yield of around 0.9 t/ha. In other countries, the area presently under rice is small with great potential for expansion in both rainfed and irrigated rice. For example, Ethiopia is one country that does not grow rice at present, but around 250 000 ha (in first phase) and consequently around 1.0 million ha could come under rice. In Ethiopia, tef (*Eragrostis abissinica*) is grown in around 2.0 million ha and is a staple food with microscopic seeds, narrow germplasm base, and 0.5 t/ha yield. If this country is to be self-sufficient in food production, some other crops have to be introduced, and in our estimation, around 20% of the tef area could be replaced with rice.

All of these East African countries, except Malawi, have a food deficit, and a large sum of foreign currency is being spent on food imports. In Tanzania alone, the rice requirement is around 400 000 t/yr due to increase in income and population, and in consumers' taste preference. The price of rice also ranges from US$0.5 to US$2.5/kg in these countries. Because rice consumption in many of these countries is increasing, there is a good opportunity to introduce better varieties and a complete technology package.

MALAGASY REPUBLIC

In this region, Malagasy Republic, a major rice producing country, until 1970 exported rice, but now it imports around 300 000 t/yr. The total area is around 1.3 million ha with an average yield of 1.7 t/ha, and with consumption about 150 kg/person, among the highest in the world.

Varietal requirements

In Tables 1 and 2, an attempt has been made to outline the growing environments in different groups. Varietal adjustment will have to be made according to growing conditions and environment requirements. Three varietal groups are predominant according to water availability.

For production increase in Malagasy, several areas can be developed in the near future. Descriptions and constraints for each area are as follows:

- Central Highlands is a 300 000 ha area in rice in valleys at 1200-1500 m elevation, where the average minimum temperature is not more than 17°C. The constraints on this area have been low fertilizer use and lack of high-yield, short-duration varieties with cold tolerance at seedling stage.
- The Lake Alaotra area has about 90 000 ha at an elevation of 800 m with cool temperatures and a lack of water which prevents double cropping. Here the seedbed is sown in September-October, seedlings are transplanted in December January, and harvesting is done in April-May. Ninety percent of the area is under the local selection, Makalioka 34, a javanica type with 180-d duration. Constraints in this area include labor shortage for land preparation, transplanting, and weed control; little or no fertilizer use; soil nutrient imbalances; and lack of short-duration improved varieties.

Table 1. Varietal requirements for Malagasy Republic.

Malagasy	Irrigated	Cold tolerance 1300-1700 m (Sep-Apr) Cool areas 1000-1300 m (May-Oct-Jan-Feb)
	Rainfed	Cool 1000-1300 m rainy season (Sep-Apr)
	Upland	No cold tolerance 800-1200 m Sep-Apr Hot season

Table 2. Varietal requirement for East African conditions.

Ethiopia	Cold tolerant irrigated (800-2000 m) Cold tolerant rainfed (800-2000 m) Lowland irrigated main crop (100 m-500 m) Cold tolerant lowland irrigated winter crop
Kenya	Irrigated lowland main crop Irrigated lowland cold tolerant second crop
Tanzania	Irrigated lowland main crop Irrigated lowland cold tolerant 2nd crop Irrigated or rainfed cold tolerant above 800 m
Malawi	Irrigated lowland (Blue Bonnet-50 type) Irrigated lowland 2nd crop cold and heat tolerant

- The Northwest and West Coast areas including the country's only double-cropped rice land, 7000 ha in Bezaha, have 3-5 mo rainfall. Constraints on these areas include lack of high-yield short-duration cultivars; poor maintenance of irrigation system; salinity, alkalinity problem in most of the Marovoay area; lack of fertilizer and production inputs; and poor transport and marketing infrastructure.

Research on varieties

Mostly traditional varieties are grown in Madagascar. These include indica and javanica rice introduced to different ecosystems by immigrants several centuries ago. Since rice is not new to this country, a variety of ecotypes are available for strong adaptation but not for production. Local selections and cross-bred varieties are Makalioka-34, Vary Lava Marovoay-47, Ali-combo, Tsipala-A, Rojofotsy-1235, Hmbalalava-1283, and Vary Vato 462 for wetland rainfed and irrigated conditions.

Boina 1329 and RS-25T are for dryland conditions in the northwest. The other commonly grown introductions, Chainan-8, IR8, IR20, TNI, and Taichung line 137. IR36, IR38, and IR45 are of recent introduction. Since Malagasy's environment is complex and local varieties are 4-9 mo duration in some situations 3-mo-old seedlings are transplanted.

The possibility of yield improvement is great in Malagasy by means of breeding and by the introduction of varieties to different areas from IRRI, Taiwan, Indonesia, Japan, Nepal, etc. The target areas may require varieties with cold tolerance, salinity and/or alkalinity tolerance, resistance to BI and other diseases, short stature, and short duration. Many of these entries are available from IRTP at IRRI. Table 3 shows some potential varieties for the eastern Africa region.

KENYA

The annual rainfall of Kenya is about 740 mm/yr in only a seventh of the country, which is low rainfall for rainfed rice. The total area of rice is around 8000 ha, mostly grown in Mwea, Ahero, West Kano, and Bunyala irrigation schemes. Basmati and Sindano are two varieties that predominate. With irrigation water available and proper adjustment of varieties, a second crop with cold tolerance at seedling stage would be most desirable. Introduced improved lines should be evaluated for the following traits: strong seedling cold tolerance, early maturity, high yield, short stature, resistance to the prevalent pests and disease, responsiveness to high fertility conditions and good eating quality. Varieties should be tested during the DS.

TANZANIA

Tanzania's temperature, climate, and rainfall are favorable for rice cultivation in certain areas . Two crops of rice can easily be grown in some locations. In the future the hectarage in rice could be increased considerably. Emphasis should be given to improved management and screening suitable genotypes. Average yield is very low, but it can easily be raised to 2 t/ha with ordinary management. With a supply of inputs, credit, suitable varieties, and marketing facilities, the yield of

Table 3. Potential varieties for East African region.

Country	Group	Varieties
Kenya	A	IR19728-6, IR19728-9, IR19743, IR19746, IR22105, IR22107-113, IR20107-120, IR13429, IR22107-41, IR25840, and IR25898
	B	Basmati-370, Basmati-198, Basmati-C-662, Karnal-Basmati, Mahsuri
Tanzania	A	Lines included in Group A as in Kenya
	B	Line IR26, IR28, IR30, IR32, IR34, IR36, IR38, IR40, IR42, IR43, IR46, IR50, IR52, IR54, IR56, IR58, and IR60 need to examine carefully
	C	CH-988, China 1039, K 143, Shenei, Tatsumi-mochi, IR9758K2, IR20656B, IR15429, IR9224-K1, Barkat, IR1552
Malawi	A	Group A as in Kenya during dry season
	B	IRAT-139, IRAT 140, IRAT-79, UPLRI-5, IR1552, Mahsuri, IR43 for rainfed upland areas
Ethiopia	A	Cold and mid-hill area -- Madise, Atte, Tatomarshi, Pierrot, Grilina, Fujisaka-5, RP79-27, FH207, IET1444, and Allorio
	B	Group A as in Kenya for tropical Gambela area and Group B as in Tanzania

lowland varieties can be raised substantially. In the lowland areas the varieties are mostly unimproved types, such as Faya India, Faya Theresa, Kihogo, Supa India, Kikogored, T-14, Affaa-Mwanza, and Mataniko, which are low-yielding photoperiod sensitive cultivars that are good for adverse climatic conditions. Some of the released varieties, especially IR8, IR20, IR22, IR36, and IET2397, could be extended into favorable areas with appropriate technological packages. Excellent yield test results with IR54, IR36, and IR8 have been achieved in a 130-140-d growing period at Moshi (800 m). For areas near Mbeya at 1000 m cold-tolerant and Bl-resistant varieties would be needed. Entries performing well at this location may also be useful for the DS crop in lowland tropical areas which need seedling and tillering stage cold tolerance. In Arusha, near Moshi at about 800 m, a problem of cold stress arises in the DS irrigated crop.

Tanzania has a large hectarage under rice, and the area could increase with irrigation development. Different varietal groups are needed for the major target environments of irrigated, upland, rainfed at low elevation (0-800 m); and irrigated, upland, and rainfed at higher elevations above 800 m. Rice is being tested at Ifakara station, which coordinates overall activities on rice at Dilosa, Morogoro, Mbeya, Mitwara, Mwanza, Tabora, Tanga, Ruva, and Dakawa. Mbeya may be a good site for cold tolerance trials.

MALAWI

Malawi, a small land-locked country, is very productive and self-sufficient in food production. It exports maize, rice, and other industrial crops, such as tobacco, sugar, and tea. It grows a variety of crops with well-developed farming and cropping systems; however, there can be much more done in rice improvement. Upland rice is not grown in Malawi. Rice is a cash crop in Malawi. The varieties Bluebonnet 50 and Faya 14 M-69 are commercially grown under irrigated and rainfed lowland conditions. The rainfall in some areas is high and well-distributed with a favorable temperature pattern. Therefore, there is also a good possibility for upland rice cultivation.

The variety Bluebonnet 50 is somewhat cold tolerant but not heat tolerant, and at Salima station in DS it suffers sterility due to high temperatures greater than 38 C during flowering time. The variety seems to have panicle tolerance (spikelet fertility) to low temperature during booting stage, but its growth at seedling and tillering stages is poor during the DS under irrigation. Therefore, it appears that root and seedling cold tolerance is lacking along with tolerance to high temperatures during flowering. Bluebonnet 50 gives a yield of 3.5 to 4 t/ha and matures in 130 d during WS, whereas, during DS it takes 150 d and yields 2.5 to 3 t/ha.

In Malawi, a wider base of different varieties is needed, including at least 5 to 10 commercial varieties that have good quality, are high yielding, and are of different maturity groups. Different groups of varieties may be needed during the wet and dry seasons . The DS varieties need cold and heat tolerance, but WS varieties could be higher yielding and of Bluebonnet 50 maturity or similar maturity group.

ETHIOPIA

Although Ethiopia does not grow rice, this country could be a major producer of rice in the future. In the Gambela area there is the possibility of growing an irrigated lowland tropical type and a seedling stage cold tolerant second crop in the same location. In the mid-hill region a single irrigated crop with cold tolerance could be grown. A single rainfed upland crop could be grown in the 1000-2000 m range. Around 250 000 ha in the near future and about 1.0 million ha in the distant future could come under cultivation. The potential areas are Gambela (tropical lowland), Woretta area near Lake Tana, and the mid-altitude area of well-distributed rainfall (in the temperate area). The large swampy regions (Bardar) where crop cultivation is presently not practiced may also be suitable for rice cultivation.

HIGH YIELDING VARIETIES TECHNOLOGY PROJECT FOR RICE IN TROPICAL AFRICA

K. ALLURI

INTRODUCTION

The High Yielding Varieties Technology (HYVT) Project at IITA started in 1981 with funds from the Commission of the European Communities to intensify research efforts and to strengthen international testing and demonstration of elite germplasm of rice and other food crops adapted to African conditions for eventual distribution to farmers. For rice improvement in tropical Africa, the first 2-yr phase was a coordinated multilocational effort that would reinforce existing research at national, regional, and international levels.

Based on reports from national and regional representatives of east, central, southern, and West Africa, phase I involved: provision for various levels of training, including short-term courses for researchers and producers and programs leading to M Sc and Ph D degrees; appointment of the author as rice agronomist/breeder and his relocation to IITA's High Rainfall Station at Onne, Nigeria; emphasis on intensifying research efforts within Nigeria and initiation of a systematic international network for testing elite germplasm.

In 1982 several activities were initiated in Nigeria: screening and evaluation of segregating material for dryland rice, in well-monitored acid soil strips at Onne, and yield and observational trials at Zaria and Gusau; and for shallow swamps, Fe-toxicity screening at Bende and Ito-ikin. Previous activities leading to the development of superior HYVs for both upland and paddy in Nigeria (Ibadan, Ikenne, Onne, Ilorin, Badeggi, Adani, and Bende) were substantially increased. Outside Nigeria, a modest beginning was made to make promising cultivar seed available for evaluation and utilization by national programs.

Evaluation of phase I of the HYVT Project in 1983 revealed that considerable groundwork had been laid in the following areas:

- Varietal improvement research to develop superior cultivars tolerant to major production constraints in the humid forest ecology. The rice materials being evaluated included *Oryza sativa* germplasm collected from the humid tropics in Africa, superior cultivars in various ecologies of Africa, WARDA Testing Program, the IRTP of IRRI, and breeding populations and cultivars from IITA.

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- Systematic screening for soil acidity, SBs, and Bl disease.
- Swamp rice research. This would focused on Fe-toxicity tolerance for developing superior cultivars.
- Agronomy. Time of planting, fertilizer (sources, rates, and combinations), soil, crop residue and fertility management trials, and plant density trials were conducted. These were oriented toward developing appropriate packages of cultural practices to enhance yield performance of the superior cultivars.

A great deal of basic information still needs to be sought from research work, particularly on the problem of grain filling. Because the infrastructure for the multiplication and distribution of elite lines for trials was found to be grossly inadequate at Onne, the evaluation committee recommended that the Ibadan headquarters assume the responsibility of seed multiplication and distribution as well as the coordination of the major activities related to the African Rice Program.

Following the evaluation of phase I, it was proposed that special attention be given to major constraints to rice production across all ecologies in eastern, central, and southern Africa with the major areas of emphasis for rice continuing to be the development of well adapted high-yielding varieties with improved grain quality and resistance/tolerance to: Bl, low soil pH, Fe or Al toxicity, SBs, and *Diopsis*.

In addition, special attention would also be given to RYMV and cold tolerance for lowland rice culture and drought tolerance, early maturity, and glume discoloration for dryland rice culture.

The African Rice Testing Program would be initiated in phase II with its major activities to include seed multiplication, processing, nursery composition, packing, seed dispatch, monitoring for trial evaluation, data processing, and dissemination of results for the cooperators.

The 1984 African Rice Testing Program included two trials: the first African Upland Rice Observational Nursery (AURON) and the first African Lowland Rice Yield Nursery (ALRYN). Fifty entries were adopted for the upland nursery and 16 entries for the lowland nursery. Thirteen sites for upland and 21 sites for lowland nurseries were identified in 13 countries. The test sites would be characterized, and the trial composition and the type of trials would be amended and increased in the future. A monitoring tour for each region would be conducted upon receipt of information on the planting of the trials.

MULTILOCATIONAL TESTING PROGRAM AS A TOOL FOR HYVT PROGRAM

The African continent has considerable diversity in physical, biological, and social environments. Its diversity greatly influences rice production. It is also noteworthy that six species of the genus *Oryza* originated in Africa. Among them, *O. glaberrima* is often found in farmers' fields mixed with the Asian species, *O. sativa*. The diversity in the natural habitats, cultural practices, selection pressures, and probable natural out crossing of *O. glaberrima* with *O. sativa* have all led to considerable diversity in Asian rice in Africa.

Although differences in rice pests and diseases will be elaborated on by others, it is relevant to mention that none of the virus diseases of Asia or America are

known to occur in Africa, and that the stalk-eyed fly and RYMV are African specific, while several species of insect pests and strains of some pathogens differ from Asian ones. These differences underscore the need for relevant rice research in Africa.

However, some similarities in rice culture and production between Africa and other continents exist. The similarity in irrigated rice is indicated by the superior performance of several cultivars from Asia in Africa (e.g. IR5, IR8, and IR46). This suggests that testing the introductions for their adaptation and performance in Africa has merit.

Rice breeding programs of Africa are relatively recent and small compared to those of Asia. As such these programs should focus research on African-specific and African-important stresses utilizing African landraces in the breeding programs for their adaptation genes while using the introductions for other needed traits.

The merits of evaluating a wide range of germplasm are undisputed while it is of even greater value to use it to generate suitable breeding material. The importance that most national programs in Africa attach to rice improvement is rather low, compared to the need for and the consumption of rice. As shown in Table I, most African countries have been importing rice to meet food insufficiencies.

Table 1. Total rice imports to Africa in 1983 and 1984, FAO, 1984.

Country	Total rice imports (1000 t)	
	1983	1984 (estimated)
West Africa		
Benin Republic	20.0	20.0
Cape Verde	7.2	5.0
Chad	3.5	5.0
Gambia	37.8	40.0
Ghana	24.7	50.0
Guinea	77.0	80.0
Guinea Bissau	21.8	20.0
Mali	52.0	90.0
Mauritania	59.4	60.0
Senegal	320.5	370.0
Togo	18.0	25.0
Upper Volta	7.2	20.0
Central Africa		
Central African Republic	10.5	10.0
Sao Tome	1.0	2.0
East Africa		
Ethiopia	25.0	25.0
Somalia	29.3	70.0
Tanzania	29.4	72.0
Southern Africa		
Angola	40.5	43.0
Lesotho	0.0	2.5
Mozambique	66.5	110.0
Zambia	8.7	10.0

The control of pests and diseases by chemicals is not the best means to grow more rice because chemicals are expensive, need specialized training and equipment, and can also be hazardous. Varietal improvement through resistance breeding is the *only* practical solution. It is necessary to utilize available resources efficiently for rice research to develop appropriate technology for increased rice production in Africa.

A coordinated, multilocational breeding program is aimed at developing varieties and technology for higher and more efficient rice production. The evaluation and monitoring aspects of the program help to disseminate the latest research information and improve the quality of research and its usefulness. By sampling diverse environments within a short span of time such a program also reduces the time required to determine the suitability of a variety for an ecology. The system reveals the adaptability and productivity of genotypes under a range of environments, thus identifying superior varieties suitable for specific environments and/or a wide range of situations. The concept of systematic coordinated testing of rice varieties has been successfully carried out by national (e.g. All India Coordinated Rice Improvement Project in India), regional (e.g. WARDA in West Africa), and international (e.g. IRTP of IRRI) organizations.

The concept of multilocational testing, the basis for the High Yielding Variety Technology Project, is not new; thus, the Project will benefit from the existing testing networks and will modify the testing system to benefit national programs in Africa. The system has just been initiated, and constructive criticisms and modifications are welcome to evolve a sound program.

INSECT PESTS AND DISEASES OF RICE IN AFRICA

M. S. ALAM, V. T. JOHN, AND KAUNG ZAN

Rice is the staple food of more than half of mankind, and 90% of the world's rice is produced and consumed in Asia. Although Africa's rice area is only 3.5% of the world's total area and about 2.2% of its total production, rice production in Africa registered a steady increase from 1961-65 to 1982. However, the per hectare yields in the major rice-growing countries in tropical Africa, excluding Egypt, have remained low in general.

Rice production is affected by a wide range of insects, diseases, weeds, birds, and other vertebrate pests. Insects and diseases are two major constraints that limit rice production in Asia and Africa. Figures on crop loss due to insect and disease attack are not widely available. Cramer (19) estimated the world's average yield loss at about one-third of the value of the crop: 13.8% is caused by insect pests, 11.6% by diseases, and 9.5% by weeds. Barr et al (13) estimated that the yield loss attributable to insects, diseases, and weeds in Africa was 33.7% of potential production of which insects and diseases account for 14.4 and 5.8%, respectively.

MAJOR INSECT PESTS OF RICE

In Africa more than 80 species of insects have been reported to attack rice, but only about 15 species are considered important. Because of the diverse conditions under which rice is grown, from temperate to tropical areas and in different altitudes, pest problems also vary from one area to another. Most insect species causing damage to rice in Africa are indigenous species, different from those found in Asia (Fig. 1). Within Africa, the severity of rice insect pests differs considerably in different climatic zones and ecosystems (Table 1, 2). The insect pests of rice in Africa are classified according to the plant parts they damage: internal stem feeder, leaf feeder, leaf and stem sucker, grain sucker, and root feeder. The relationship of crop phenology and field infestation of major insect pests in irrigated rice in Nigeria is shown in Fig. 2.

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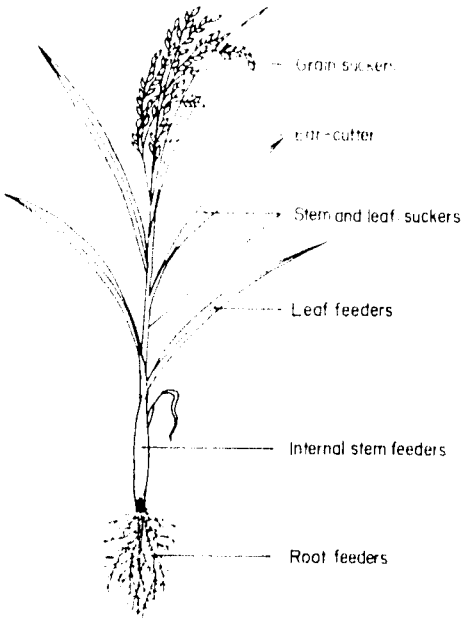


Africa	Asia
Stenocoris spp	*Leptocorisa acuta*
Aspavia spp	
	Mythimna spp
Nilaparvata meander[a]	*Nilaparvata lugens*
Nephotettix spp[a]	*Nephotettix spp*
Sogatodes cubanus[a]	*Sogatella furcifera*
White flies	*Brevennia rehi*
Mites	*Thrips*
Epilachna similis	*Dicladispa armigera*
Nymphula stagnalis	*Cnaphalocrosis medinalis*
Hispids	*Hydrellia spp*
Hydrellia sp	*Nymphula depunctalis*
Spodoptera sp	*Spodoptera mauritia*
Chilo spp	*Tryporyza incertulas*
Maliarpha separatella	*Chilo spp*
Sesamia spp	*Sesamia inferens*
Diopsis spp	*Orseolia oryzae*
Orseolia oryzivora	
Termites	*Mole cricket*
Mole cricket	*Termites*
Root aphid	

[a] *Potential pests*

1. Insect pests of major importance to rice in Africa and Asia (9).

Table 1. Prevalence of rice pests in the major climate zones (2, 3, 9).

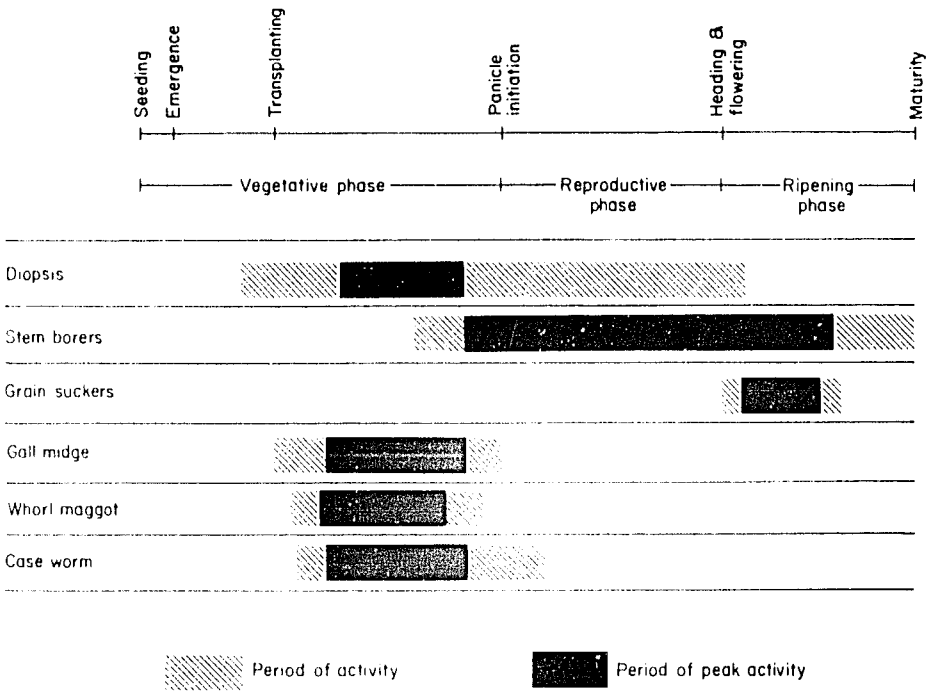
Insects	Humid tropical	Guinea savanna	Sudanian savanna
Maliarpha separatella	++	++	+
Chilo spp.	++	++	++
Sesamia spp.	++	+	+
Diopsis spp.	++	++	+
Orseolia oryzivora		++	++
Grain suckers	++	++	+
White fly	+	++	++
Termite	++	++	+
Armyworm	+	+	+
Nymphula depunctalis	++	++	—
Whorl maggot	+	+	—
Black beetle	+	+	—
Aphid	—	+	—
Mole cricket	—	+	+
Hispa	+	+	=
Leaf folder	+	+	—

++ = abundant, + = present but not abundant, — = not present

Table 2. The relative occurrence of insect pests in different ecosystems (2, 3, 9).

Insect	Upland	Lowland	Irrigated
Maliarpha separatella	++	+++	+++
Chilo spp.	++	++	++
Sesamia spp.	++	+	+
Diopsis spp.	+	++	+++
Orseolia oryzivora	–	++	++
Nymphula stagnalis	–	+	++
Grain suckers	++	+	++
Termite	++	+	–
Epilachna similis	++	+	+
Army worm	++	+	+
Aphid	+	–	–
Mole cricket	++	+	+
Whorl maggot	–	++	++
White fly	–	+	+
Black beetle	+	+	–
Leaf folder	+	+	+
Hispa	+	++	+

+++ = widely abundant, ++ = abundant, + = present but not abundant, – = not present



2. Major insect pests of lowland rice in Nigeria and their relation to growth stages of plant (9).

Internal stem feeders

Among the insects attacking rice, internal stem feeders generally cause the most damage. In this group, lepidopterous borers and two dipteran, the stalk-eyed fly and GM, are important. To their feeding habits and the late appearance of external injury symptoms, their presence usually remains undetected for some time. Among the internal stem feeders, SBs including stalk-eyed fly, are most widespread and observed more frequently than GM. In Africa, SBs, mainly *Pyralidae*, such as *Chilo*, *Maliarpha*, *Scirpophaga*, and *Adelphrupa* genera, and the Noctuidae, such as *Sesamia* genus, are reported (7). Among these, three species, named according to the color of the full-grown larvae, are white SB, (*Maliarpha separatella*), striped SB (*Chilo* spp.), and pink SB (*Sesamia* spp.) are common in Africa.

White stem borer (*Maliarpha separatella* Rag.). Only one species in this genus is considered a rice pest. It is predominant in all rice ecosystems in Africa. The adult moth is yellow, with a reddish-brown line along the edge of the forewings. Unlike other SBs, its infestation is reported to not produce the usual symptoms of "dead heart" or "white head," but if the infestation is at early flowering stage and feeding damage is serious then sometimes "white head" symptoms appear. The damage on the rice stem is very typical; perforated knots with necrosis inside the internode (37). Some yield components, such as number and weig filled grains, are affected by the attack of this insect (7, 26). During adverse environmental conditions, larvae of white SB can undergo diapause in rice stubble.

Pink stem borer (*Sesamia* spp.) This is the most polyphagous insect among the borers. It is more destructive on upland than lowland and irrigated rice. Two major species, *S. calamistis* and *S. botanephaga*, are present in Africa. *S. calamistis* seems to be the most common in east and west Africa, Malagasy, and southern Africa (17, 18). Generally the adult moth is light brown. The larvae feed inside the stem, cutting off the growing part of the plant from the base, causing the tiller to die. This condition during vegetative stage is known as "dead heart." Similar damage during flowering stage results in empty white panicles known as "white head."

Striped stem borer (*Chilo* spp.). Several species of Chilo are reported as rice pests in Africa, but *Chilo zacconius*, *C. diffusilineus*, and *C. partellus* are most common. *Chilo* species are also polyphagous. Adults are pale yellow with irregular black spots on the forewings and wing tips. After hatching, the young larva feeds on the leaves and then bores into the stem. As a result of larvae feeding inside the stem, the plant shows "dead heart" and "white head" symptoms at the vegetative and reproductive stages, respectively.

Stalk-eyed fly. Indigenous to Africa, there are many species of *Diopsis*, but the most important species are *Diopsis (thoracica) macrophthalma*, *D. apicalis*, and *D. collaris*. Among these, *D. macrophthalma* is predominant (18, 11). It is more abundant in humid tropical and Guinea savanna than in Sudanian savanna zones. It is more serious in irrigated and lowland rice ecosystems than in upland rice. It generally attacks the rice plant at the early tillering stage. Peak infestation usually occurs between 20 to 40 DT (11). "Dead heart" damage, similar to that caused by

lepidopterous SBs occurs. Late infestation can also cause "white head" symptoms, but this is not very common. The adults are easy to recognize by two long projections at the side of the head with eyes on the tips and two big spines on the thorax. *D. macrophthalma* is bigger than *D. apicalis* and *D. collaris*. Moreover, the wings of *D. macrophthalma* are transparent and have no black spots at the tips whereas in *D. apicalis* and *D. collaris*, there are black spots at the wing tips.

Gall midge (*Orseolia oryzicora* H and G). The GM is well established in countries of Guinea and Sudan savanna, such as Sudan, Cameroon, Mali, Upper Volta, Ivory Coast, Senegal, Guinea Bissau, and Nigeria (12, 23, 25, 14). This species is morphologically distinct from the Asian species. It is one of the most serious and widespread pests in Upper Volta in irrigated, rainfed, or lowland rice (14). The adult fly is about the size of a mosquito, nocturnal, and phototropic. The feeding of the maggot stimulates the leaf sheath to grow into a gall (silver shoot). Tillers with galls do not bear panicles.

In addition to the direct feeding, the GLHs and planthoppers are vectors of several virus diseases in Asia. In Latin America, planthoppers, *Sogatodes oryzicola* and *S. cubanus*, are vectors of hoja blanca virus disease. In Africa, *Sogatodes cubanus* is reported on rice and maize fields but feeds mainly on grasses. Fortunately, none of these virus diseases existing in Asia and Latin America is detected in Africa yet.

White fly. With recent increases in rice cultivation, the incidence of white fly is gradually increasing. There are two species of white flies which have so far been reported to infest rice plants in Africa, namely *Aleurocybotus indicus* and *Trialeurodes oryzae* (20). *Trialeurodes* is more common in Upper Volta during the hot DS, but *Aleurocybotus indicus* is common in irrigated rice in the Senegal river valley. From February to April in 1983, white-fly infestation was also observed in paddy screen houses and irrigated rice fields on IITA's farm at Ibadan, Nigeria (Alam, 1983 unpublished). White fly outbreaks depend on environmental conditions; high temperature and low humidity favor its rapid development. The incidence of this insect is also reported in Mauritania (2, 3).

Leafhoppers. Two species of GLHs, *Nephotettix modulatus* and *Nephotettix afer*, are found in Africa.

Planthoppers. In this group, there are mainly species of the genus *Nilaparvata*, *Sogatella*, and *Sogatodes*. In Africa, some species of *Nilaparvata* and *Sogatodes* are present. *Nilaparvata meander* was reported in Sudan and French Guinea (21). In Nigeria BPH was reported (39) and hopper burn was noticed in one field at Ibadan in 1983 (8).

Grain suckers

There are at least 15 species of grain suckers that have been reported in Africa (1). Of these, *Aspavia armigera*, *Stenocoris claviformis*, *Reptortus* sp., *Nezara* sp., and *Mirperus* sp. are important. Both adults and nymphs cause damage to developing grains. The damaged grains have diffused brown spots at the point of feeding. Heavily damaged grains are either partially filled or empty.

Root feeders

In this group, termites, mole crickets, black beetles, and aphids are important.

Termites. Among termites, *Microtermes* and *Macrotermes* species have been reported as pests of rainfed upland rice. They attack the plants below the ground level. As a result of their attack, the plant shows wilting symptoms and ultimately dies. If the infestation occurs at booting or flowering stage, "white head" symptoms also appear.

Mole crickets. Both nymphs and adults of the mole cricket burrow along beneath the soil surface and attack the plants below ground close to the roots. Generally, this brown insect occurs only on upland rice or on irrigated rice if there is inadequate water supply. Young seedlings are most commonly attacked.

Aphids. There are two species of aphids which have been reported to attack the roots of upland rice plants in Sierra Leone (4). Generally, hot dry weather encourages the build-up of the colony. During the late harmattan season in December 1982, the aphids, *Rhopalosiphum padi* (L) and *Tetraneura nigriabdominali* Sasaki were observed feeding on the roots of some upland rice varieties at IITA in Ibadan, Nigeria (5).

CONTROL

Insects can be controlled by chemical, cultural, and biological methods. Of these, the conventional method of insect control is chemical because of its immediate impact on the target pest. However, chemical control of rice insect pests is not

Table 3. Major insect pests of rice for which varietal resistance has been recorded (10, 30, 31, 36, 38).

Common name	Scientific name	Progress in breeding for resistance
Yellow stemborer	*Scirpophaga incertulas*	A, B
Striped borer	*Chilo suppressalis*	A, B
	Chilo zacconius	A
Pink borer	*Sesamia* spp.	A
White stemborer	*Maliarpha separatella*	A
Stalk-eyed fly	*Diopsis macrophthalma*	A
Gall midge	*Orseolia* spp.	A, B, C, D
Brown planthopper	*Nilaparvata lugens*	A, B, C, D
Green leafhopper	*Nephotettix virescens*	A, B, C
Whitebacked planthopper	*Sogatella furcifera*	A, B, C
Rice whorl maggot	*Hydrellia philippina*	A, B
Rice delphacid	*Sogatodes orizicola*	A, B
Rice bug	*Leptocorisa varicornis*	A, C
Rice stink bug	*Oebalus pugnax*	A
Rice leaf folder	*Cnaphalocrosis medinalis*	A
Rice hispa	*Dicladispa armigera*	A
Rice thrips	*Baliothrips biformis*	A
Zigzag rice leafhopper	*Recilia dorsalis*	A
Rice caseworm	*Nymphula stagnalis*	A

A = sources of resistance identified, B = resistant varieties released, C = genes for resistance identified, D = insect biotypes encountered.

Table 4. Varieties/lines tested against major insect pests of rice at IITA.

Insect	Varieties tested (no.)	Varieties identified as resistant (no.)	Condition of test
Pink borer (*Sesamia* spp.)	800	6	Field and screenhouse
White borer (*Maliarpha separatella*)	2,000	5	Field
Striped borer (*Chilo zacconius*)	600	10	Screenhouse
Stalk-eyed fly (*Diopsis macrophthalma*)	2,036	35	Screenhouse
Whorl maggot (*Hydrellia* sp.)	430	2	Field
Caseworm (*Nymphula stagnalis*)	700	4	Field
Gall midge (*Orseolia oryzivora*)	244	6	Field
	6,810	68	

always rewarding. Failure to apply the right insecticide at the right time and at the right dosage often leads to decreased benefits to the farmer. Consistent use of insecticide has led to the development of resistance of some rice insects to certain insecticides. Therefore, a successful pest control program will have to utilize not only chemicals, but also other components which will be more effective, less costly, and easily adaptable by farmers.

Different cultural control methods can be effectively used against pests. Use of R varieties is one of the most effective methods of controlling insect pests. It provides an inexpensive method of insect control and is compatible with other control methods in the IPM approach. To date, varietal resistance has been recorded for about 19 insect pests of rice, and varieties resistant to 8 insects have also been released (Table 3). IRRI and some countries in Asia have developed several varieties with resistance to SBs, GLHs, BPHs, and GM, but most of the insect species of rice in Africa are different from those found in Asia. As such, the insect resistant varieties developed at IRRI or other Asian countries may or may not be best suited for use in Africa for controlling insects. Therefore, at IITA major efforts have been made to identify the sources of resistance to African species of SBs (white, pink, and striped), stalk-eyed fly, GM, RCW, and RWM. The success of resistance breeding depends to a great extent on the development of suitable screening techniques. At IITA, screening techniques against stalk-eyed fly and pink SB have been developed. A total of 6810 varieties/lines were screened at IITA against 7 insect species. This led to the identification of 68 varieties as R or MR (Table 4). Some selected R sources are listed in Table 5. Unfortunately, most of the varieties identified as R or MR have poor agronomic characteristics and yielding ability. Therefore, a breeding program has been initiated utilizing R donors to develop varieties R to insect pests. The search will also be continued to

Table 5. Sources of resistance to major insect pests in Africa (27, 28, 29, 30, 31, 38).

African striped stem borer	Stalk-eyed fly	African pink stem borer
TOs 2513	IR579-160	W1263
Taitung 16	Iguape Cateto	Taitung 16
PR403	Leuang 28-1-64	SML 81B
ITA6-20-1-BPI	DNJ171	DNJ171
IR503-1-91-3-2-1	CTG680	DNJ146
PR325	IR589-53-2	Sikasso
H8	E. L. Golpher	
Ratna	IR1561-38-6-5	*African white borer*
Malagkit Sungsong	Huange-Sengoo	ITA6-4-2
SML81B	TD10A	IR1168-76[a]
	Magoti	IR1561-38-6-5[a]
Gall midge	TOg 6324	ITA7-7-2[a]
W1263	TOg 6367	TKM6[a]
BW100	TOg 5560	
PTB18	TOg 6481	*Caseworm*
PTB21	TOg 6399	IRRI Acc. 6621
PTB10	TOg 6390	IRRI Acc. 12580
	TOg 6392	IRRI Acc. 12556
Whorl maggot	ITA121[a]	IRRI Acc. 20427
IR430-373-1-3	DJ12-539-2[a]	
Taitung 314	HPU741[a]	

[a]Moderately resistant.

find better sources of resistance in varieties with good agronomic characteristics and high-yield potential.

Agronomic practices have some potential for reducing the population of many pest species and of increasing the beneficial ones. Closer spacing in mangrove swamp decreases the infestation of *Maliarpha separatella* (3). Infestation of SBs can also be reduced by shifting planting time. Rice planted late (after July) had higher infestation rates of all of the three major lepidopterous borers than those planted at the beginning of the season (6). During the infestation period, some mechanical methods can be used effectively to minimize populations of SBs and GM. Adults of lepidopterous borers and GM may be trapped and killed by a kerosene lantern as a light trap and a trough filled with a kerosene-water mixture (1 part kerosene in 10 parts water) placed under the light trap. CW infestation can be reduced by draining water from the infested field and keeping the field dry for 3-4 d. If draining water from the infested field is not possible, a small amount of kerosene can be added to the water surface to kill the floating CW larvae. Collecting of grain-sucking bugs in the afternoon by sweep net and killing them in kerosene water may also be practiced.

Another approach to insect control is by insect pest management, the manipulation of pest or potential pest populations so as to diminish their injury or render them harmless (22). Surveillance, monitoring, and forecasting of pests form major components of pest management (16). IPM systems for rice are in varying stages of development throughout Asia (24). Although WARDA has

initiated a pest management program in West Africa, a lot of fundamental information on the biology and ecology of insect pests and their natural enemies is still needed.

MAJOR DISEASES OF RICE

Although about 70 major and minor diseases of rice have been listed by Ou (35), this paper will restrict itself to the more common ones reported in Africa (Table 6).

Blast

Rice Bl caused by *Pyricularia oryzae* Cav. is the most common and severe disease of rice in Africa. The disease is especially severe in upland and drought-prone areas, affecting leaves, nodes, and floral parts, particularly the neck of the panicle.

Distribution. The disease is reportedly serious in Ghana, Mali, Nigeria, Togo, Upper Volta, Guinea Bissau, Senegal, Sierra Leone, and Malagasy (41). It has also been observed in high altitude, low-temperature-prone areas of Cameroon. Although details of the occurrence of this disease in other parts of Africa are not available, it is logical to expect that the disease is widespread in Africa.

Symptoms. Bl on leaves is identified particularly by characteristic spindle-shaped lesions. The disease, however, starts as pin-point lesions, and depending upon the susceptibility of the variety and the favorability of the environment, can kill the entire leaf or plant. A detailed scale for rating the disease reaction on leaves is given in the Standard Evaluation System for Rice (32).

The most serious stage of the disease is neck Bl, or rotten neck, which usually is seen as a blackish necrotic area at the base of the panicle. Sometimes the infection also occurs at the rachis or rachilla causing varying degrees of

Table 6. The parts of plant affected by more common rice diseases and the pathogens involved.

Disease	Part of plant affected	Causal organism
Blast	Leaf, node flowering axis.	*Pyricularia oryzae* Cav.
Leaf scald	Mature leaves	*Monographiella albesens (= Rhyncosporium oryzae)*
Sheath blight	Leaf sheaths, leaves	*Thanetophorus cucumeris (Rhizoctonia solani)*
Sheath rot	Flag leaf sheath	*Acrocylindrium oryzae*
Narrow brown leaf spot	Leaves	*Cercospora oryzae*
Brown spot	Leaves, spikelets	*Helminthosporium oryzae*
Glume discoloration	Spikelets	*Acrocylindrium oryzae*
		Curvularia sp.
		Alternaria (Trichochonis)
		Fusarium sp.
False smut	Spikelets	*Utilaginoidea virens*
Bacterial blight	Tillers, leaves	*Xanthomonas campestris* pv. *oryzae*
Bacterial streak	Leaves	*Xanthomonas oryzae* f. sp. *oryzicola*
Rice yellow mottle[a]	Whole plant	Rice yellow mottle virus

[a] African specific. The rest are reported in most rice-growing countries.

sterility of grains. In susceptible varieties, the nodes of the flowering axis are also infected, causing the panicle to break at the nodes.

Factors favoring the disease. BI is aggravated by drought, low light intensity, and nutritional imbalances, especially K deficiency. At Suakoko station in Liberia, IR3880-17, C22, B451-220-57, and IRAT13 have been identified as R to BI. These, however, need to be confirmed in other locations. Other factors that favor the disease are: excessive N supply, close planting, heavy dew formation, change in the virulence of the causal pathogen, and the susceptibility of the host variety. Temperature also plays an important role; relatively lower temperatures (20-28 C) are more conducive to infection; thus, the disease is more severe in cooler locations and/or in cooler months.

Resistance. Many rice varieties with superior resistance to BI have been identified by carefully controlled screening tests (15). These varieties have shown resistance at several places in multilocational trials. Table 7 lists varieties from different sources with resistance to BI.

Brown spot

Caused by *Cochliobolus miyabeanus* (*Helminthosporium oryzae*), BS has been reported from upland, hydromorphic, mangrove, and lowland ecologies of several countries in Africa. Severe infection of rice plants by BS is reported from Benin, Mali, Nigeria, and Upper Volta (41).

Symptoms. Brown spots, oval or oblong usually with a yellow halo around each, are seen on leaves. The spots vary in size and number; the larger spots are sometimes 5 mm long. The susceptibility of a variety is often determined by the area affected by the spot. Infection can also occur on seedlings, which often leads to the death of seedlings. Seed infection is characterized by spots on the grains.

Table 7. Resistant varieties for rice diseases.

Disease	Resistant donors	
	Tall	Dwarf
Blast	Tetep	ITA257
	Lac 23	ITA120
	OS6	ITA150
	Moroberekan	IRAT13
		IRAT14
Leaf scald[a]	Remadja	–
Sheath blight[a]	Ta-poo-cho-z	Pankaj
	Dissi Hatif	
Bacterial blight[a]	BJ1	IET4141
	DV85	
	Cempo Selak	
Rice yellow mottle	LAC23	
	Moroberekan	IR1846-293-3
	OS6	

[a]Results from tests outside Africa.

Leaf scald

This disease caused by *Monographella albescens (Rhynchosporium oryzae)* has been reported in upland, swamp, and irrigated ecologies.

Distribution. Occurrence of leaf scald in Benin, Ghana, Ivory Coast, Liberia, Nigeria, Senegal, Sierra Leone, and Upper Volta has been confirmed (41). The disease is especially severe in high rainfall areas of West Africa although information on the occurrence of the disease in east, central, and south Africa is scanty.

Symptoms. The symptoms of the disease are seen mainly on leaves. The infection starts from leaf tips or margins as brown necrotic areas and the lesions gradually progress, under favorable conditions, to form successive light-brown and dark-brown bands. The area affected on the leaf varies from negligible to about 50% with older leaves more affected than younger ones.

Leaf scald is reported on varieties with excess foliage and under heavy fertilization. Varieties with broad leaves show more infection than those with narrow leaves. Similarly, low light intensity due to overcast sky tends to increase disease.

Resistance of a high order for this disease has yet to be detected.

Sheath blight

The disease caused by *Thanetophorus cucumeris (Rhizoctonia solani)* is becoming a serious problem in some rice-growing countries of Africa.

Symptoms. Under normal circumstances ShB is often inconspicuous, restricting itself to basal leaf sheaths of dying tillers. The basal sheaths often display oblong blotches usually with water-soaked areas and with light-brown peripheries. Under favorable conditions of high humidity, shade, and heavy N fertilization, ShB moves to the upper leaves that often display band-like zonation, killing the leaves. In extreme cases, ShB reaches the panicles, killing the entire plant or tillers.

Sclerotia are seen on the affected parts. These are whitish when young but dark brown when old. In extreme cases, the tillers die resembling the "kresek phase" of BLB.

Varieties R to this disease have not yet been found although a few tolerant varieties have been reported in Asia (Table 7).

Sheath rot

Caused by *Acrocylindrium oryzae*, sheath rot is becoming important in many lowland areas particularly subjected to low temperature (around 20°C) during flowering period. It is more appropriate to say that sheath rot is a condition which arises out of a situation where the panicles get choked.

Symptoms. Sheath rot is characterized by oblong to irregular brown blotches formed at the base of the flag-leaf sheath covering the panicles. Severe infection reveals visible mycelium (whitish in color) inside the flag-leaf sheath. This leads to infection of the spikelets as they emerge from the infected sheath and often the panicles are incompletely exserted. The affected panicles are often sterile, discolored, and with dark patches.

Glume discoloration

Glume or grain discoloration is often a complex syndrome where saprophytic/pathogenic organisms are involved, and several species of fungi are implicated (35). Grain discoloration can be the result of other infections also as in sheath rot or due to cold or drought-induced choking of the panicles. However, when incubated the infected grains revealed the presence of the following organisms as major ones at IITA (34): *Acrocylindrium oryzae*; *Alternaria* (*Trichochonis padwickii*); *Curvularia* sp. (black kernel); *Fusarium* sp.; and *Nigrospora oryzae* (grain spot).

Symptoms. Discoloration is partial or complete and may restrict itself to the glumes or may extend to the kernel. When the kernels are affected germination is reduced. Grain discoloration is a serious problem since discolored grains have poor marketability and milling recovery.

In heavy rainfall areas the discoloration is quite serious since high moisture tends to promote colonization of these fungi. By contrast, in drier weather, there is less disease. Wounds caused by the feeding of insects are yet another predisposing factor for this disease. The syndrome is more pronounced on high-yielding varieties grown under upland than under lowland conditions.

Varietal screening is in progress to identify varieties with tolerance to grain discoloration.

Bacterial leaf blight

The causal agent of BLB, *Xanthomonas campestris* pv. *oryzae*, has been reported in Cameroon, Malagasy, Niger, and Mali (33, 41). This disease can be a serious constraint in lowland rice production.

Symptoms. At tillering stage BLB is characterized by death of tillers (kresek stage or wilt phase). Affected tillers wilt and die, resembling "dead hearts" caused by SBs. However, unlike the dead hearts, the wilted tillers will not dislodge easily when pulled, and the basal portion is slimy when crushed due to the presence of abundant bacterial cells.

After the maximum tillering stage, the more common BLB symptoms are seen. The margins and apices show wilted, greyish, necrotic, water-soaked tissue, and the border between wilted and green area is wavy. When infected leaves are cut transversely and dipped in distilled water, the bacterial ooze can be seen from the vascular tissue. Excessive N application and low light intensity (shade) can increase disease severity.

Rice yellow mottle virus disease

Unlike other rice virus diseases, the African specific RYMV is easily transmitted mechanically by sap inoculation. Insects with chewing mouth parts, such as *Chaetocnema* beetles, are also known to transmit the disease in the field. RYMV is reported mainly in irrigated or lowland paddy in several African countries, such as Kenya, Nigeria, Niger, and Upper Volta.

Symptoms. The infected plants are generally stunted, the leaves showing yellow discoloration to light-yellow mottling depending upon varieties. Some show orange discoloration while many African-specific upland varieties are highly

tolerant to RYMV. Young plants are more susceptible to RYMV than older ones, and if the infection is severe, flowering is affected. Seed setting is extremely poor in severe cases.

Recently, the wild rice species, *Oryza longistaminata*, has been found to harbor the virus (33) under natural conditions. This suggests that field spread of the virus might result from this species.

BREEDING FOR DISEASE RESISTANCE

The major objective for disease control is to breed R varieties. Although, R varieties are not available for all diseases, donors are available for some (Table 7).

CONTROL

Losses from rice diseases in Africa must be minimized. It is essential that the rice disease situation in each country and in each location be studied with reference to seasonality, intensity, and yield loss. With such information it is possible to use the following strategies to control or minimize losses from these diseases:

- *Use of resistant varieties* — Genetically R or tolerant varieties are preferred whenever such varieties are available. For instance, several BI resistant varieties are available for lowland and upland ecologies, and BI can be greatly minimized by growing such varieties. Similarly, varieties with high levels of tolerance to BLB are available, and if these are tested in disease-prone areas and their resistance is confirmed, then these can be directly introduced or used in an appropriate breeding program.
- *Judicious use of N fertilizer* — Diseases such as BI, ShB, leaf scald, and BLB are aggravated with increased application of N. Therefore, it is necessary to monitor the plant health when N application is contemplated. While fertilizer is necessary for proper plant growth and production, balanced application, particularly of P and K, should not be ignored while excessive doses of N can result in greater disease intensity. Application of K, on the other hand, has been recommended in cases where BS is a serious problem. Some of these beneficial effects of fertilizer use, however, need to be confirmed.
- *Proper choice of planting time* — In areas where the weather pattern and disease cycle are known, it is possible to adjust the planting time to escape the peak disease period. If the cold season begins in October, this will result in BI and sheath rot. Therefore, varieties should either be planted early or early-duration varieties used, so that the crop will mature before the unfavorable season sets in.
- *Appropriate crop rotation* — Diseases can be minimized by breaking the continuity of the pathogen. Therefore, unless R varieties are grown, it is preferable to grow one crop of rice in the most favorable period and to grow a different crop in the following season. The best example is the Sahelian zone where a good rice crop can be grown between June and October followed by a good wheat crop in November-February.

- *Quarantine* — Legislative control of plant pathogens, nematodes, and stored grain pests is an effective tool in preventing their spread in new areas. Phytosanitary and quarantine regulations are rigidly implemented in several countries. Thus, while exchange of germplasm is one of the important steps for crop improvement, this should be done under an effective and speedy plant quarantine umbrella.

CONCLUSIONS

Considering the differences in species of insect pests and disease pathosystems in Africa and elsewhere, genetic improvement must be geared toward resistance breeding. More information on the prevalence, incidence, and extent of damage by insect pests and diseases is needed, especially for central, east, and northern African countries. WARDA has been monitoring the pests and diseases in its member states in West Africa; however, in-depth studies are still needed on the biology and epidemiology of pathogens, and the biology, ecology, and economic threshold of important insect pests, since these components are essential for a sound resistance breeding program and for an effective IPM approach.

Another very important need is for close, continuous monitoring of potentially destructive diseases, such as BLB, virus diseases, and of potential insect pests. The fact that virus vectors, such as BPH and GLH, have been reported in Africa underscores this need.

One can safely conclude that the need for more in-depth research on the insects and diseases of rice in Africa is imperative. Thus, the international research centers, such as IITA, IRRI, and WARDA, and regional centers in many African countries need to help African national programs independently and in collaboration in their respective areas of competency and mandate.

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NATIONAL RICE RESEARCH AND PRODUCTION

RICE PRODUCTION IN KENYA

J. N. NJOKAH

INTRODUCTION

Rice is not a staple food for most Kenyans except for communities along the Indian Ocean. Until recently, rice was eaten mainly on special occasions by the average Kenyan family. However, the trend has changed and rice is now a regular dish, especially among urban communities. Consequently, the very rapid growth of urban populations has placed a strain on rice availability. Also, an improvement in the standard of living of these communities has been accompanied by a shift in taste, making rice almost as frequent as *ugali* (maize meal) in the diet.

Most of Kenya's rice is grown in irrigation schemes. Together, these schemes account for about 90% of the marketed rice. In addition, subsistence level rice cultivation has been practiced in parts of the country for over 80 yr, mainly on the coast and within the Lake Victoria basin in western Kenya. In the irrigation schemes improved varieties are grown with sophisticated technology, and high yields are usually realized. Subsistence level cultivation is more haphazard. Several indigenous cultivars are grown at a relatively low level of technology, usually giving low yields.

AREA UNDER CULTIVATION AND YIELDS

As noted earlier, most of the marketed rice in Kenya is grown in the Irrigation Settlement Schemes managed by the National Irrigation Board, a statutory board of the government. At present there are four such rice schemes. The largest and oldest, Mwea with 5700 ha, is located in the Mwea plains to the south of Mt. Kenya. The other three, Ahero with 500 ha, West Kano with 500 ha, and Bunyala with 300 ha, are located within the Lake Victoria basin. These four schemes together cover about 8000 ha. Presently, the area under subsistence rice cultivation is not well documented, and most of the rice produced is consumed within the family. This is especially true on the coast where rice is a staple food. A substantial amount of rice grown by subsistence farmers in western Kenya is probably marketed. Table 1 presents rice production data from the irrigation schemes in the period 1973-74 to 1982-83.

National Irrigation Board, Nairobi, Kenya.

Table 1. Rice hectarage and paddy yields in irrigation schemes in the period 1973/74 – 1982/83. Annual Reports of the National Irrigation Board, 1973/74 – 1982/83.

Year	Area cropped (ha)	Paddy yields tonnes	t/ha
1973-74	7403	33 563	4.5
1974-75	7249	31 558	4.4
1975-76	7255	36 996	5.1
1976-77	7366	43 640	5.7
1977-78	7949	36 813	4.6
1978-79	8123	34 912	4.3
1979-80	8666	37 476	4.3
1980-81	8743	41 153	4.7
1981-82	8131	38 613	4.7
1982-83	8014	36 412	4.5

Even though rice has been a relatively unimportant cereal crop in Kenya compared with such crops as maize, sorghum, and millets, it is becoming increasingly popular with town dwellers. To meet this increased demand in the last 3 to 4 yr, the government, through the Ministry of Agriculture, has embarked on a campaign to promote rice production under rainfed culture, hydromorphic conditions, and even in small-scale irrigation units. Research on rainfed rice has also been initiated and is geared towards generating appropriate technology for rice production in these areas to supplement the output from the irrigation schemes.

CONSUMPTION, EXPORTS, AND IMPORTS

All of the rice grown in Kenya is consumed within the country although some small quantities were exported to Uganda between 1973 and 1976. When weather conditions permit good crops of maize, wheat, sorghum, and millets, rice imports into Kenya are usually not significant. However, substantial imports were made in 1976 and again in 1981, reflecting adverse weather conditions that created a serious food shortage that necessitated importation of essential food grains such as maize, wheat, and rice, despite fairly stable rice output from the irrigation schemes. Statistics of milled rice imported into Kenya in the period 1973-1981 are given in Table 2.

RICE PRODUCTION SYSTEMS AND ECOLOGIES

As previously noted, most of Kenya's rice is grown in irrigation schemes with water supplied from rivers, and in one scheme, from Lake Victoria. Mwea, the largest single scheme of 5700 ha, is irrigated by gravity, but in the other schemes, water is pumped from rivers or the lake. Land preparation is mechanized and consists of a single wet rotavation operation. Rice seedlings are raised in a wetbed nursery and then transplanted manually by the farmers. In these schemes, cropping is

Table 2. Imports of milled rice (tonnes) into Kenya in the period 1973 – 1981. Statistical Abstracts, Ministry of Finance and Economic Planning, Kenya, 1982.

Year	1973	1974	1975	1975	1977	1978	1979	1980	1981
Tonnes	-23	1502	4	10 001	24	111	241	1239	4939

programmed by the management, and all agricultural inputs are provided to the farmer by the Board when they are required. Fertilizer and pesticide rates are standardized, based on scheme recommendations. Improved varieties are generally grown in the schemes although Sindano and Basmati, two locally adapted varieties, are grown in Mwea because of their high grain quality. The schemes are located at about 1200 m above sea level on soils generally high in clay content and with a pH range of 6.5 to 7.9. Large hectarages around the lake (40 000 ha) are considered suitable for rice production if developed. In western Kenya two crops of rice per year have been grown until recently, but there is now a shift toward a single crop because continuous flooding and the associated problems of land preparation were found to have adverse effects on yields and farmers' incomes. The possibilities of growing a rainfed food crop during the off-season are being explored.

Outside the irrigation schemes, rice is grown in seasonal swamps, valley bottoms, on the shores of Lake Victoria, and on the banks of the Tana River. Here, conditions vary from hydromorphic to continuous flooding, and there is little water control by the farmers. The crop is generally direct sown. Even though some improved varieties may have found their way into these areas, a wide collection of local varieties is still grown, especially in the coastal areas. The same variety is sometimes grown under different names in different areas. Varietal mixtures are common in the seed that is usually grown. As indicated previously, production data from these areas are hard to obtain since most of the rice grown is consumed by the farmers or sold in the village markets. This subsistence cultivation is estimated to contribute not more than 10% of the total rice produced.

In addition to these two rice growing conditions, there are now efforts to promote rainfed upland rice and rice cultivation in small-scale irrigation units.

RESEARCH AND EXTENSION

For a long time, rice research in Kenya has been directed towards irrigated rice to take care of the operational problems occurring in the irrigation schemes. This work has been coordinated from Ahero Irrigation Research Station, located in one of the irrigation schemes, the Ahero Pilot Scheme in western Kenya. There is also a substation in another scheme, Mwea in central Kenya. Because of the very close contact between the research personnel and the extension staff in the schemes, the impact of the research has been significant in ensuring not only stable yields but also high yields of more than 4 t/ha.

Early research work was organized on a project basis by the International Land Development Consultants with FAO/UNDP backing. From its inception, the

major objective has been applied research to assess optimum methods for cultivation of rice and other crops under irrigation. To date, emphasis has been on the selection of suitable varieties, cultivation methods, determining optimum water and fertilizer requirements, and establishing effective and practical crop protection measures as well as soil and water management practices. The information that is generated in the irrigation schemes reaches the farmer quickly because of the very close relationship between the researcher, the extension agent, and the farmer. The researcher and the extension agent belong to the same establishment, and together they organize farmers' seminars, field demonstrations, and training for field staff. Any promising results are tested on farmers' fields to ascertain their validity.

Outside the irrigation schemes, extension services are provided by the Ministry of Agriculture. Research on rainfed rice has recently been started under the ministry.

The most important rice diseases in Kenya include BI caused by *Pyricularia oryzae* and RYMV. The latter is transmitted by leaf-feeding beetles such as *Sesselia pusilla*, *Chaetocnema pulla*, and *Trichispa serica*. These two diseases are more serious in western Kenya, where the first two varieties to be grown in the irrigation schemes, Sindano and Basmati, had to be withdrawn after only a few seasons. Sindano was withdrawn because of its sensitivity to both BI and RYMV, and Basmati was withdrawn because of its susceptibility to BI. They were replaced with improved varieties of the IR series, which through screening trials were found tolerant to the two diseases. The current commercial variety in western Kenyan schemes is IRI561-228-3-3. BG90-2 is also grown on a limited scale, especially in schemes where single cropping is practiced. Some otherwise high-yielding varieties have not been widely grown because of their susceptibility to RYMV. Other diseases that may require attention in the future include ShB, BS, SR, and glume discoloration.

Insect pests that are considered important include SBs (*Maliarpha separatella*, *Sesamia* sp, *Diopsis thoracica*). The sporadic incidence of leaf miners and CW have also been reported. These are usually easily controlled by suitable systemic insecticides. Birds are a serious threat, and farmers must scare them from their fields during the ripening phase. Rats could cause some damage where field hygiene is inadequate.

Theoretically, growing two or more rice crops a year is desirable and should give higher returns per unit area. However, experience with double cropping on large-scale irrigation schemes in Kenya has revealed certain short-comings. It creates a situation where the soil remains submerged for long periods without getting sufficient time to dry. This continuous flooding creates difficulties in mechanized land preparation, specifically the bog-down of tractors. Crop performance is generally poor under double cropping, and it is suspected that some toxic substances probably accumulate in the soil due to the prolonged submerged conditions. Incidence of diseases and insects is also higher under these conditions because of the continuous availability of the host crop for most of the year.

FUTURE PLANS FOR INCREASING PRODUCTION

Recognizing the growing demand for rice in Kenya, the government is committed to increasing rice production in the country. The National Food Policy emphasizes self-sufficiency in food production. Towards this goal, the government is promoting rainfed rice and small-scale irrigation units in several traditional rice growing areas. Large-scale irrigation schemes have also been proposed in the Kano plains in western Kenya and at the Tana River delta at the coast. Indeed, the potential for increased rice production in the country is great.

KEY RESEARCH AREAS ON IRRIGATED RICE IN KENYA

J. J. NJOKAH AND M. M. OKHOBA

INTRODUCTION

Compared with research on other cereal crops, such as maize and wheat, rice research in Kenya is a relatively new endeavor. In the early 1960s, some trials were conducted in Mwea, the oldest and largest of the rice irrigation schemes, based mainly on operational aspects of the scheme. Organized rice research was started towards the end of the 1960s with the establishment of Ahero Irrigation Research Station. This station, located in the Kano plains within the Lake Victoria basin, was set up to conduct applied research to assess optimum methods for the cultivation of rice and other crops under irrigation. The station would also establish the most appropriate irrigation system in view of full-scale development of the irrigable potential of the Kano plain.

To date, the station has grown into a full-scale research station with a mandate covering all aspects of irrigated rice in the country. In the last 3 to 4 yr, the Scientific Research Division of the Ministry of Agriculture has initiated research on rainfed upland rice to meet the needs of farmers who are growing rice along river banks, lake shores, and swampy areas as well as in valley bottoms.

This paper discusses the main research areas on irrigated rice in Kenya. No results from specific trials are presented as the objective is to give a general view of the research activities.

VARIETY SELECTION AND CROP HUSBANDRY

Variety selection

At the time the Ahero Irrigation Research Station was established in 1969, only seven varieties were available in the country, the most popular commercial varieties being Sindano (a local variety) and Basmati 217 (introduced from Pakistan). These seven varieties obviously excluded a large number of indigenous rice varieties that were being grown in several parts of the country (especially at the coast) under subsistence cultivation and which had not been properly collected and identified.

National Irrigation Board, Nairobi, Kenya.

Sindano and Basmati were already being grown commercially at the Mwea Irrigation Settlement Scheme, and with the establishment of irrigation schemes in western Kenya, they were introduced into these new schemes. In the western Kenyan schemes, however, Sindano was found to be seriously susceptible to both BI and RYMV. Basmati was susceptible to BI. After only a few seasons, both varieties had to be withdrawn and suitable alternative varieties obtained. To meet the immediate needs of the disease-prone western Kenyan schemes, it became necessary to import new rice introductions. New cultivars were obtained from IRRI in the Philippines, Tanzania, Surinam, Japan, Mauritius, Colombia, some other Asian countries, and more recently from IITA in Nigeria. To date, there are about 300 cultivars at the research station. These new introductions were screened rigorously at both Ahero and Mwea.

The four main objectives of the selection program are:

- To obtain high-yielding varieties that would increase the yield of rice, thereby making a contribution towards national food production, raising farmers' incomes and minimizing government subsidies.
- To obtain varieties that would not easily succumb to outbreaks of diseases, especially BI and RYMV. This would not only increase production but also reduce the cost of crop protection by use of chemicals. This continuous screening would also ensure availability of alternative varieties in the event of a breakdown of the resistance of existing varieties such as the breakdown of IR579-48-1-2 to BI in the western Kenya schemes in 1977-78.
- To obtain varieties whose maturation periods would facilitate the desired cropping intensity (e.g. early-maturing varieties where two crops a year are grown and late maturing high-yielding varieties where only a single crop is grown per year).
- To obtain varieties with acceptable milling recovery and good cooking and taste qualities.

New introductions must pass through the Plant Quarantine Station in Muguga, where they are screened for the presence of seed-borne viruses, nematodes, pathogenic fungi, and bacteria. Only disease-free material is released. Sometimes heat treatment or tissue culture may be employed to supply disease-free plant material. Once the introductions have passed the Plant Quarantine Station, the screening program adopted at the Ahero Irrigation Research Station consists of the following four stages:

- Observational nurseries in which the seeds are multiplied and assessed for some major traits (e.g. tillering, plant height, lodging, and reaction to major diseases under field infection).
- Variety trials in which statistically designed experiments are conducted on small plots in the research fields in which acceptable varieties from the observational nurseries are compared with commercial checks. The better varieties enter site performance trials.
- Large-scale variety trials (site performance trials) are statistically designed and carried out on large plots on research fields and in the schemes.

- Minibag program whereby small quantities of seed of promising varieties are given to farmers to grow on their fields under standard scheme recommendations.

Observations are standardized according to IRRI's *Standard Evaluation System for Rice* (1).

From these screening trials several varieties outstanding in one or more traits have been identified. For example, IR561-228-3-3, which has medium yield potential (5-6 t/ha), is tolerant to both BI and RYMV, is medium maturing, exhibits no lodging, and has good grain qualities, is now widely grown in western Kenya. Another example, BG90-2, which has high yield potential (up to 8 t/ha), is moderately tolerant to BI but not RYMV, has acceptable grain qualities, and exhibits no lodging, is being grown where single cropping is practiced. Other promising varieties are IR54, IR2793-80-1, BG34-8, BWI96, and IET2254.

In the process of screening varieties, it became evident that some local varieties possessed certain desirable traits, such as resistance to BI and RYMV as well as excellent eating qualities, probably because of their long history of cultivation and adaptation in the country. There are now plans to make a comprehensive collection mission in traditional rice-growing areas of the country to be funded by the International Board for Plant Genetic Resources (IBPGR). The discovery of useful genes in local germplasm and the desire to make a greater contribution towards rice improvement in Kenya have led to the establishment of a modest breeding program at Ahero. This program will strive to solve some specific local problems, especially improving some commercial and promising varieties in those traits in which they are found deficient.

Crop husbandry

Thus far, studies have been conducted on growing seasons; fertilizer rates, methods of application, timing of application, and different sources of fertilizer elements; plant densities; weed control; and crop establishment.

Kenya has a bimodal pattern of rainfall distribution creating what are called a long-rains season (March-July) and a short-rains season (September-December). In western Kenya, studies have shown that a rice crop can be grown successfully in either season if factors such as land preparation are not limiting. Better yields are generally obtained in the short-rains season; the lower yields of the long-rains are probably due to less solar radiation, lower temperatures, and higher relative humidity, conditions that promote the incidence of diseases. Early planting (February-March or August-September) tends to give good yields.

In Mwea in central Kenya, rice is not grown during the long-rains. One reason is low temperatures in the months of June through August, which tend to increase grain sterility. There are also some socioeconomic factors that make yields in the long-rains season lower than those obtained during the short-rains. The long-rains season is the best time to grow food crops, such as sorghum, maize, and various grain legumes. Farmers, therefore, divide their time between looking after their paddy and their plots of food crops. Labor is also evidently scarce during this season.

Fertilizer trials have shown N to be required for rice in Kenya, and current recommended rates are 26 to 52 kg N/ha, using sulfate of ammonia, applied in two split applications. P is deficient in parts of Mwea, and recently an N × P interaction was indicated, with no response being recorded from application of N in the absence of P. No positive response to K has been recorded. Even though there may be benefits to N fertilizer incorporation, so far this has not been practical; therefore, both applications are broadcast. Alternative sources of N, such as urea, have been tested but not found superior to sulfate of ammonia.

Current trials aim at raising the N levels applied as well as elucidating the N × P interaction. A trial is in progress to study the possible use of *Azolla nilotica* (an aquatic fern that lives in symbiotic association with N-fixing blue-green algae) as an alternative source of N. *Azolla* is quite common in paddy fields in western Kenya.

Even though plant population studies have shown 20 × 20 cm spacing to give optimum plant densities, this has not been easy to achieve because of the practical problem of transplanting in rows. There is quite a big variation in the plant densities achieved by different farmers. In Mwea, where low tillering Sindano and Basmati are still grown, a spacing of 10 × 10 cm is recommended.

The most common weeds in the irrigation schemes are grasses, followed by sedges, and then broadleaf weeds. Hand weeding is the most common method of weed control so far, but experiments with herbicides are being conducted in view of growing labor scarcity and rising cost of labor. This labor scarcity has also necessitated investigations to compare transplanting with direct seeding as well as use of rotary weeders and rice transplanters.

Growing two rice crops a year has been practiced in western Kenyan schemes since their inception. A number of problems have, however, arisen necessitating a shift to single cropping. These problems are mainly in land preparation; frequent bog-down of tractors has lead to high breakage, low output, prolonged rototillage periods, and reduced cropping intensities. Attempts to screen short-duration varieties that would increase the turnaround time required for the soils to dry sufficiently have not been fruitful.

The shift to single cropping has made it necessary to look at other food crops that could be grown in rotation with rice. The idea is to grow paddy during the short-rains season and grow a rainfed food crop during the long-rains season. It is hoped that this would also help the farmers in the irrigation schemes to meet their food requirements because to them rice is more of a cash crop than a food crop.

CROP PROTECTION

Entomology

The rice crop in Kenya is exposed to many environmental, technological, and biological factors that influence its yields. Insect pests are constraints to increased rice production in Kenya, especially in cases of high incidence.

A wide range of species infest different parts of the rice plant at various stages of growth, resulting in reduced yields. Among the main pests of rice in Kenya are SBs. The major species recorded on rice are *Maliarpha separatella* (Pyralidae-

Lepidoptera), *Sesamia calamistis* (Nectuidae-Lepidoptera), *Chilo partellus* (Pyralidae-Lepidoptera), and the stalk-eyed borer *Diopsis* spp. (Diopsidae Diptera) composed mainly of *D. thoracica (D. macrophthalma)* and small proportions of *D. apicalis*. Other pests of significance are the CW (*Nymphula depunctalis*, Pyralidae, Lepidoptera), the rice leaf mining beetle (*Trichispa sericea*, Chrysomelidae-Coleoptera), and several species of plant bugs including *Stenocotis* sp and *Aspania* sp.

Since the inception of irrigated schemes in western Kenya, the WSB (*M. separatella*) has remained the most prevalent insect pest encountered. Sporadic incidence of the pink stem borer (*S. calamistis*) and the stalk-eyed fly (*Diopsis*) have been noted to cause some damage. The situation is slightly different in Mwea (central Kenya) where the leaf mining beetle, the CW, and the stalk-eyed fly are the most common insect pests.

Control measures so far have been based on chemical control, and insecticide evaluation trials at Ahero over several seasons have shown carbofuran 5G (a systemic carbamate insecticide) applied at the rate of 1.0 kg ai/ha to be effective on the pest complex of the irrigated schemes. Fenitrothion 50% EC at 0.5 kg/ha has also been used in Mwea. Further insecticide screening studies have indicated suitable alternative insecticides, and economic rates and time of application are currently being tested. Granular formulations are both systemic and selective; thus, they are preferred because they spare and allow influence of such biological control agents as parasites and predators. Preliminary observations at Ahero have shown high *M. separatella* egg and pupal parasitism by the ectoparasite *Cassarina* sp. *(Inchmeumenidae)*. Further intensive studies are being conducted to confirm the parasite/predator species composition and abundance on rice pests with a view to encouraging an IPM strategy. Plant host resistance to SBs is also being looked at, mainly by screening varieties for tolerance/resistance to borer damage.

Birds can also cause enormous damage to the rice crop, the extent of damage varying with seasons. The *Quelea quelea* birds and the village weaver birds (*Ploceus cuculatus*) cause extensive grain loss, while wild ducks, especially *Alopoden* spp, cause severe damage to rice seedlings. Control measures, including aerial spraying and the use of birdscaring devices, have been effected when necessary. To contain the pest problems in the irrigation schemes, a general pest monitoring program has been established; it assesses the incidence, abundance, and seasonal distribution of the common insect pests of rice.

Pathology

Several fungal and viral diseases affect rice in Kenya. The main fungal diseases encountered are Bl caused by *Pyricularia oryzae*; BS caused by several fungal species including *Cochliobolus* spp, *Helminthosporium sigmoidium* (*Leptosphaeria salvinii*) and *H. sigmoideum* var. Irregulare; ShB caused by *Cortisium* sp. (*Rhizoctonia solani*); SR, and glume discoloration which have been found to be caused by a complex of *Sclerotium* based fungi especially *H. sigmoideum* var. Irregulare and other fungi. With the increased incidence and extensive yield loss experienced in the mid 70s due to Bl, research activities were directed

towards selecting for varieties R to BI disease and screening for suitable fungicide for its control. Through this program, R varieties have been identified and are being grown commercially in the formerly BI-ridden zone. Suitable fungicides for the control of common seed-borne fungal diseases have been identified, and currently Benomyl, a systemic fungicide, is used as a standard seed dressing in the schemes. Recently the incidence of BS, SR, and glume discoloration have been increasing; thus, greater emphasis will be required in the future in looking for R varieties. This should be supplemented with cultural and chemical control. The only viral disease of rice recorded in Kenya is RYMV, which is known to be transmittable both mechanically and through insect vectors. Intensive variety screening for resistance to RYMV has been undertaken with positive results. Thus, several varieties, including the commercial IRI561-228-3-3, have been found moderately R. Other studies to control insect vectors, such as *Sesallia pussila*, *Chaetocnemapulla* and *Trichispa sericea*, have shown promise, especially in reducing the incidence of RYMV in susceptible varieties. It has been observed that up to 60% grain yield losses may be incurred when RYMV inoculation is done at 30 DAT or earlier.

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RICE IN TANZANIA

H. M. CHING'ANG'A

THE IMPORTANCE OF RICE

Rice is the world's most important food crop. Rice is a strategic component of food security and a crucial element in the staple food economies of several African countries. Demand for rice in Sub-Saharan Africa is becoming more acute as a result of a general dietary shift from conventional foods, and it is postulated that demand will continue to rise. Production has to be stepped up to avert a serious economic drain on the foreign exchange reserves in most countries.

RICE IN TANZANIA

Tanzania is neither a major world producer nor consumer of rice; however, rice is one of the major cereals grown in the country. It is believed to have been introduced to East Africa by Arabs and Indian traders in early times. Tanzania is the second largest rice producer in East Africa after Malagasy. Rice improvement and production in Tanzania as an important cereal dates back to the early 1920s, when varietal testing and selection were in progress for yield improvement among the local varieties.

Rice area and production

Rice production in Tanzania ranks fourth among the cereals in terms of volume and second in terms of value. The crop is grown in all regions of the country covering an area of over 275 600 ha (7) under extremely varied conditions ranging from upland, rainfed flooded, to irrigated ecosystems. However, most of the rice grown in Tanzania is peasant grown rainfed rice located in the river valleys and basins. The major rice producing areas in the country include:

- Usangu and Kyela plains in the Mbeya region
- Kilombero and Wami basins in the Morogoro region
- Southern plains and Rufiji basins in the Coast region
- Kalimawe plains in the Tanga region
- Bukene and Puge plains in the Tabora region
- Southern parts of Shinyanga in the Shinyanga region

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Irrigated rice is mainly grown on large-scale state farms covering an area of approximately 10 000 ha.

Although rice production in Tanzania has increased gradually by the expansion of area (Table 1), nevertheless, yields have not increased correspondingly. Like many developing countries, Tanzania has been facing the problems of low production under farmers' conditions. The national average rice production per hectare is between 0.5 and 1.0 t only, which seems to be low compared with 3 to 4 t/ha under rainfed conditions in Asian countries. On the other hand, on state farms the average yield is about 8 t/ha. The low yields at the farmers' level may be attributed to such factors as: use of low-yielding traditional varieties, lack of irrigation facilities, poor soil and water management, little or no application of fertilizers and manures, poor weed control, and traditional methods of cultivation.

Self-sufficiency: supply and demand of rice

In recent years, rice has become an important food commodity, and its consumption has increased from 15 kg/yr per person in the 1970s to 34 kg/yr per person in the 1980s. It is estimated that about 50% of the people of Tanzania are rice eaters. The demand is increasing each year and the level of production cannot keep pace with it. The demand for rice has increased to about 383 000 t/yr as income, consumer taste, and population (currently more than 18 million) have risen. Production is below consumption, and rice is imported in some years as shown in Table 2. Tanzania aims to attain a level of production of more than 458 000 t of paddy by 1985, from which it is anticipated there will be buffer stocks to supplement yield losses in unfavorable years and a small surplus for export to neighboring countries.

Rice ecology

Rice is grown in all 20 regions of mainland Tanzania and Zanzibar. Conditions under which rice is grown are varied. Generally, the rice-growing ecosystems in

Table 1. Rice harvest in Tanzania from 1969 to 1982 (6).

Year	Harvested area (1000 ha)	Yield (t/ha)	Production (1000 t)
1969	144	1.9	172
1970	151	1.3	192
1971	151	1.3	202
1972	NA[d]	–	178
1973	NA[d]	–	193
1974	137	1.0	141
1975	137	1.1	157
1976	137	1.3	180
1977	150	1.3	203
1978	250	1.3	260
1979	200	1.2	250
1980	275.6	1.1	291
1981	275.6	1.0	280
1982	280	.9	267

[d]NA[d] = data not available.

Table 2. Rice imports to Tanzania from 1974 to 1982 (6).

Year	Imports (1000 t)
1974	71
1975	64
1976	9
1977	45
1978	55
1979	7
1980	80
1981	45
1982	30

Tanzania can be grouped as follows: irrigated lowland rice (controlled), rainfed lowland periodically flooded, and upland or dryland, and hydromorphic.

Reliable statistics on areas under different ecosystems are difficult to obtain; however, it suffices to mention that most of the rice is peasant-grown under rainfed lowland and swamp conditions where cultivation methods and varieties vary greatly from place to place. Some rice is also grown under upland ecology. At present, upland rice is one of the predominant rainfed crops grown in Zanzibar. Places such as the eastern slopes of Ukiriguru, Usambara mountains, Southern Highlands, and rolling areas bordering Kilombero basin are important for upland rice.

Rainfed lowland ecosystem. This is the predominant rice ecosystem in Tanzania. Most of the peasant-grown rice is in the valleys of the Rufuji river and its three major tributaries (Kilombero, Great Ruaha, and Luwegu rivers). Other valleys include those of the Pangani, Wami, Ruvu, and Ruvuma rivers. Rice is also grown on the flat plains on the shores of Lakes Malawi and Victoria. Swampland in Singida, Dodoma (Bali swamp), Shinyanga, and Mwanza (Kwimba district) are known for swamp rice. Yields in these areas range from 0.5 to 1.0 t/ha.

Irrigated lowland ecosystem. About 27% of total area under rice cultivation is irrigated. Irrigated rice is mainly grown by the National Agricultural and Food Corporation farms at Mbarali, Ruvu, and Dakawa. More than one-third of the country's rice is supplied by these three rice irrigation schemes. Kilangali State Farm, with an area of 300 ha, is now being used for rice seed multiplication. Yields are generally high in this ecology varying from 8 to 12 t/ha. Presently, only one crop is usually grown in the WS at Mbarali due to low temperatures during June and July and lack of a short duration variety. Very few farmers traditionally irrigate their rice paddies, but areas where irrigation is practical are found on the Usangu plains where Mbarali is located, in the Mkomazi valley in northeastern Tanzania, and the Magugu district in the Arusha region. Such farmers obtain up to 4 t/ha even though fertilizers are rarely used.

Upland ecosystem. Upland rice is grown on naturally free-drained soils where the water table is always below the rice roots. Therefore, the moisture supply is entirely dependent on rainfall. This type of culture is found in such places as the eastern slopes of the Uluguru and Usambara mountains, in the Southern Highlands, and in the rolling areas bordering the Rufuji basin. Only a small proportion of the total area under rice cultivation is grown with hydromorphic rice.

Production problems

Although the area under rice production has been increasing steadily from the 1970s to date, yields per hectare have been decreasing. Low yields realized in Tanzania can be explained by a number of constraints: environmental, biological, management, and socio-economic.

Environmental constraints. There is no doubt that rice production in Tanzania is more influenced, especially in recent years, by the amount and distribution of rainfall than by any other factor. Information gathered to date indicates a close association between cereal grain shortage and drought incidence. For instance, rice yields were low between 1973 and 1976 due to drought. On the other hand, some years registered low yields due to floods caused by excessively heavy rains.

Temperature greatly influences the growth pattern, duration, and yield of the rice plant. In high altitude areas, such as Kilimanjaro and the Usangu plains, low temperatures limit production. In such areas the mean minimum temperature towards the end of the growing season drops below 20°C. At Mbarali only one crop of rice is produced per year due to low temperatures during June and July.

Biological. The major biological constraints are the lack of high-yielding improved varieties, and damage due to diseases, insects, and weeds. Farmers need varieties with reasonable but stable yield levels, appropriate growth duration, and tolerance or resistance to environmental stresses and devastating diseases and insects (2).

1. *High yielding improved varieties* — Most peasant farmers in Tanzania use traditional, low-yielding varieties grown in mixtures. Emphasis is placed on aroma, flavor, and nonstickiness as the criteria for deciding which variety to grow. The traditional varieties are numerous and sometimes extremely mixed; this results in uneven ripening, which makes harvesting laborious and prolonged. These varieties are both poor in yield and plant type and lack disease and insect resistance. Examples of these varieties include Supa India, Kihoc,o, Faya, and Afaa strains.

The MVs, such as Supa 8 and IR579, are grown on state farms only. Peasant farmers do not accept them mainly due to their poor cooking and eating qualities. These rices are non-aromatic, sticky, and dry up when cooked. Also, due to their short stature, the MVs are prone to flood damage, and attempts to encourage farmers to adopt them seem fruitless.

It is our hope that with the release of the new variety, Katrin (IE 72397), IR8 will be replaced. Katrin has high yielding ability and good cooking and eating qualities.

2. *Diseases and insect pests* — Losses due to diseases and insects are estimated at more than 20%. Among the fungal and bacterial diseases, Bl is the most widespread and devastating disease in Tanzania. Leaf, neck, and panicle Bl have been recorded in most areas where rice is grown. There is no variety available in Tanzania that is immune to the disease, but some, especially the introduced IRRI and IITA varieties, have shown differing levels of resistance to Bl.

BS is also very common in all rice-growing areas, especially those under upland rice culture. It is not as damaging as Bl most likely because it occurs late in the growing season when rice starts to or has already booted. It is more devastating in those areas with low fertility sandy soils and those stricken by drought. Narrow BS

caused by *Cercospora oryzae*, though common and widespread, is a minor disease occurring late in the season.

White tip caused by *Aphalenoides oryzae* has not been given much attention in Tanzania probably due to its concealed nature of expression and loss, which is sometimes enormous. Samples randomly collected from most rice-growing regions of Tanzania all revealed these nematodes. Nematodes were observed even in rice samples without symptoms.

BLB is a major disease in all areas of Tanzania where rice is given supplementary irrigation, such as on the state farms and in those areas naturally flooded in valleys and low-lying areas. Generally, there are few data on diseases of rice in Tanzania. More diseases than have been reported here are certainly damaging the rice crop, but they need to be studied before there is confidence to report them.

Quite a number of insect pests have been observed in rice fields. Some of these insects have been studied in other countries but not in Tanzania. Insects, such as the striped SB (*Chilo*), the pink SB (*Sesamia* sp.), stalk-eyed fly (*Diopsis macrophthalmia*), are known to damage rice in the fields. However, losses caused by them are considered to be minor. Another insect of importance is the cutworm (*Spodoptera* sp.). These are very devastating in some years and almost unnoticed in others. They can cause up to 100% loss if the rice plants are attacked 2-3 WAS.

3. *Weeds* -- Weed control is one of the most labor-intensive operations in rice production. In Tanzania, hand weeding is the most common practice of controlling weeds among the small farmers. Use of herbicides in rice culture is still limited for a number of reasons, among which the cost-benefit ratio is crucial. When improved weed control practices are compared with techniques currently used by the farmer, the increase in rice yield is often about 10% or an average increase of 0.25-0.5 t/ha (2).

The distribution of the major weed groups (grasses, sedges, and broad-leaved weeds) in Tanzania is irregular, but all three groups occur at serious levels of infestation in the different rice-growing cultures. The major weed species common in the different rice ecosystems include grasses, such as *Echinochloa colona*, *Eleusine indica*, and wild rice (*Oryza longistaminata*). Broad-leaved weeds consist mainly of a stoloniferous *Convolvulus*, *Ipomoea aquatica*, *Commelina* spp., *Stylanthes mauritiana*, *Calinsoga parviflora*, *Ludwigia abyssinica*, and *Ammania baccifera*. Of the sedges, *Cyperus* spp. are the most serious.

Management. Yield is the expression of the interaction between the genotype and environment. Management creates a favorable or unfavorable environment. The yield potential of MVs can only be realized if improved cultural practices are adopted. Of importance are: good land preparation; proper use of seeding rates or spacing (in cases of rice grown in rows); weed control; the right planting time; water control and management under irrigated ecology; and sufficient use of fertilizers. The situation in Tanzania now is that a majority of the peasant farmers have had little exposure to the use of these innovations. They still use traditional cultivation practices.

Socioeconomic constraints. The unavailability or delayed arrival of inputs,

such as improved seeds, fertilizers, pesticides, herbicides, and credit, are some of the factors contributing to low yields in Tanzania. Also, the high labor input limits all good husbandry, and research and extension linkage is absent.

RESEARCH AND EXTENSION

There is ample evidence that increased rice production in Asian countries was achieved by improving the research and extension services (2). The role of the researcher is to develop new technology, while the extensionist transfers it to the farmer. Although some research findings are available from the research stations, these have not been extended to and used by the farmer. There presently exists no satisfactory linkage between research and extension in Tanzania.

The developed technology needs to be evaluated by the researcher at the farmers' level through on-farm demonstrations and trials. Since the colonial times, emphasis has been placed on station-based research rather than farm-based research. Therefore, extensive off-station trials need to be organized and conducted by the crop coordinators in collaboration with extension agencies under the Adaptive Research Program. Such programs need proper infrastructure, adequate manpower, transport, and financial resources in terms of inputs to be given to the farmers in the initial stages. Unfortunately, these are all grossly lacking in both research and extension services.

Research

The agricultural policy of the government of Tanzania is to support production to the domestic market most heavily while continuing to export some processed farm products in order to earn foreign exchange. Long-term agricultural development will require increased efficiency by improving farming systems and techniques used by farmers rather than by merely increasing the area planted. The workers and peasants, who now constitute more than 95% of the farming community, will be the historic vehicle of development, and as a matter of priority, research policy and emphasis will be put on their problems.

During the colonial past, the research system was geared to the needs of relatively large capital-intensive farms. The system served the interests of small farmers on a very limited basis. Consequently, crop production levels from small holdings have remained inherently low in comparison with those attained on large estates or plantations. The new agricultural research strategy is to develop economically viable crop production packages of recommendations by farming systems research methodology as opposed to the single commodity interdisciplinary approach of the past. Emphasis is being placed on the improvement of food grains, such as rice, with the ultimate aim of attaining self-sufficiency in food.

In 1974 under the Directorate of Crop Development of the Ministry of Agriculture, 18 crop research coordinating committees were established for each crop or discipline program in order to: plan research projects for each crop or program; and to monitor the performance and evaluate the effectiveness of each. These committees, each headed by a coordinator (a senior scientist in the

particular field) meet once each year to review the research projects and formulate recommendations wherever appropriate. Members of these committees include research scientists in the program and extension and other representatives engaged in work related to the particular program. A maximum of 12 to 20 members is recommended for each committee.

In 1981 the research set up under the Division of Research of the Ministry of Agriculture was given a parastal status and fell under three major organizations: Tanzania Agricultural Research Organization (TARO), Ilonga Agricultural Center, and Tropical Pesticides Research Institute. TARO has responsibility for all of the agricultural research activities in the country except in four southern regions.

Research on rice in Tanzania started as early as 1935 at Ukiriguru, but emphasis on rice began in the 1960s when research was based at Ilonga Research Institute near Kilosa in the Morogoro region. In 1975, the rice research headquarters was moved from Ilonga to Ifakara where liaison and coordination of rice research of the Institute is done. In 1985, aware of the glaring need to increase rice production, the government of Tanzania decided to intensify and strengthen its research efforts to meet the increasing demand for rice arising from population and urban growth. The need to achieve self-sufficiency in rice production was a realistic goal. The strategy included the initiation of a national rice improvement program through research and pilot irrigation schemes in the major rice-growing areas of the country.

Attempts have been made to develop varieties with greater yield potential for Tanzania's varied agroecological zones since 1935 (1). The present rice breeding program was initiated at Ilonga in 1966 (4, 5). The program has two broad responsibilities: varietal development and improvement of management practices. The main thrust of research has been on breeding, but some work on agronomy was also undertaken.

The objective of the breeding program is to develop varieties with the following characteristics: higher grain yield, resistance to diseases (especially BI), lodging resistance, non-shattering habit, short stature, early maturity, and high seed protein. The breeding work has concentrated on improvement through selection of indigenous rice varieties, varietal introduction and evaluation, hybridization between local and introduced varieties, and mutation breeding of indigenous varieties. Outstanding lines from this work have been screened in multilocational National Variety Trials since the late 1960s. Based on these trials several varieties have been released to farmers.

Work on improvement of some of our traditional varieties through selection started at Ilonga in 1966 (4). A number of local varieties have been developed through pure-line selection. It has been shown that some of the traditional rices have a potential yield of 6-7 t/ha after they have undergone selection. Varieties developed through this method include Faya Theresa, Afaa Mwanza selections I/159 and 0/746, Kihogo Red (Morogoro), Kihogo selections 7, 22, and 23, Gamti (Tunduru), and three upland varieties (Dunduli ya Milimani, Salama, and Afrika).

Hybridization work, involving a series of crosses between local and introduced varieties, was started in 1971 at Ilonga. Outstanding lines advanced to the ninth generation were further screened in the multilocation National Variety Trial, and

on the basis of this trial, one promising line was recommended and released to farmers in 1983. The variety has been named Selemwa.

From testing and evaluation trials, IET2397, introduced from IITA, was released to farmers in 1983 and later named Katrin. Some useful materials have been identified from the mutation breeding work. Although promising, most of these are tall with a high incidence of lodging. Although rice research has registered a number of successes, it continues to face problems, some of which are: 1) insufficient funds to meet both recurrent and development expenditures, 2) inadequate research infrastructure facilities, 3) inadequate transport to supervise field trials, 4) unavailability of experienced rice researchers, and 5) lack of rice publications.

Extension

Agricultural extension in Tanzania is divided into field- and center-level extension. Field workers are controlled at the ministerial level under the Extension and Technical Service Division. The extension machinery has not been able to contribute much because of the following constraints: 1) inadequate research technology available for transfer to farmers, 2) lack of transport facilities, 3) lack of proper work plans, and 4) lack of liaison with research staff for field demonstrations.

FUTURE PLANS

There are two options for increased rice production in Africa; these are expanding the rice cultivation area and increasing yield per unit area (2). By increasing the land area under controlled irrigation, and by an expanded research effort and an integrated rice development program for peasant farmers, Tanzania will reach its goal of self-sufficiency in rice production in the near future.

Tanzania offers good opportunities for the rapid expansion of rice cultivation in areas such as the Rufiji basin and the swampland in the Kwimba district and the Shinyanga region. Attempts are being made by the government to expand the area under irrigated rice. A recent move in that direction has resulted in the expansion of the Mbarali Rice Farm and the development of two other irrigation schemes at Madibira and Kapunga in the Usangu Plains, as well as some smaller ones near Bukoba to the west of Lake Victoria, and in the Tanga region in the Korogwe district.

Available statistics show that the Rufiji River basin has great potential for agricultural development. The basin covers an area of 177 000 km^2, which is about 20% of the total land area of mainland Tanzania. A nationwide total of 622 400 ha has been identified as suitable for irrigation. Of this, 329 600 ha are in the lower Rufiji valley. Another 208 000 ha are in the Usangu plains where Mbarali is situated, and 4800 ha are in the Little Ruaha valley. The Rufiji basin is drained by the Rufiji river and its three major tributaries. In fact, the basin covers entirely or in part, 8 of mainland Tanzania's 20 regions. These are the Coast, Morogoro, Dodoma, Mbeya, Iringa, Ruvuma, Lindi, and Singida regions.

The Kilombero valley, where the Agricultural Research Institute Ifakara is situated, covers an area of about 11 000 km^2. The broad and almost level floor of this valley lies at an average altitude of 300 m. Almost all of the area experiences six wet months. The rainy season usually begins towards the end of November, and it ends between the middle and end of May. There are marked spatial differences, but the mean annual precipitation in the Kilombero valley is between 1000 and 2000 mm. The temperatures are typical of a semi-humid tropical valley. The mean monthly minimum and maximum temperatures range from 16 to 23°C and 27 and 35°C, respectively. Rice is the main crop in the valley, generally grown as rainfed rice, but along the banks of the river it is irrigated using flood water from the river. The area offers potential for small-holder development of rice production without the need for large-scale investment (3).

As for the second option, sizeable increase in rice production can be achieved through a balanced combination of research and extension and through added incentives to produce more. To release the second option above, our research efforts should be expanded. The research capabilities of Tanzania, as in other African countries, are much more limited than in the rice growing countries of Asia. Having realized this, the government readily signed a memorandum of understanding with IRRI in October 1983 aimed at enhancing Tanzania's capabilities in research on rice and rice-based cropping systems. According to the memorandum, the Genetic Evaluation and Utilization (GEU) Program, designed to develop varieties that possess high-yielding potential, good grain quality, and resistance to prevalent diseases and insects, will be given priority. Other areas of research to receive emphasis will include soil and crop management. Particular attention will be given to the efficient formulation and methods of application of fertilizers (particularly for rainfed systems), to the use of organic manures, and to the contribution which biological nitrogen fixation can make to rice production. Since the area under the irrigated ecology is going to increase, irrigation water management research is needed to identify how the use of irrigation water can be made more efficient so that less water is used to obtain equal or greater rice yields. The rice research program, among others, is one of the most starved as far as manpower is concerned. To date, there are five scientific officers, one Ph.D. and four M.Scs. As noted above, the program will continue to experience an acute manpower shortage if this research is fully undertaken. It is hoped that a steady and significant training program will be embarked on in cooperation with IRRI and IITA.

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THE STATUS OF RICE PRODUCTION, CONSUMPTION, AND RESEARCH IN ZIMBABWE

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INTRODUCTION

Rice as food is widely accepted by both black and white Zimbabweans. Due to its restricted availability and higher cost compared with maize, rice is considered a delicacy by the black community. Palmer and Parsons (2), writing about the history of Zimbabwe for the period 1890-1909, pointed out that Shona farmers produced a wide variety of crops including rice. Sawer (3) stated that rice was a staple diet for the Mashona people in the 19th century before its displacement by maize. Unlike maize, rice presently occupies a very small proportion of the agroindustry of Zimbabwe, and various reasons can be given for the current low level of rice production in Zimbabwe. However, the continued increase in local consumer demands for rice, which far surpasses local production, coupled with Zimbabwe's policy of self-reliance in food production, have prompted the country to re-examine local production potentials.

RICE PRODUCTION SYSTEMS

Two rice production systems exist in Zimbabwe: *vlei* rice production on hydromorphic soils; and irrigated commercial production. The former is practiced by communal area farmers while the latter is the system used by state farms and white commercial farmers. Evidence shows that *vlei* rice production has been practiced in Zimbabwe for more than 100 yr, while irrigated rice production was started in the 1950s in drier and warmer parts of the country.

Vlei rice production

The *vlei* rice system is practiced at a subsistence level and has changed very little over the years. Rice fields are generally located in valley bottoms, river banks, and other areas with slow drainage. The soils in these areas are generally Vertisols. Due to their subjection to marked hydromorphy, these soils invariably have grey subsoil colors and possess a zone of mottling as a result of the seasonally fluctuating water table.

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The duration of the hydromorphic conditions varies with rainfall amount and distribution, catchment area, water table, and various aspects of water loss. These factors determine whether or not *vlei* rice can be grown. The exact area under *vlei* rice production has not yet been determined although this system of production is practiced in many parts of the country where hydromorphic conditions exist.

Soil tillage with ox-drawn plows is normally done in winter while the soil is still moist from residual moisture. The crop is sown before the major rains. This is done to ensure that the crop is in the ground before the soil is too wet since these soils are difficult to work under wet conditions. The previously harvested crop generally supplies seed for the following crop. The seed is broadcast, and either an ox-drawn branch or a spike-toothed harrow is dragged across the field to incorporate the seed.

Rice is usually intercropped with maize. This is done to reduce the risk of crop failure. Monoculture rice is also common. In wet years a good crop of rice is harvested while maize may fail, and the opposite is true in drier years.

Almost no *vlei* rice growers apply fertilizers or pesticides to their rice crops except in a few cases where fertilizer is applied to the maize. Weeding is normally delayed since farmers give first preference to weeding dryland crops (maize, groundnuts, etc.). One or two hoe-weeding operations per rice crop are common.

Several *vlei* rice varieties and lines have been grown over the years. The exact types and origins of these varieties have yet to be determined. They closely resemble the indica types, being tall, leafy, and late maturing, but they are still adapted to local conditions. These varieties include both red and white rice types when classified by the color of their pericarp. They appear to have been selected for low input conditions as evidenced by their poor response to higher N levels. They are resistant to various diseases, although the red rices are susceptible to BI caused by *Pyricularia oryzae*. Grain discoloration caused by the fungus, *Nigrospora oryzae*, is common throughout the country, but it does not appear to cause serious crop damage. The *vlei* varieties have a high tolerance to a variety of stress factors and show a good ability to recover from moisture stress and grazing.

The average rice yield in *vlei* cultivation is 1.0 t/ha although this fluctuates depending on the amount of rainfall and its effect on the duration of hydromorphic conditions. During wetter years, yields increase to over 1.5 t/ha. During drier years the crop may be a complete failure. The total production from these areas is not known since the total hectarage has not yet been determined. All of the rice produced under this system is consumed in the area of production.

Traditional rice harvesting is done several times in sequence since the rice panicles ripen unevenly from the main culm to the later tillers. *Vlei* rice is panicle harvested by hand using knives. The bundles of panicles are placed in hessian bags. The rice is later sun dried, either in the harvesting bags or on protected, clean, sand-free surfaces. The traditionally-acquired knowledge of processing this crop is used to determine when the panicles are dry enough for threshing. The panicles are either threshed in the open or within the sacks. The straw is removed and the paddy is winnowed to remove the chaff. Clean paddy is further sun-dried to required MC. Subsequently, the paddy is filled into 50-kg hessian bags or into 25-litre oil tins to measure yield. The paddy is then stored in bags or placed in

traditional granaries. Paddy thus dried and stored can keep for 24 mo or more, but seed is usually renewed yearly.

The rice is processed by traditional methods of pounding with mortar and pestle followed by winnowing. The polishing and pearling thus achieved is very slight, yielding grains with a lot of red or brown tegmen. For red rice destined for rice flour, the partially polished rice is washed and soaked for a short time to soften it for pounding or grinding into flour. After being soaked, the rice is spread to dry off excess water before it is pounded or ground and sieved into flour. A grinding stone is used for grinding. The resultant flour is sun-dried and used to prepare *sadza* (a stiff porridge made from maize, sorghum, finger millet, other millets, and rice flours). This is a staple in the diet of black Zimbabweans.

Rice dishes are prepared in a variety of ways by the black community in Zimbabwe. The white rices make boiled rice dishes. Plain boiled rice is eaten with relish dishes, such as meat or vegetable stews. The glutinous red rice is traditionally ground into flour and made into a traditional porridge. Due to the inadequate availability of rice, all these dishes, though preferred to others, are considered delicacies and reserved for special occasions.

Commercial production

Commercial rice production under irrigation in Zimbabwe was initiated in the early 1950s although the enthusiasm for it was not accompanied by a full complimentary production technology. Various problems became apparent including: diseases, weeds, nutritional disorders, and processing. Because of these problems, commercial production was greatly reduced although research efforts were continued to investigate the various aspects of rice production. Consequently, research has produced some very useful results and recommendations, which are currently being used.

The total hectarage under commercial production is very small. About 400 ha were planted to rice during the 1983-84 growing season. Only two producers, namely, the Agricultural and Rural Development Authority (ARDA) and the Buffalo Range Group constitute this hectarage. ARDA estates are growing rice on black basalts in the western part of the country while the Buffalo Range estate is in the Southeastern Lowveld and lies on paragneiss soils (redclay loamy soils). Both estates are in the semi-arid regions with low rainfall (average 500-600 mm). Day temperatures range from 29°C to more than 40°C and night temperatures from 16°C to 25°C.

Both estates are growing rice under flood irrigation. Sprinkler irrigation was used at Buffalo Range until recently when it was replaced with flood irrigation, which proved to be a better system. Rice is irrigated at 40% depletion of available moisture giving 15-20 irrigations per crop.

The crop is drilled at 100 kg/ha seed rate in 20-25 cm rows. A post-emergent herbicide is applied at sowing to control major weeds. One or two hand weedings may still be necessary. High fertilizer inputs under this intensive system are necessary. N application rates range between 100 and 250 kg N/ha with appropriate P and K levels, depending on the soil types.

Three varieties are being grown commercially: Blue Belle, Le Bonnet, and

IR400. The first two are from the USA while IR400 is an IRRI variety. Blue Belle and Le Bonnet are long-grained types which are acceptable to the local market, while IR400 is medium-grained and is not popular on the market even though it gives the highest yields. Table 1 shows some of the characteristics of these varieties observed over 3 yr under sprinkler-irrigation conditions in the Lowveld. Paddy or flood-irrigation systems would give slightly different results. Commercial producers would average approximately 70% of the research yields shown in Table 1.

Rice is harvested by combine harvesters. Varieties that are suitable for combine harvesting are preferred. IR400 is unsuitable because its panicles do not stand above the canopy. Harvesting is normally done when the grain MC has reached between 22 and 25%. Crop harvesting at lower grain MC levels has been shown to affect quality. Tampering System Driers are used for drying the grain to between 13 and 15% MC before processing. The few processing machines available in the country for hulling and polishing have a recovery rate of 50-60%. This is a rather low recovery rate and could be improved by acquiring more modern machines.

Commercial rice production reached a peak in 1970 when 1488 ha were grown, and thereafter, production declined continuously. This decline is largely attributed to the decision made by the Sabi-Limpopo Authority to cease production in view of production and marketing problems experienced in 1969-70. Production problems included BI disease, nematode infestation, irrigation control, and bird menace (Quelea). Subsequently, research has found solutions to some of these problems.

Local rice production provides a relatively small proportion of the total domestic requirements. Table 2 shows details of paddy rice production in white commercial farming areas and purchase area farms owned by blacks. The area planted to rice from 1980 to 1984 decreased markedly, and no figures of total production are available for this period.

RESEARCH AND EXTENSION

Rice research has gone through peaks and falls between 1952 and 1984. However, the need for research on this crop has always been appreciated, and after having identified production problems in the 1950s, researchers have been able to solve some of them. Generally, the problems included the following: irrigation problems, fungal diseases (particularly BI), nematode infestation, varietal selections, weeds, harvesting, and processing. Since rice production has been undertaken on a very limited scale, very little extension has taken place.

Table 1. Characteristics of three varieties grown commercially in Zimbabwe.

Variety	Yield (kg ha⁻¹ (12.5% MC))	Maturity (d)	Blast rating	Height (m)	Lodging (%)
IR400	7 398	147	Very light	0.81	0
Le Bonnet	7 028	123	Very light	1.3	3
Blue Belle	6 072	116	Very light	1.36	3

Table 2. Commercial rice production and trade from 1974 to 1978 (1).

Year	Area planted (ha)	Production (t)	Imports (t)
1974	727	395	6 860
1975	857	592	5 597
1976	569	310	1 744
1977	480	260	8 073
1978	605	453	2 766

FUTURE PLANS FOR RICE PRODUCTION IN THE COUNTRY

The need to develop and increase rice production in Zimbabwe has now been fully appreciated. The Department of Research and Specialist Services (DR & SS), which has a national mandate to conduct research on food crops, has included rice in its priority areas for research and development. Plans are being made to formulate a national rice research and development program.

A chairman was appointed and charged with the task of forming a coordinating committee for rice production. The committee is to include representatives of departments and institutes that are presently or would in the future be involved in rice production or research. These have been identified as: Assistant Director (Crops Research Division); Assistant Director (Research Services Division); Head, Lowveld Research Station; Head, Plant Protection Research Institute; Head, Chemistry & Soil Research Institute; Head, Agronomy Institute; the Rice Agronomist and representatives from the Departments of Agriculture, Technical and Extension Services (Agritex), and Rural Development and Cooperative Development. The committee's terms of reference are to review all existing knowledge of rice production in the country with a view to making it available for the purpose of stepping up productivity in both the commercial and communal areas. The communal areas are the former Tribal Trust Land, for example, land held in trust by the President of Zimbabwe.

Long term research and development plans are under the auspices of the DR & SS. These will involve an appraisal of rice research and production methods in the country and the formulation of a national rice research and development program. In formulating a national research program, assistance from and liaison with international organizations and research institutions involved in rice research and development are considered necessary, hence our participation in the present workshop.

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RICE RESEARCH IN ZIMBABWE

I. M. MHARAPARA AND N. R. MUGABE

INTRODUCTION

Two systems of rice production are practiced in Zimbabwe: commercial production under irrigation in the semi-arid regions of the country; and traditional subsistence production under hydromorphic conditions (*vlei*) in the higher rainfall areas. Rice research work under irrigation commenced in the early 1950s at the Lowveld Research Stations. These stations serve the semi arid regions of the country, ie. the Lowveld, characterized by low rainfall, hot, dry summers, and occasional *guti* weather (heavy overcast with drizzle and cool winds).

Initially, research efforts concentrated mainly on the investigation of irrigated commercial rice production techniques. Rice production under hydromorphic conditions has not received much attention. Considerable knowledge of rice growing under irrigation has been accumulated from work conducted at the Lowveld Research Stations, and this has been used to formulate recommendations on most aspects of production. Nonetheless, more research work over a wider range of agroecological conditions needs to be done under both irrigated and hydromorphic conditions.

PREVIOUS RICE RESEARCH EFFORTS

Various aspects of rice production under irrigation in the southeastern Lowveld of Zimbabwe have been investigated since 1952. Some of the investigations produced conclusive results while others are being continued.

Germplasm collection and screening

Only a few varieties are considered indigenous to Zimbabwe. Among the indigenous or local varieties, the red pericarp types seem to be dominant. The history of germplasm introduction dates back to the late 1940s or early 1950s. These introductions came from the following sources: U.S.A., India, Philippines, China, and recently from Japan and East and West Africa. The national rice

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program continues to acquire promising lines from various sources and to test them for adaptability and performance.

The first rice variety trials involving 42 entries were conducted at Sabi Valley Experiment Station in the early 1950s (Sabi Valley Annual Report 1950-55). Most of these varieties, except one called Ambarikore, performed very poorly in terms of yield, susceptibility to disease, and lodging. Variety trials have continued as more introductions were acquired. The emphasis on screening has been, until very recently, on high input and management-responsive varieties suited to the irrigated commercial rice production schemes. The following characteristics were selected for: high yield under conditions of high inputs of fertilizer, pesticides, and machinery usage; long grain; efficient water usage; low grain cracking percentage; short stature and lodging resistance; early maturity (i.e. 100-130 d); resistance to diseases (particularly BI caused by *Pyricularia oryzae*); photoperiod insensitivity. As a result of this work Blue Belle emerged as a variety with most of the above requirements.

The realization of the need for research on *dry* rice has necessitated initial selection for varieties with most of the characteristics identified in the commercial rice research as well as the element of drought tolerance.

Seed size

Investigations on seed size were conducted in which grains of four varieties were separated into four length categories (long, short, intermediate, and mixed lengths) before sowing.

The investigations yielded the following trends:

- The mean grain weight, as represented by the 1000 grain weight of harvested seed, was not affected by the size of seed planted.
- There was a tendency for seed with longer grains to produce a greater proportion of long grains than the shorter or unselected seed.

The implications of this are important because indications are that seed size is heritable and that selection for increased length can result in progeny with longer grain, a desirable commercial attribute. The work to study the heritability of grain size and its implications for increased yield may be resumed. Results from IRRI suggest that for isogenic lines that differ only in seed size, a yield increase with larger grain is possible.

Spacing and seedrates

Trials conducted on variable plant population densities as affected by spacing and seedrates produced the following results:

- A linearly decreasing trend for lodging with increasing seedrates.
- No significant difference in yield was obtained under row spacings ranging from 150 mm to 460 mm. Variation in yield may be associated with lodging in varieties that are susceptible to lodging.
- No significant difference in yield was shown with seedrates ranging from 50 to 100 kg/ha. A linear trend showing an increase in yield with lower seedrates has been observed.

- The number of panicles per unit area decreased with an increase in row spacing, and it increased with higher seedrates, particularly at wider spacings.
- The weight and number of grains per panicle were not influenced by row spacing, but they decreased with increasing seedrate at any given spacing.

From this work the following recommendations have been drawn: row spacing should be between 20 and 30 cm, and seedrate between 70 and 100 kg/ha, depending on the availability of seed. The actual seedrate has to be adjusted at all times depending on the germination percentage of the particular batch of seed.

Fertility

Most of the research work on rice has been done on paragneiss soils (chromic alfisols). The soils vary greatly with respect to depth and texture, but most are shallow to moderately shallow and are characterized by large reserves of weatherable minerals. The phosphate status is inherently low which necessitates maintenance applications of phosphate (80 kg P_2O_5) to every crop. Potash status of the paragneiss soils is relatively high, and no yield responses to potash have been demonstrated. The fact that the soils are inherently low in mineral N has confined fertility studies to those involving N. The average pH of these soils lies between 5.5 and 6.5 ($CaCl_2$).

The N requirement of rice has been investigated with respect to total N application, split applications, and timing of split applications. A summary of results obtained follows:

Requirements

- The optimum N requirement is between 135 and 145 kg N/ha. It has been shown that rice responds to high levels of N up to a point when lodging becomes important, especially with tall varieties.
- N response is more pronounced following a cereal such as wheat than it is after a legume.
- The crop's response to N is quadratic in nature and can be affected by variety, field conditions, planting date, and disease.

Time of application

- The level of N applied at planting is one of the most important single factors determining yield.
- Optimum topdressing time was found to be at panicle initiation stage (elongation of the second internode), and this was found to be at 77 d from planting for Blue Bonnet.
- Splitting topdressing is more beneficial for late-maturing varieties than it is for early-maturing varieties.
- Yields are decreased considerably by delaying topdressing to later than the stage of elongation of the second internode.
- Too early an application of topdressing tends to increase vegetative growth and height.

- Where topdressing is essential, two topdressings are adequate and have been shown to increase yield slightly. More than two applications is not beneficial on certain soils.
- Milling percentage increases with N levels for Blue Belle (60 kg N/ha: 62.1%; 300 kg N/ha: 71.7%).
- Polished whole grains increase with N levels for Blue Belle (60 kg N/ha: 22.8%; 300 kg N/ha: 56.5%).

Crop water use and irrigation schedules

The objectives of these studies were to determine the effective use of water by the rice plant, to determine whether measurement of open-pan evaporation would provide a satisfactory estimate of evapotranspiration, and to determine the influence of a reduced soil moisture regime on evapotranspiration. The following results were obtained:

- Actual crop evapotranspiration (Et) as a fraction of pan evaporation (Eo) ranged from 0.32 in the early growth stages to 1.05 at full canopy.
- Peak Et/Eo ratio coincided with panicle differentiation, maximum water use, maximum effective root depth, and peak leaf area index.
- No significant reduction in Et/Eo ratio from panicle differentiation to maturity was evident.
- A reduced moisture regime (less frequent irrigations) reduced the maximum Et/Eo ratio over the complete crop cycle.
- Removal of water stress reduced the vegetative phase considerably.
- Moisture stress increased the percentage of discolored grain.
- Rice yields under the paddy system increased to more than 12 t/ha.
- A standard Class A evaporation pan can be used satisfactorily to estimate water use.

Time of sowing

It has been found that the yields of both short and medium, later maturing varieties of rice, represented by Blue Belle and Blue Bonnet, respectively, are likely to be reduced with successive delays in planting over the period from early October to early December. Detailed observations are as follows:

- Yield variations over this period are likely to be small and depend on the ensuing weather conditions.
- Advance in planting date tends to reduce the number of days to maturity.
- The incidence of BI tends to become severe with the advance of planting date.
- The planting date should be geared to varietal maturity to ensure that the chances of *guti* and rain during harvest are minimal.

Pests and diseases

Rigorous quarantine measures are applied to all new material brought into the country. Introductions go through tests at the Plant Protection Research Institute in Harare for diseases and pests in general and for the white tip nematode (*Aphelenchoides besseyi*) in particular. Successful introductions are further tested at Chiredzi Research Station in the quarantine nursery for field screening.

Some specific findings follow:

- *Pratylenchus* spp. of nematode have been found in high numbers on several occasions in Lowveld crops, sometimes in association with extensive crop damage, and at other times no serious damage was recorded.
- In fungicide trials conducted in the Lowveld, low disease incidence made it impossible to evaluate the effectiveness of the fungicides under local conditions.
- Rice should be grown on the same field once every 5 yr to reduce disease buildup and to maintain soil conditions.

Time of harvest and quality

Optimum time of harvest has been determined to be when the grain MC is 22-25%. Harvest losses and sun cracking are minimal at that stage.

Blue Belle, which has long, slender, translucent grains, remains the best commercial prospect in the early-maturing varietal group. Pearl-grained rices are unpopular. With many more recent introductions, research on consumer preferences needs to be done.

CURRENT RESEARCH PROGRAMS

A number of rice research programs are currently in progress. A synopsis of the programs follows:

- Irrigation × Nitrogen × Variety trial is being conducted to study the performance of two varieties of rice under two different multiple cropping systems, two irrigation methods, and two fertilizer levels with short and long duration rices, under paddy and flood systems with ratooning. This research investigates the possibility of producing three cereals per year; measures the amount of water required in the two irrigation systems and the economics involved; and investigates the potentials of ratooning. In application, the combination of measurements of all inputs will allow economic calculations of the feasibility of the two systems, which will directly benefit commercial and small-scale irrigation farming.
- Variety × Planting Date trial is being conducted to investigate the effect of climatic factors, especially cold temperatures, on the growth and grain production of rice. An assessment of climatic conditions conducive to physiological "white heads," which commonly occur in the Lowveld areas, will be applied to improving rice production.
- Variety Trials are being conducted to introduce and select materials which on a broad basis have the following characteristics:

  Suitable for hydromorphic conditions
  - Low input requiring varieties, with higher and more stable yield potential
  - High level of pest and disease resistance
  - Drought and cold tolerance

Suitable for intensive commercial production

- Highly input responsive
- Suitability for new production systems being developed, e.g. two crops per summer season
- Cold tolerance and high level of disease and pest resistance
- Long-grained high quality rices

The improved varieties will be injected into the two rice production systems, and it is hoped that they will boost production levels.

- Cropping Sequence Trial is currently investigating alternative rotational crops in a three-crops-a-year cropping system. Upon application this will provide farmers with feasible alternatives that are still profitable and agronomically sound.
- *Vlei* Rice Production Methods Trials are assessing the various possible methods of rice production under hydromorphic conditions and developing a more efficient method in terms of moisture conservation.
- Ant-hill Soil Trials are being conducted to reduce soil pH on old ant-hill sites by either leaching or acidifying or both and thus making Fe available. The information gained will be applied to improve rice growth on such sites that occur in the irrigated rice fields in the Lowveld.

FUTURE RESEARCH PROGRAMS

Considering the envisaged expansion in the rice production program in Zimbabwe, the following aspects may need to be investigated:

- Long term effects of continuous rice production on the field with respect to yield, soil condition, and pest and disease buildup.
- Nutrient responses of rice under hydromorphic (*vlei*) conditions and the overall assessment of rice production potential under these conditions.
- Assessment of traditional varieties for possible useful characteristics that could be used for breeding purposes, e.g. cold, drought, and pest resistance, and organoleptic properties.
- Varietal collection and screening particularly for yield, drought tolerance, cold tolerance, grain quality, disease resistance, and possibly ratooning ability.
- Comprehensive assessment of quality preferences of the Zimbabwean population, its importance and implications for the research program.
- Rice storage problems.

THE ZINA YEAR RICE PROJECT IN MADAGASCAR

R. R. SOLANGE

INTRODUCTION

Rice is the staple food of the Malagasy people. For some time, the Malagasy Democratic Republic has been facing an increasing deficit in rice production (Table 1). Production cannot keep up with population growth, which stands at 9.7 million with an average increase of 2.75% per year. Hence, Madagascar is compelled to import 150 000 to 200 000 t of milled rice per year to provide for the needs of the country.

Production depends on several factors including the choice of variety, farming techniques (including sowing and transplanting), soil type, irrigation, use of fertilizers, and control of rice pests.

In *Agriculture Horizon 2000*, FAO estimated that, on a global scale, 20 to 40% of the harvest is lost in the field because of pests and diseases. This proportion is perhaps highest in developing countries. Reducing this proportion of waste will result in an equivalent increase in production. In Madagascar efforts are underway to control two of the main rice pests, stemborers (SB) and hispa.

This report will give an overall picture of the Zina Year Operation, an extensive pest control program carried out by the Ministry of Agriculture in the region of Alaotra Lake, the rice granary of Madagascar. Included is a discussion of the project's goals and organization, an evaluation of the pest control systems employed, and an evaluation of the project's impact on rice production in the region of Alaotra Lake during its first year of implementation (1982-1983).

OBJECTIVES

A 1981 survey showed that between 7.4 and 62.7% of the rice tillers were infested by insects in the areas sampled. Given the pressing need to increase production, it was decided that an insecticide campaign against pests (SB and hispa) would be carried out. The valley of Lake Alaotra was selected for the project as commercial production there represents between 30 and 35% of total milled rice production in Madagascar. It was planned that 50 000 ha of paddy fields in the region would be treated by airplaine. The operation was predicted to result in an increase of 25 000 t of paddy, corresponding to 17 500 t of milled rice.

Ministry of Agriculture, Ambositra, Democratic Republic of Malagasy.

Table 1. Rice production in Malagasy Democratic Republic from 1963-1983[a].

Year	Area (ha)	Production (t)	Yield (t/ha)
1963	850 000	1 559 000	1.83
1964	855 000	1 648 000	1.92
1965	849 000	1 589 000	1.87
1966	883 000	1 753 000	1.98
1967	901 000	1 831 000	2.03
1968	913 000	1 873 000	2.05
1969	913 000	1 858 000	2.63
1970	997 050	1 945 900	1.84
1971	997 150	1 893 000	1.84
1972	1 017 850	1 923 600	1.89
1973	1 053 200	1 913 000	1.82
1974	1 063 520	2 013 440	1.89
1975	1 078 210	1 972 100	1.83
1976	1 063 920	2 042 500	1.92
1977	1 175 265	2 067 266	1.75
1978	1 132 535	1 945 900	1.71
1979	1 163 860	2 044 935	1.75
1980	1 199 155	2 108 910	1.75
1981	1 152 370	1 850 490	1.60
1982	1 159 000	1 976 000	1.73
1983	1 219 000	2 147 600	1.76

[a]Source of statistic data: Years: 1963-1973: FAO, 1974-1981: Agricultural Statistic Service-MPARA, 1982-1983: Rice Coordination Service–MPARA

In the short term, the chemical fight against SB and hispas will contribute to increasing the effective harvest, and consequently reducing rice imports, and saving foreign currency. The medium term objectives (2 to 3 yr) are to train staff in the organization and the management of a large-scale pest control operation; to implement an alarm network that will monitor the pests' progress and signal the timing for control measures; and to perfect techniques for farmer use (choice of insecticide, formulation, and equipment).

ORGANIZATION

The Ministry of Agriculture entrusted the following societies with the implementation of the project:

- CIBA-Geigy S.A. Basel, Switzerland, for the technical implementation and the scientific follow-up;
- COROI, for logistic support; and
- Societe des Travaux Aeriens de Madagascar (TAM), for insecticide application by air.

In order to cope with the distribution of paddy fields over the region of Alaotra Lake, three operation centers were established, each comprising 16-18 000 ha. They were the Northern Operation Center at Andramosabe-Ambohijanahary; Western Operation Center at Ambongolava, which also serves as headquarters;

and Southern Operation Center at Ambatondrazaka.

A team of 100 technicians from the three societies and agents from the support organizations (Circonscription de la Vulgarisation Agricole a Ambatondrazaka and Societe d'Amenagement du lac Alaotra) was distributed among the three operation centers.

An extensive campaign of information and promotion among the farmers underlined the importance of following an agricultural calendar. This campaign also clarified the pest control program and showed the precautions to be taken during treatments. Notice boards, radio broadcasts, printed hand-outs distributed in more than 50 *fokontany* helped to obtain a satisfactory degree of information diffusion at all levels. Effective information dissemination was essential for the success of the operation. It allowed farmers to understand the operation and stimulated their cooperation.

ACTIVITIES

Pest control operations were initiated at a specific pest-infestation threshold to optimize efficiency. To determine the threshold a network of light traps was established to monitor the population of adult moths. The counting of egg-masses was carried out by special teams. The number of larvae in the stems was also counted.

Dimecron 100 SCW, a systemic insecticide composed of phosphamidon, whose action is simultaneously effective against SB and hispa, was the product used. Spraying was carried out by plane under ultra low volume. The collected data (number of adults trapped, density of egg-laying, and condition of vegetation) allowed the persons responsible to organize insecticide applications. With the data they could prioritize sites requiring treatment, indicate the amount of product to be used, determine the parameter of application (flight altitude and width of spraying), and control the quality of application.

To have an accurate evaluation of the project results, treated and untreated plots were chosen. The evaluation of the effects of the project upon rice production in the Lake Alaotra region was made during the period between 20 May and 5 June 1983.

Three systems were implemented to monitor pest infestations: counting of the insects, twin pilot plots, and light traps. The results of the control systems have been evaluated and a few changes in their organization have been recommended. Also, some preliminary information about the dynamics of the white SB (the primary pest species) population has been revealed.

Evaluation of the twin plots system

The twin plots system was used to control the efficacy of insecticide treatments on treated and untreated plots. For larva control, the plots were visited every week and the tillers were dissected and examined by a team of four persons, each of whom was responsible for 40 hills. The data gathered during the project were analyzed to see if monitoring based on 40 hills per plot was sufficiently precise in determining larva infestation. The results showed that it was unnecessary to monitor more than 40 hills per plot and that a reduction to 32 hills is justified.

(days)

Evaluation of the light traps control

The light trap system was used to provide a daily record of the adult borer population to define the zone to be treated first; to obtain information concerning the development of borer infestation in time and space; and to evaluate the usefulness of the light traps system to get reliable and precise data concerning borer infestation.

Twelve light traps were established in the project region (four per center). To evaluate the rate of moth population growth, weekly averages from daily catches were calculated and reported in a logarithmic table. The results showed that little difference existed between neighboring traps; differences were important across regions, however.

This system of regular sampling using light traps can provide information on the development of the population which is appreciably better than the information which could be obtained by counting egg-layings. The data show the possible increase of the adult population and also establish the relationship between the dynamic of this population and weather factors.

The seasonal fluctuation of light-trap catches was compared to the egg counts of the closest plot (average distance of 1 to 2 km). Besides the fact that a high density of egg-layings was paralleled by a great number of adult insects, there was no correlation between the two sets of data. Further research is necessary to understand the relationship between light-trap catches and egg infestation before using light-trap data to determine treatments.

Although less important than the white SB, the pink SB (*Sesamia calamistis*) has also been considered a rice pest in the Lake Alaotra region. The data obtained from the three control systems have confirmed this. However, treatments with insecticide must be launched on the basis of data on white SB infestation.

Evaluation of the impact of the insecticide treatments on rice production

Two methods were used to evaluate the impact of insecticide treatments on rice production. The principal method was the evaluation of the yield difference between the treated and untreated plots in farmers' fields. The owners of untreated plots were compensated for their yield loss on the basis of the current local purchase price of paddy. The untreated plots were chosen before the start of the applications and were the object of follow-up studies throughout the program.

At the beginning of the project (January 1983), 24 pairs of pilot plots were established in the region (each pair including one treated and one untreated plot). Each plot had an area of 4 ha, and each pair had to have the same characteristics regarding rice variety, soil type, land preparation, date and method of sowing, as well as weed infestation. The distance between treated and untreated plots was about 1-2 km to reduce the risk of reinfestation of the treated plots by the SB from the untreated plots.

Yields were evaluated through the harvest of an area of 500 m^2 located approximately at the center of the 4-ha pilot plot. Area measurements, harvest, weighing, and yield calculations were supervised by a representative attached to the project. The rice was harvested according to the traditional methods of reaping by sickle and threshing by hand.

Table 2. Yield averages for pilot plots.

	Paddy yield (kg/ha)			
	Treated	Untreated	Difference	% increase
Weighted av	2.852	2.283	569	25
North	3.890	3.047	843	28
West	1.943	1.579	364	23
South	2.851	2.322	529	23

The yield increases due to the control program are given in Table 2. Each region represented a specific area of the treated region. Thus, the average yield differences shown for each region were weighted with regard to the respective areas they represented. The total production increase of the whole project area was obtained by multiplying the weighted yield increase by the total treated surface. The weighted yield increase was 532 kg/ha. Therefore, the total increase in production for the 68 730 ha treated was estimated to be 36 373 t of paddy.

In general, farming methods were better in the North, where a considerable proportion of the rice was transplanted and weeded. Yields were approximately double those of the West, where direct sowing without weeding was predominant.

CONCLUSION

1983 was the first year of the project's operation. In 1984 the project is expected to continue and to be extended to the main rice-growing plains in subsequent years (Marovoay and Highland plains). Besides the assembly of elements necessary to the project itself, accompanying research was carried out in the following areas: the number of eggs laid, the incubation period of laid eggs, empty eggs, eggs parasitized, adult nocturnal behavior, and the non-toxicity of Dimecron 100 SCW to fish.

In conclusion, this study on the Zina Year Project is not the fruit of individual research but the reflection of the 1983 Campaign Implementation Report organized by the Ministry of Agriculture. The Ministry of Agriculture hopes that all countries that produce and consume rice and whose common objective is food self-sufficiency will make use of it.

The operation shows the close relationship that must exist between research and extension. It is one of the chief methods used by the government in the development of our country. As is written in the charter of the Malagasy Socialist Revolution: "The Major Power in the year 2000 will be those countries which are able, first of all, to feed their citizens, and afterwards, to export food to other countries."

RICE IN MALAWI

W. H. MAMBWE

PRODUCTION OF RICE

Area under rice

In Malawi rice is ranked fourth in crop production. It is produced along the shores of Lake Malawi, Lake Chirwa plain, and Shire River plain. These are at a 0 to 500 m altitude where most irrigated schemes are situated. The total hectarage of irrigated schemes in the country is 2675 ha. Most of the remainder is rainfed lowland at an altitude of 500 to 1000 m. Most rainfed self-help schemes are situated at this altitude. The total hectarage of rainfed lowland is 25 622 ha. Rice is also being grown in the swamp areas (dambos) of the western part of the northern and central regions. These are upland areas at an altitude of 1000-1500 m. Rice cultivation was begun in these areas in the 1982-83 WS.

Yield

The only commercial varieties recommended to farmers in Malawi are: Bluebonnet, recommended for irrigated schemes; and Faya I4/M/69, recommended for rainfed sites. Bluebonnet gives an average yield of 3-4 t/ha, and Faya I4/M/69 averages 2.5-3 t/ha.

Other introductions have been tested that are not yet recommended to farmers. These give an average yield of 4-7 t/ha.

Research on these introductions is attempting to identify a better variety that may replace the low-yielding Bluebonnet.

Some statistics on rice in Malawi

Information on Malawi rice production, consumption, and exportation can be found in Tables 1, 2, and 3, respectively. Production figures are necessarily estimates which have been based on sales to ADMARC; however, all of the farmers' produce may not have been sold this way. ADMARC buys local rice (Faya strains including Faya I4/M/69) from farmers. The rice then goes to National Oil Industry for milling. This milled rice is sold locally to different firms within the country.

Lifuwu Rice Research Station, Malawi.

Rice is exported mainly to South Africa. The only variety that is exported is Bluebonnet. Weather conditions contributed to the low export figures that are found in Table 3. As rice production more than meets rice consumption, Malawi does not import rice.

Production systems

Transplanting is done to a well-puddled soil into 2.5 cm of standing water. It is mainly practiced in the irrigated schemes. Four seedlings per hill of Bluebonnet and three seedlings per hill of Faya in row planting eases weeding. Transplanting days for seedlings raised in a wetbed nursery are: in the WS, 15-25 DAS; and in the DS, 20-30 DAS.

Table 1. Rice production in Malawi from 1971 to 1980.

Year	Production (t)
1971	17 111
1972	19 829
1973	17 599
1974	21 296
1975	13 929
1976	24 744
1977	24 094
1978	31 382
1979	20 634
1980	16 858

Table 2. Consumption of local rice in Malawi from 1979 to 1983 (W. M. Magombo, ADMARC).

Year	Consumption (t)
1979	6 008
1980	5 919
1981	6 039
1982	5 929
1983	5 841
Total	29 739

Table 3. Rice exports from Malawi from 1976-77 to 1983-84.

Year	Exports (t)
1976-77	8 644
1977-78	8 655
1978-79	7 421
1979-80	8 211
1980-81	9 322
1981-82	7 081
1982-83	1 967
1983-84	407

Under upland rainfed conditions, Bluebonnet and Faya are drilled at the rate of 75kg and 63 kg/ha respectively, in rows at the recommended spacing.

Pests

- Armyworm (*Spodoptera mauritia* Boisd) — Armyworms were found in some schemes (e.g. Mpamantha). Lebaycid is sprayed at the rate of 1.0 ml to 1.0 litre of water at 24 and 39 DT to control the moths. Sevin (Carbaryl) is sprayed at the rate of 84 g to 15 litre of water at 60 and 70 DT to control the armyworm.
- Stem borers — A few white heads were noted in most irrigated schemes. Lebaycid is sprayed at 24 and 39 DT to control the stalk-eyed shoot fly. Sevin is sprayed at 60 and 70 DT to control SBs.
- Birds — Quelea species are common in most rice-growing areas. Scaring is the method used currently. The tin-string method is also being used in some schemes. Netting could also be used, but it seems to be an expensive method for farmers.

Diseases

- Blast — Bl caused by *Pyricularia oryzae* was noted at some schemes (e.g. Lifuwu and Limphasa). Hinosan chemical is sprayed at the rate of 100 cc to 20 litre of water.
- Brown spot — BS caused by *Cochliobolus miyabeanus* was noted at some schemes (e.g. Lifuwu). Hinosan is sprayed at the rate of 100 cc to 20 litre of water. Bavistin is sprayed at the rate of 25 g to 15 litre of water.

RESEARCH/EXTENSION

The research department in Malawi is conducting rice experiments in all ecologies to assess different parameters related to farmers' problems. Their results are discussed and then passed on to the extension department to be released to farmers. From farmers the extension department learns about problems that occur in different ecologies and passes them on to the research department where those problems are included in experiments. There is a liaison officer who communicates with both departments regularly.

PLANS FOR INCREASING RICE PRODUCTION IN THE FUTURE

The following is a list of plans for increasing rice production in Malawi:

- Convert rainfed self-help irrigated schemes into full operational irrigated schemes, so that rice can be grown in both seasons, winter and summer, instead of summer only as it is practiced now.
- Increase the size of the present irrigated schemes so that more rice can be produced from each scheme.
- Some rainfed estates have started growing rice; this should be encouraged so that the output of rice in the country is raised.

- For a long period we have been concentrating only on the shores of Lake Malawi, the Shire River and Lake Chirwa; now we need to look at upland areas and utilize more dambos which are standing idle in these high altitude areas.
- Bluebonnet rice, which has found a market in South Africa, is failing to compete because South Africa is importing a lot of rice from Asia where most varieties yield more than Bluebonnet. Work should be done to identify high-yielding introductions that can replace Bluebonnet.
- Presently under rainfed conditions, only Faya 14/M/69 is recommended, but this Faya strain is not doing well in some sites due to temperature, altitude, and photoperiodism effects. The cultivation of local varieties that are already suited to the local conditions is required.
- Selection of short-season varieties for the upland rainfed areas would promote rice production in the high altitude areas where Faya 14/M/69 is not maturing properly because of temperature and altitude effects.

ENVIRONMENTAL RESOURCES

Soil

Under rainfed conditions, rice is normally planted in the dambos. The soils of these dambos range from sandy clay loam to heavy clays depending upon the age and the origin of the soils. Along the Malawi lake-shore, Shire River, and the Lake Chirwa plain where most irrigated schemes are situated, the textural class of soils varies from sandy clay loam to heavy clays of montmorillonite. The pH of these soils ranges from 3 to 8.

Climate

All rice varieties grown in Malawi are of the indica type that thrives in tropical to sub-tropical growing conditions. The temperatures are high along the lake shore, Shire River, and the Lake Chirwa plain. They reach above 31°C and are essential for fast early growth of rice.

In the high altitude of the western part of the northern and central regions, the temperatures are slightly lower and long-season varieties are not suitable. In

Table 4. Climatic data for main rice production areas in Malawi.

Area	Altitude (m)	Range of mean max temp (°C)	Range of mean min temp (°C)	Annual rainfall (mm)	Evaporation (mm)	Latitude
Karonga	480	27-33	17-23	1060	2280	9°53'S
Nkhatabay	480	25-31	15-22	1535	1795	11°36'
Nkhotakota	480	25-32	15-22	1550	2225	12°55'
Salima	480	26-34	15-22	1290	2280	13°45'
Mangochi	480	27-34	14-22	720	2430	14°28'
Khanda	630	24-30	11-19	910	1765	15°21'
Chikwawa	110	28-34	14-22	770	1980	16°02'
Makhaoga	80	28-35	13-23	750	2210	16°31'

general, the rains commence in the latter half of November. In the south, rains cease late in March, while in the north, they continue for another month. November is normally the hottest month, while the lowest temperatures occur in June–July.

Water

Most irrigated schemes are situated on the deltas of the rivers. Lake Malawi, Shire River, and Lake Chirwa also provide good sources of water. In the northern region, the Rukuru rivers provide good sources of water. In the central region, Bua and Dwangwa are good water sources.

Farmers who grow rice in the dambos in the high altitude of the western part of the northern and central regions depend entirely upon rainfall. Rainfall varies from 800 to 2500 mm.

COUNTRY REPORT FOR ZAMBIA WITH EMPHASIS ON EXTENSION ACTIVITIES AND CONSTRAINTS TO RICE PRODUCTION[1]

INTRODUCTION

Rice has been grown in Zambia since 1947 with the major rice production areas being in Northern, Eastern, Western, Luapula, and North-Western Provinces. Very small areas under rice exist in Southern, Central, and Copperbelt Provinces. Rice is grown both under upland rainfed conditions and in dambos by small-scale farmers. A few rice projects are irrigated. Only one species, *Oryza sativa*, and two sub-species, *Indica* and *Japonica*, are grown in Zambia. The important varieties grown are: Malawi Faya, Sindano, Var.1345, Angola Crystal, Var.1632, Supa, 7601, and several other local selections. Research is continuing to find varieties suited to different ecological regions. Table 1 shows the hectarage, production, and marketable surplus of rice in Zambia for the last 5 yr.

Zambia has great potential for rice production. With about 2.31 million ha of floodplain and 0.60 million ha that are seasonally waterlogged, the potential is immense. In addition, 2.7 million ha of available swamps and lakes may be utilized in the future for deep water varieties of rice.

EXTENSION ACTIVITIES AND CONSTRAINTS TO RICE PRODUCTION

In each of the nine provinces, the Crop Husbandry Officer, in some cases supported by a Rice Officer, is responsible for promoting and encouraging rice production in the province. A number of rice demonstration plots are set up at selected agricultural camps. These are meant to show the farmer improved husbandry practices, such as planting in rows, applying fertilizer, weeding, and harvesting.

Despite these efforts by the Extension Officer, the farmers still face a lot of problems. One action that would assist farmers is the provision of such simple mechanical devices as planters, weeders, and threshers. Many farmers still broadcast their seed when planting, creating a lot of weed problems. In addition, topdressing of the crop becomes difficult because there are no lines to follow. Also, simple equipment such as sickles and threshers would help in reducing labor requirements at harvest.

[1] Presented by the Department of Agriculture, Ministry of Agriculture and Water Development, Government of Zambia

Table 1. Hectarage, production, and sales for 1978-1983 in the main rice production areas of Zambia.

Province	1978-79			1979-80			1980-81			1981-82			1982-83		
	ha	Prod[a]	Sales[b]	ha	Prod	Sales	ha	Prod	Sales	ha	Prod	Sales	ha	Prod	Sales[c]
Northern	1 160	10 250	8 660	1 980	21 390	11 210	2 230	22 430	16 760	2 460	24 350	21 560	3 115	42 700	36 400
Eastern	280	7 850	5 940	1 200	11 880	7 400	1 600	12 500	6 620	1 100	13 600	6 420	1 400	13 730	7 200
North-western	160	2 200	1 760	360	2 800	1 170	200	1 750	1 140	250	1 500	1 380	320	2 790	1 900
Western	160	5 000	3 800	360	5 025	3 785	2 930	20 850	7 930	1 710	14 400	5 800	1 720	17 000	12 900
Luapula	540	5 815	3 620	340	3 750	1 485	280	4 420	870	2 880	4 290	1 725	310	5 010	4 100
Total	2 300	31 115	23 780	4 240	44 845	25 390	7 240	61 950	33 320	8 400	58 140	36 885	6 865	81 230	62 500

[a]Total production expressed in 80 kg/bags. [b]Actual purchases by marketing organizations expressed in 80 kg bags. [c]Number is approximated to hundred 80 kg bags.

There is a lack of seed of pure varieties. Seed of the few recommended varieties is not readily accessible to farmers. It is common, therefore, to find farmers growing a mixture of varieties that have different maturity dates. This creates a lot of problems in milling, resulting in poor quality polished grain and a high percentage of broken grains.

Another constraint to rice production is the lack of a proper marketing system. There have been cases where farmers have had surplus production, but they have failed to find a market for their produce.

Most of the agricultural extension officers at field level have little or no knowledge of rice production techniques. This is because of the complete absence of the crop in the syllabus at agricultural training colleges. There is, therefore, a need to increase training of staff in this respect and include rice as one of the priority crops in the curriculum of these colleges.

OTHER ORGANIZATIONS INVOLVED IN RICE PRODUCTION

The Extension Service of the Department of Agriculture has been supported by various organizations helping to promote rice. These include: the Chinese-run Kafushi Rice Project in Central Province; the Korean Agrotechnical Team in Kafue flats; the Rice Resuscitation Project in Western Province, financed by the Netherlands government; an Africare program to boost rice in the Chama area of Eastern Province; the SIDA-funded integrated rural development and FINNIDA agricultural extension programs in Luapula Province, and more recently, the EEC in Northern Province. FAO is also involved in the development of an irrigation and water management project at Chiyabi on the shore of Lake Kariba.

OTHER EFFORTS THAT COULD BOOST RICE PRODUCTION

The price paid to the farmer for rice presently (March 1984) is quite attractive (US$23.68/80 kg bag). In the past, a few farmers undertook to produce rice seed themselves, but there was no reward for this special effort. An incentive price should be paid to farmers considering growing rice seed.

The two most common diseases are BI, caused by the fungus, *Pyricularia oryzae*, and BS, caused by the fungus, *Helminthosporium oryzae*. The occurrence of these diseases has caused significant losses in grain yield. At present, there is no control used against these diseases. There is, therefore, need for a variety that is both R to fungi and high yielding. The breeding program should also look at varieties that are resistant to such common insect pests as SB, hoppers, and GM.

In conclusion, a national program encompassing research, extension, and a good marketing system, could greatly improve rice production in Zambia. Zambia would appreciate an in-country training program for its extension personnel with international participation from IITA and IRRI.

A REVIEW OF RICE RESEARCH IN ZAMBIA — PAST, PRESENT, AND FUTURE

S. C. PRASAD

Since the early 17th century, Zambia has been well-known on the explorers' route in Africa. The Arab traders knew Zambia from their early travels and subsequently acted as guides to the European explorers. Both eastern and western explorers had contacts with Asia. It is through them that rice was introduced to Zambia, via Oman, Somalia, Zanzibar, and Kilwa, probably two centuries ago. Since then, the people in Zambia have become acquainted with different food habits from their traditional ones.

Presently the number of rice varieties is limited to about 16. Most of these were introduced from neighboring countries, such as Malawi, Kenya, Tanzania, Zaire, and Uganda. These are the major countries growing rice in east and south-central Africa.

Rice is called *mupungu* in some local languages in Zambia. It is not surprising that a village on the famous Arab trade route on the shore of Lake Tanganyika, in the northern part of the country, was named Mpulungu because rice was eaten there by the visiting traders. In spite of its long association with Zambia, rice continued to be an alien food, and farmers' interest in increasing rice production was not forthcoming. Shortfalls in locally produced rice have necessitated importation at an enormous cost.

The decade after independence (1964-74) showed a gradual transformation in the thinking of the national leaders. The President of the Republic of Zambia, His Excellency Dr. K. D. Kaunda, emphasized "that for the next 50 yr or so the majority of our people will simply have to live on the land" (1). In Zambia, 2% of the land area is under cultivation. The area in rice is still far from satisfactory, but the potential remains at about 2.31 million ha of flood plain, 0.13 million ha of dambo[1] area, and 2.7 million ha of waterlogged areas. This offers a vast potential, if exploited properly, and could result in including Zambia on the list of rice producing and exporting countries in Africa. Currently Malagasy, Tanzania, and Egypt share 60% of the total African rice production (9).

Zambia is blessed with climatic conditions under which various crops can be grown profitably. Among many new crops, one crop which has been successfully

[1]Dambos are shallow linear depressions on the plateaus which become seasonally waterlogged.

Rice plant breeder and rice research coordinator, Luapula Regional Research Station, Mansa, Zambia.

grown under new technology is hybrid maize (SR 52). The level of acceptance of hybrid maize counteracts the claim that the traditional agricultural system is difficult to change.

Rice production has shown an upward trend through area expansion. Production increased from 2860 t in 1979-80 to 6400 t in 1982-83, as hectarage increased from 3670 ha to 6000 ha. However, the per hectare yield remained practically unaffected, stagnating at about 1.0 t/ha. The large area increase has been due to the farmers' keen interest despite the relative absence of improved production technologies such as fertilizer, change in varietal complex, or plant protection methods.

Though rice as a food cannot substitute for maize, which is the staple for many Zambians, it can positively contribute to the diet. This will release pressure on the demand for maize and also offer a pleasant and nutritious change. At present, it is eaten as a specific meal, and on an average about 10 rice meals a year are consumed per family in Zambia.

In the past, rice was grown at a subsistence level, and very little was available for sale. Fortunately, this situation has changed. Despite the absence of commercial production, the bulk of rice is produced by subsistence and emergent farmers. With good integrated support from research and extension services, many more emergent farmers may be induced to grow rice.

Against this background and history concerning rice in Zambia, the research efforts of the past and present will be reviewed, and the projected future of rice will be discussed.

PAST RESEARCH EFFORTS

Because rice has been an insignificant crop in the past, it has failed to attract research attention. No reference was made to rice in the 1963 (4) Annual Reports of the Ministry of Agriculture although it is known that the extension service was active in the Namushakende area of the present Western Province in the 1950s. A reference that rice existed as a crop in Zambia is seen in the 1965 Annual Report (5). It was reported that rice was grown in Barotse Province on about 400 ha by subsistence farmers, but that very little was marketed through organized channels.

Rice research did not begin until early varietal trials were conducted in the Luapula Province in 1967-68, and in the Copperbelt and North-Western Provinces in 1968-69. These trials were still young, but their importance and possibilities began to be felt. Consequently, the government of the Republic of Zambia invited assistance from the French government, and in 1969 the Rice Scheme was initiated. An interim report by Leblanc in 1970 laid the foundation for the Rice Extension Program, which operated with technical supervision by French experts under the Society for Technical and Economic Assistance (SATEC) from 1971 to 1974 in the Luapula, North, North-Western, and Copperbelt Provinces. The SATEC team not only initiated the extension work but included some research in their program. The research program in general continued till 1975-76 but slowed

down by 1977-78 with almost a total halt from 1978-79 to 1980-81 due to lack of staff and budget. Luapula Province benefited considerably because it was the headquarters of the SATEC team and has become the center of rice coordination in the country.

A variety collection, variety trials, and some fertilizer trials constituted the core activities of the research program.

This early work resulted in the identification of suitable varieties and fertilizer recommendations. More importantly, they proved the high potential productivity of rice in Zambia and guided future planning. These goals were achieved despite tremendous problems, mainly inadequate research facilities, lack of trained manpower, and the unfamiliarity of most workers with rice. The problems may be illustrated by the following example: out of 115 trials reported, only 66 contained some data, and only 14 of those were appropriate for analysis. Of these 14 trials, 9 were from the main station and 5 were from off-station sites.

Variety collection

Variety collection began in 1968-69 with 63 entries that subsequently increased to around 400. These entries were from IRRI, West Africa, SATEC, and some local collections. Although the collection was incomplete, it formed the source of materials for variety trials. However, by 1977-78 this program could not be continued, and ultimately many materials were lost due to poor storage conditions at Mount Makulu. On the basis of studies made at the Luapula Regional Research Station at Mansa, this collection was divided into three groups.

The first group consisted of 20 selected entries, which ultimately made Master Number (MNo) 2310, from which current varietal recommendations have been made. The second group consisted of 58 varieties, which were put to further test under MNo 2057. The third group was not included in the testing program and was put in storage. Further collections, including materials from IITA, CIAT, Senegal, etc., were placed in storage. Despite this situation, which was largely uncontrolled, reasonable varieties were selected that served the first purposes of varietal collection, testing and recommendation. Some of the important lines and their characteristics are shown in Table I.

Variety trials

With the inception of a research program, emphasis was placed on varietal testing, primarily because there were no varieties worth naming. Trials began in 1967-68 in Luapula and other provinces and continued vigorously till 1974-75. During 1975-76 a few unreplicated trials were conducted while collections were maintained at Luapula Regional Research Station. However, during 1976-77 and 1977-78, there were only limited unreplicated trials and some varietal reselection work. During 1977-78, Luapula Regional Research Station discontinued regular trials and endeavored to produce seed from varieties I632, Sindano, and Kalembwe. Single plant selections of these varieties were made, and these were placed in storage. From that time until 1980-81, variety collection, variety trials, and fertilizer experiments in rice remained suspended.

Table 1. Characteristics of some lines as observed under MNo. 1787.

Variety	Yield (kg/ha)			Growth to flowering	Disease	Approximate date of flowering	Growth after flowering	Approx. date of harvest	Cold damage
	0N	40N	80N						
BPI 76	1974	2014	1757	Fair	No	End May	Fair	Mid - July	Yes
Sindano	–	3954	2855	Good	Slight	Beg May	Good	Beg - June	No
Peta	3075	1648	402	Fair	Slight	Mid May	Fair	End June	Yes
Mansa 4	3038	1757	1281	Good	No	Beg May	Fair	End June	Yes
TN1	2563	5162	3661	Good	No	End April	Good	Beg June	No
Radin Goi	3954	1135	1157	Good	No	Beg May	Fair	End June	Yes
SL70	3587	1281	2160	Good	Slight	Beg May	Good	End June	Yes
Faya	3075	1647	1391	Fair	Slight	Beg May	Fair	End June	No
Gomti	2855	3038	6882	V-good	No	Beg May	V-good	Beg June	No
IR8	4576	2746	1904	V-good	Slight	Mid May	V-good	End June	Yes
Kaoshung 21	3697	5272	4283	Good	No	Beg May	Good	End June	Yes
Tainan 3	1684	1830	1208	Good	Slight	Mid May	V-good	End June	Yes
Mele II	3771	3134	3771	Fair	No	Beg May	Fair	End June	No
Sigadis	2928	440	147	Fair	Slight	Beg May	Fair	End June	Yes
IR532-E-257	2416	4065	8788	Fair	Slight	Mid May	Fair	End June	Yes
B5DD	4246	3624	3990	Fair	No	Beg May	Good	Mid June	Yes
Mas 2401	2746	1245	586	Fair	No	Beg May	Fair	End June	Yes

Because of the earlier work conducted at Luapula Regional Research Station, a few varieties were selected for further testing including Radin Goi, Sindano, SL70, and the following varieties, which SATEC brought from their experience in Malagasy: 1329/7 and 1329/13. Entry 1632 was excluded on the basis that in the long run a japonica variety would not be preferred over an indica. However, the core of material came from the earlier collection via MNo 2310 and was supplemented by 20 SATEC entries. The base varietal trial of MNo 2310 conducted at Luapula Regional Research Station and the yields are shown in Table 2. Some of the selected varieties were further promoted and tested in multilocation trials designated as Regional Rice Variety Trials under MNo 2439 and MNo 2551 which are shown in Tables 3 and 4.

Thus it appears that a reliance on the collections and evaluation quickly resulted in the selection of Sindano, which is still valid. The varieties introduced by SATEC failed to meet the requirements of Zambian conditions, and there was no second line of varieties to complement Sindano in the trials. The gap continued until 1980-81 when a group of researchers attempted to screen varieties from IRRI and made 30 selections.

These primary experiments very clearly demonstrated that rice can be successfully grown throughout the country. Yield expectations are more than 3 600 kg/ha at Siatwinda in southern Province. A record yield of 5850 kg/ha was obtained from Sindano.

Under the SATEC program, upland rice varietal trials were also conducted

Table 2. Basic rice varietal trial MNo 2310 conducted at Luapula Regional Research Station in 1972-73.

Variety	Yield (kg/ha) (results on the basis of reps)	
	4	5
1329/5	2885	2799
Sindano	2500	2835
1329/7	2381	2515
Mansa Rice 59	2337	2366
1329/13	2292	2475
Radin Goi	2159	2573
SL70	2037	2573
Faya	1954	2259
Gamti	1854	2416
IR5	1787	1881
SATEC RS 25T	1753	2115
1329/10	1718	2147
Mete	1671	2016
SATEC1697	1502	1739
IR432-E-257	1474	1988
1632/1	1040	1382
SATEC1562	921	1017
SE ±	298	316
Mean	1895	2215
C. O. %	31	32

Table 3. Regional rice variety trial MNo 2439.

Variety	Location							Mean
	Luapula		Southern	Eastern		North-Western		
	Mansa	Chabilikila	Siatwinda	Jumbe	Msekera	Nkuluwashi	Kamafafa	
Sindano	3500[a]	2600	5850	3930	4490	2300	2800	3638
1325/5	2700	3200	5210	5320	2310	2310	3100	3449
Radin Goi	4100	2700	5260	3650	2600	1100	2000	2059
SL70	2500	2600	4050	3390	3130	1300	1900	2700
1329/7	3900	2500	4600	3680	2700	1500	3800	3240
132 9/13 12	3700	2200	4750	3240	3270	1100	2600	2870
SE. +	770	N. S.	190	211	203	N. S.	N. S.	-
Mean	3400	2600	4950	3870	3080	1600	2700	--

[a]Variety Blue bonnet. Yield kg/ha

Table 4. Regional rice variety trials MNo 2551.

Variety	Location						Mean
	Luapula		Southern	Eastern	Western		
	Chabilikila	Lendongoma	Siatwinda	Msekera	Kataba	Kakeme	
Sindano	1710[a]	3588	5400	1120	1156	1068	2340
1329/5	1790	3929	5311	415	716	515	2113
1329/7	1480	3387	5259	973	1080	561	2113
1632	1600	1668	4693				2743
Blue bonnet				1070			
Burma					2790	2474	2632
Angola crystal					2287	1901	2099
Mean	1640	3143	5233	895	1606	1303	
S. E. +	126	404	N. S.	N. S.	236	202	
C. V. %	15	13	--	--	36	37	

[a]Yield in kg/ha.

during 1969-70 and 1970-71. In the absence of satisfactory yields, it was considered at that time that upland rice was not feasible in Zambia. Among the many reasons for this inference were emphasis on moisture stress and heavy disease pressure from Bl, BS, and ShB. Variety I697, probably an early one, was found to be badly damaged by birds. Thus, earliness as a desired characteristic appeared to be hazardous. Studies on rainfed upland rice were abandoned until 1980-81 when varieties obtained through IITA were tested at Luapula Regional Research Station.

Similarly, there was minimal or no work done in many specific fields, such as cold tolerance, deep water, flooded and swampy shallow-water conditions. These remain to be explored by Zambia, but a start has been made.

It is worth mentioning that in the past many experiments failed because of

insufficient knowledge of dambos. This situation was clarified by Ferreira (2). Not only were dambos classified, but some indicator plants, such as *Miscanthium*, improved the effectiveness of proper choice of site for rice production. Prior (8) further clarified the types of dambos and their potential exploitation for increasing rice production, especially in the high-rainfall zones.

Fertilizer trials

The series of fertilizer trials started during 1967-68 by the research branch provided very little information owing to insignificant data. The research branch and SATEC conducted trials from 1971-72 to 1973-74, and information leading to current fime recommendations was gathered. Current recommendations stand at 200-300 kg/ha of 'D' Compound as basal dressing followed by a topdressing of 70-100 kg/ha ammonium nitrate at 6-8 wk. There have been no subsequent modifications because the varietal complex has remained practically unchanged.

With the likely change in varietal recommendations, it has become increasingly important to conduct trials for future recommendations. Detailed N,P,K trials have been laid out at Luapula Regional Research Station for both paddy rice and upland rice.

Some trials were conducted on such minor elements as sulfur, Zn, boron, and molybdenum. Some interaction was reported between boron and Zn. Sulfur application showed a significant yield increase at Luapula Regional Research Station and at Jumbe in Eastern Province, but these results from only 1 or 2 yr need verification.

The results on continuous cropping at Luapula Regional Research Station are conflicting and misleading due mainly to a shifting of sites. Such a study needs organized testing to obtain tangible results. Since such a work is very important for farmers, it is hoped that proper experiments will be laid out in the future.

Pests and diseases

Very little attention has been paid to pest and disease problems because there has not been a general population buildup, partially because rice fields are isolated and the crop is grown by shifting cultivation methods in very limited and scattered areas. However, reports have been made of the Black Maize Beetle, an unidentified Blue Lady Beetle, and some caterpillars and SBs. Recently, Prasad (6, 7) reported the presence of GM and vectors causing orange leaf disease. GM has also been identified in the northern part of Luapula and on the flood plains of Chambesi and Zambezi though population buildup is slight, causing no appreciable damage. Other identified insects are rice leaf rollers and folders. Incidently severe damage by *Trichispa sericea* (rice beetle) has been observed at the Farmers Training Center at Kawambwa in Luapula during the current growing season.

Bl and BS incidence has been frequently reported and visual estimates of losses accounted for in some cases. The presence of different physiological races has not been studied thus far. However, the sowing of International Rice Blast Nursery (IRBN) material during 1983-84 may provide some information. The results of this investigation are provisionally indicative of the presence of different races of Bl in Zambia.

Rodents and birds have been mentioned frequently because they not only severely damage the crop, but they also considerably increase the cost of production because they must be scared away. This form of crop protection is the responsibility of individual growers, and necessary organized effort is still lacking.

PRESENT RESEARCH EFFORTS

A humble beginning was made during 1981-82 (9) at the National Irrigation Research Station (NIRS) at Nanga and the Luapula Regional Research Station at Mansa, where screening of varieties suitable for paddy rices and upland conditions was done. Hill et al (3) reported that 423 entries, including 332 from IRRI, 23 from the cold tolerant nursery, 47 from IITA, 12 from Zambia, and 9 from Bangladesh, were tested, and on the basis of performance 63 entries were grouped by duration. IR9758-150-3 yielded 22.36 t/ha maturing in 158 d followed closely by KNIB-361-1-8-6 with 21.23 t/ha in 182 d, and KNIB-13-6 at 19.61 t/ha in 184 d. Based on this performance, a multilocational test of 30 entries was conducted during 1982-83.

From the upland testing program at Luapula Regional Research Station, encouraging results were obtained from tests in 1981-82. ITA148 yielded 1400 kg/ha although the trial was planted later and faced a drought of more than 2.5 wk.

In the same period, pre-basic seed of I632, Kalembwe, and Sindano was produced at Luapula Regional Research Station. Yield differences between drilled and transplanted rices were observed particularly in Kalembwe which yielded 1100 and 2100 kg/ha, respectively. Similarly at Kaoma and NIRS, pre-basic seed of Burma, Angola-crystal, Malawifaya, and I632 varieties was produced with success. The pre-basic seeds thus produced were handed over to Zam-Seed Company for further increase.

Thus, 1981-82 saw the beginning of a revitalized rice research program and formed the basis of the 1982-83 program. This was further enlarged during 1983-84 incorporating national and regional variety trials. During 1983-84, a National Accession Register and Maintenance of Genetic Stock was initiated.

In 1982-83, international cooperation was well extended, and seed materials came from IRRI, IITA, CIAT, and the Indian Council of Agricultural Research. During that year, emphasis was on varietal testing, and 1052 entries were tested, including 16 varieties currently grown in Zambia. Two experiments were carried out on fertilizer use.

The Peat Soil Screening Nursery from IRRI was tested at Kalabo. IR34 (R source) and E425 (a susceptible source) yielded 4478 and 1346 kg/ha, respectively, whereas IR4613-54-5 yielded 6103 kg/ha. These test results are especially important because a large area of this soil type exists. Similarly, very encouraging yields were obtained from an acid upland (pH 3.5) sandy soil site where Tox1008-15-5 yielded 2795 kg/ha. This was followed by higher yields the second year, thereby positively opening the possibilities of upland rice in Zambia.

Similarly, varieties have been identified for shallow-water rainfed situations where the soil is usually waterlogged. If the above-mentioned problem soils could

be brought under cultivation by replacement with suitable entries, substantial new rice area could be successfully developed in the country.

Similarly, the results obtained through MNo 3386, composed mainly of the entries identified at NIRS during 1981-82, have confirmed that rice can be grown very successfully in Zambia. However, enhanced yield is possible only with suitable replacement varieties. The 1982-83 resulting yields are shown in Table 5 and confirm 1967-68 studies shown in Table 1. It appears that varieties BR10 (6599 kg/ha), IR13540-56-3-2-1 (6268 kg/ha), and KAU1727 (5692 kg/ha) are highly promising. Mention may be made of IR19431-72-2 yielding 13 889 kg/ha and maturing in 128 d at Chama in Eastern Province, and this was closely followed by RP KN 2 yielding 128 227 kg/ha with a maturity of 120 d. Notable among the varieties of great promise are IR20878-1-PI (13 169 kg/ha), IR13257-46-IB-PI (11 556 kg/ha), IR3858-6 (10 867 kg/ha), Janaki (10 840 kg/ha), IR5873-91 (10 773 kg/ha), IR4819-77-3-2 (10 576 kg/ha), IR13146-13-3-3 (10 507 kg/ha), and RP1057-184-5-3-2 (10 413 kg/ha). These selections have been included in the 1983-84 testings.

During 1982-83, a program to maintain breeders' seed of varieties was initiated. Pre-basic seed of Kalembwe was successfully grown at Mansa and Malawifaya at NIRS Nanga and handed over to the Zam-Seed Company. The breeders' seed description for six varieties was accomplished at Luapula Regional Research Station, and a draft was circulated for distribution to rice researchers, seed-inspectors, and others.

The 1983-84 program has been expanded, and many aspects have been covered, such as national varietal trials, regional trials on varieties and other aspects, and location-specific trials, such as the GTZ UNDP/FAO Project on Irrigated Agriculture, and projects by Africare and a Chinese team.

Despite serious limitations and shortfalls in experimentation at many locations and a serious unfamiliarity with the crop by the cooperators, the basic objectives of fruitful results, increased possibilities of successful rice production, and overall awareness by the masses and policy makers have been achieved.

SHORTCOMINGS AND PROBLEMS IN RESEARCH

The research program in general and rice development in particular is suffering from the following inherent weaknesses:

- The Comprehensive Rice Research Team functions with a minimum compliment of scientists including a breeder, agronomist, entomologist, plant pathologist, and ecologist. Presently the team lacks the last three specialists.
- Due to the unavailability of posts, support staff such as technical officers and senior agricultural assistants are limited.
- The handling of off-station trials is hampered by lack of trained personnel.
- There is a complete absence of laboratories and equipment for conducting routine analyses and tests.
- Overall there is very weak financial support to carry out field trials properly either at the coordinating center or at other stations.

Table 5. MNo. 3386: observations on 41 promising rice varieties in 1982-83 trials at 7 locations.

Location	Variety (Yield in kg/ha)															
	NIRS-10	IRI 3564-109-1	B2360-65-1-10	Somiyun	IR19746-28-2-2	IR9758-105-3	IR9729-106-1-2-2	ECIA-S-103	IR5867-452	ITA225	China 998	RP KN-2	Kalembwe	IR36	KAU1725	IR13540-56-3-2-1
Chiyabi	11130	5590	9590	2470	650	10250	10080	3070	2540	5490	11160	2990	6780	8040	9380	11110
Mansa	4633	7233	1833	1634	2600	1400	2906	3266	2400	8266	3000	4940	2166	1066	6766	6300
Mashumba	1800	6880	1633	200	2833	3953	1000	3253	300	5433	800	2346	1833	3700	5453	5933
Kalabo	7070	5110	4100	3810	4460	5400	5240			5760	4840	5350	5790	3240	6870	4940
Siatwinda	2705	2750	3250	250	9000	1500	2463	2250	3120	4500	2505	12827	5837	4000	5598	6048
Chama	3384	5663	8370	817	6466	7034	7260	4448	7347	8065	5172	6873	6204	5135	7381	10877
Mashumba	533	4813	300	566	1740	1353	813	2600	126	2766	66	833	1046	93	3046	2333
Average	4345	5504	3844	1387	3649	3397	3978	2445	2791	5503	2342	4833	4706	3505	5834	6268

Table 5b.

Location	Variety															
	KAU 1727	BR 10	IRI13415-9-2	Pattambi 1751	KAU 1935	KAU 1676	PAU 41-306-2-1-PR-406	IR9093-211-6	BRI 61-2B-58	CR 226-116	KN1B-361-1-8-6-9-2-1-1	KN1B-361-BLK-13-9	KN1B-13-6	KN1B-361-BLK-2-5	Angolacrystal	Burma
Chiyabi	8910	10750	7940	8760	9850	8800	11990	12620	2990	–	4250	5620	4750	7080	–	–
Mansa	7366	7700	3466	3513	4666	2133	4233	4133	3666	7466	7366	5333	6133	4566	5700	6346
Mashumba	4953	5740	3566	5060	3713	1686	5213	5326	5466	7947	3826	3660	4080	4358	6486	–
Kalabo	6280	7960	6640	9780	5920	7350	3950	5700	3590	5190	5960	8060	7690	6700	4100	5860
Siatwinda	4935	4556	3370	4883	5586	4750	5361	3790	5031	2500	5203	4914	5001	4770	2075	880
Chama	8006	10064	7438	9630	7294	9191	8124	6540	8248	9609	7632	9316	8727	8615	7995	2388
Mashumba	2466	3020	2420	3766	2493	1520	3533	3000	1160	1100	2660	1726	1833	2633	1486	–
Average	5692	6599	4679	5945	5457	4678	5683	5428	3957	4581	5328	5146	5746	5790	3739	2399

Table 5c.

Location	Variety								
	Malawifaya	1632	Kalembwe	Sindano	Kajaket	Nsuke	Supa	7601	KH 991
Chiyabo									
Mansa	6380	6666	3333	5333	5000	5360	3566	2933	1046
Mashumba							2740	1813	866
Kalabo		1660	5090	3290		7500	6480	7230	2450
Sotwanda		3460	4011	2721	4557	4998	1442	2295	2881
Chama	11289	1966	6597	5766	6455	5607	6746	7929	7390
Mashumba							106	2673	933
Average	2698	1981	2814	2559	2233	3293	3398	3459	2241

- Very poor communication exists, and there are almost no visits to experimental plots for suggestions or to meet emergency needs in case diseases or pests appear.

FUTURE RESEARCH PROJECTS

Research in the following areas is proposed in order to improve rice production in Zambia:

- Strong, coordinated rice research with emphasis on varietal collection, maintenance, and varietal screening.
- Research on insect pests and diseases and their control should be initiated.
- Soil fertility, agronomic management, and fertilizer trials appropriate to the various agroclimatic regions and dambo ecologies are needed.
- Research on various methods of weed control is needed using a systematic approach. This has been completely absent from the beginning.
- Evaluate or develop and test various implements to be used in rice cultivation.
- Establish a quality laboratory to undertake testing of different varieties.
- Establish a rice-based cropping system program with well-developed research and extension components. Following the successful expansion in rice area and production, a full coordination center may be desirable.
- Overall economic feasibility studies are needed before technology recommendations are released to farmers.

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RECOMMENDATIONS OF THE INTERNATIONAL RICE WORKSHOP HELD AT LUSAKA

APRIL 9-11, 1984

1. The Workshop recognized that varietal improvement is an essential component required for increasing national rice production. The International Rice Testing Program co-ordinated by IRRI and the African Rice Testing Program (ARTP) coordinated by IITA were recommended to be used as major sources of test material. The participants agreed to conduct the testing program in two tiers. In the first tier, all appropriate IRTP nurseries and material from the rice programs in Africa will be carefully evaluated in locations where qualified personnel and facilities are available. ARTP will be recomposed using the results from the first tier tests to contain fewer and African-relevant materials. For the second tier testing, ARTP nurseries will be made available for all the national programs in the region. The following countries were identified as suitable for first tier testing:
   (a) Irrigated (normal) — Tanzania, Zambia, Kenya (Yield Nurseries only in Kenya);
   (b) Irrigated (cold) — Tanzania, Burundi[1];
   (c) Rainfed lowland — Tanzania, Zambia; and
   (d) Upland — Zambia, Tanzania, Kenya[1].

   Both IRTP and ARTP nurseries will be made available to all national programs in the region upon request.
2. The participants emphasized that for extending rice to high altitudes and for double cropping in most areas, cold tolerance is of potential importance in the region. Therefore, a stronger research emphasis should be given to cold tolerance including breeding.
3. The Workshop recommends that IRRI/IITA help the national programs to conduct a comprehensive survey for pests, diseases, and weeds in this region and findings be published.
4. The Workshop recommends that there should be an expanded training program at various levels in order to increase national research capabilities. This should be achieved by:
   (a) short-term training courses to assist in research and to increase rice technology skills at both the International Institutes and within the region; and
   (b) training outside the region should emphasize the training of trainers.

[1]Participation of Burundi and Kenya (for upland) will be confirmed after consultations.

5. It is recommended that IRRI and IITA should assist national rice research programs to develop agronomic research activities to include soils and crop management. Particular emphasis should be given to:
   (a) weed control;
   (b) fertilizer use efficiency and soil fertility management;
   (c) the use of Azolla; and
   (d) the testing and development of appropriate tools and machinery.
6. The Workshop strongly recommends to IRRI and IITA to assist the national rice programs by locating an appropriate number to rice scientists as soon as possible in this region.
7. The Workshop recommends that there should be an office for the coordination of rice research activities in eastern, central, and southern Africa, and the Director General of the Tanzania Agricultural Research Organization (TARO) should function in this capacity until recommendation number 6 is implemented. The Workshop requests also that IRRI IITA provide some financial support for this coordination work
8. The Workshop recognized that adequate attention to rice research and production programs has not been given by many governments within the region. The Workshop, therefore, recommends that the following courses of action be taken by national governments and programs:
   (a) all national rice programs be given adequate support in the form of funds, personnel and equipment necessary for their effective functioning;
   (b) due regard be given to rice quality particularly in relation to consumer preference;
   (c) ensure adequate emphasis in harvest and postharvest technologies and development in processing and marketing facilities;
   (d) encourage development of appropriate machinery and equipment inclu[illegible] hand tools;
   (e) gre[illegible] attention be given to high quality seed production and dist[illegible]ation;
   (f) a suitable rice research scientist be designated by name to liaise with the regional coordinator and international institutes; and
   (g) where national program have specific problems such as heat tolerance and rice yellow mottle virus disease (RYMV), direct contacts be made with IITA and IRRI for assistance to resolve such problems.
9. Recognizing that IRRI and IITA have taken adequate measures in dispatching disease and pest free seeds, the Workshop, therefore, urges the national phytosanitary services to exercise realistic application of regulations to expedite the exchange of experimental rice seed.
10. The Workshop participants felt that national rice research programs need effective guidance from international centers and therefore recommended that IRRI IITA give appropriate assistance in the program development.
11. Where possible, each country should endeavor to fully classify and characterize the ecosystems presently utilized and potentially suitable for rice production.

MONITORING TOUR ON RICE IN ZAMBIA AND TANZANIA

INTRODUCTION

After the close of the International Rice Workshop the participating scientists took part in a monitoring tour to rice research stations and rice-growing areas in the countries of Zambia and Tanzania. This tour was cosponsored by the International Rice Testing Program (IRTP) coordinated by IRRI, and by the International Institute of Tropical Agriculture (IITA). The monitoring program is an important component of IRTP activities.

The objective of the monitoring tour was to evaluate and exchange existing information on rice cultivars for the different ecologies, methods of rice culture, and problems of production. The places visited included major research stations, farmers' field experimental sites, and production projects. The soil and climatic conditions, rice growing systems, production practices, and prevalent pests and diseases were observed and discussed.

ZAMBIA

Chianyanya rice scheme

The Kafue Flats, with an area of about 500 000 ha of hydromorphic soils, are situated south of Lusaka. The area is seasonally flooded and with some water control would have major potential for rice production. Presently the area is little used for agricultural purposes.

The Chianyanya Irrigation Project was initiated by the Zambian National Service to develop rice production in this area. The North Korean government has provided a number of engineers and technicians for land development in this project. A total of 15 ha has been developed for rice production out of total projected area of 1000 ha. When fully operational this scheme could virtually double rice production in Zambia.

The rice varieties presently being grown are Angola, Malawi Faya, and Chambese. These are tall, late-maturing varieties and are presently highly mixed.

Land preparation is done by 4-wheel tractor and the crop is dry-seeded. Many serious problems were observed in the condition of the crop with current management practices. Land preparation is inadequate and the land is poorly

leveled resulting in a poor stand and highly variable water depth throughout the field. In addition, better water control is needed. Weed growth is severe, particularly of *Cyperus difformis*. Iron toxicity appears to be present and brown spot and gall midge disease damage was also observed.

The project staff is aware of the several problems that must be solved to obtain reasonable rice yields. Varietal trials are planned for the coming crop season to identify suitable varieties for the project. Maintaining a source of pure seed will be a major problem. The project is short of labor and suitable machinery for land preparation. At present, no fertilizer is available due to economic constraints.

Turners Asbestos Products Project (TAP)

The Turners Asbestos rice project is located at another site on the bank of the Kafue river. The International Rice Yield Nursery-Very Early was being evaluated in a dryland site close to the river. Sprinkler irrigation was applied but at levels inadequate to sustain the maximum evapotranspiration demand of the crop. The entries were severely stunted and suffering drought stress. It was suggested that good performance might be expected from these materials if the fields were bonded, leveled, and flood irrigated.

National Irrigation Research Station (NIRS)

The Zambian National Irrigation Research Station is also situated on the Kafue River floodplain. A number of rice trials were observed. The following entries appeared outstanding: Kalembwe, BR10, IR9093-2-11-6, and BG367-7. Malawi Faya is a popular variety among farmers in Zambia. It was tall and vigorous in seed increase plots on the station. It had been planted on 18 Oct and was now over 2 m tall after 6 mo in the field, but had not yet flowered. This exemplified the great need for vigorous but early-maturing varieties for Zambian conditions.

A date of seeding trial was in progress to test the effects of cold temperatures at the reproductive stage on six varieties. The two entries which appeared best were Kalembwe and KM48-13-6.

The variety Kalembwe was very impressive on the station. It is a 4-mo-duration variety with heavy panicles and long large grains. It was apparently selected as an off-type in a farmers' field of the variety 1632, an introduction from Madagascar. It is 130 cm in height.

The visit to NIRS demonstrated that high rice yields are certainly possible in Zambia with good management and a reliable water supply. However, the limitations to the state farm approach to increase rice production were clear from the visit to Chianyanya.

Luapula Regional Research Station, Mansa

The national rice research program in Zambia is coordinated from the Luapula Research Station at Mansa, Luapula Province in northern Zambia. The visit to Mansa station was made by small plane. The flight enabled excellent observations of the extensive area of dambo topography across the central African plateau. A dambo is a shallow depression in a plateau landscape comprising an area of land

with a water table located in the upper 20 cm of the soil, either permanently or seasonally, and often reaching the ground surface during the rainy season. Dambos are normally grass-covered areas in contrast to the surrounding forested uplands. They are currently used for grazing but are otherwise an unutilized land resource in Zambia.

Because of the hydromorphic conditions of dambos, these areas have considerable potential for rice development. At the Luapula station the group visited a dambo being used for rice seed production. A 3-ha field of the variety Angola was near maturity and expected to yield about 3.5 t/ha. This variety is quite tall (1.20 m) and is reportedly susceptible to BI in the uplands. A seed production field of Kalembwe was also outstanding. The good results of rice cultivation on this newly opened land at the edge of the seepage zone of the dambo suggests that there is major potential for rice production in the dambo areas. The flood water was a rust-red color in these field and some plants appeared to be suffering from iron toxicity. This particular type of dambo was classified as a sour or acid dambo.

On the basis of what we observed at Luapula Station, there appears to be potential for immediate increases in rice production in dambo areas through an expansion of the area planted. Based on the data provided it appears that this would be economically lucrative to farmers. The main constraint appears to be manpower availability. Land preparation is currently undertaken using hand hoes. It therefore seems useful to examine the possibility of mechanization in these areas. Based on the swampy nature of the fields the Swamp Tiller used in the Philippines may be tested for adaptation to these countries.

Upon arrival at Mansa, we visited the research station and were briefed by Dr. S. C. Prasad (rice breeder) and other scientific officers. Luapula is regarded as one of the poorest provinces in Zambia and is a net food importer. The major development constraints are remoteness in transportation and communications (850 km by road from Lusaka) and the complete absence of agricultural mechanization. There is a severe manpower drain to the nearby copper mines.

We also visited an acid upland site where the International Upland Rice Observational Nursery (IURON) and other varietal trials were being evaluated. The soils had a pH less than 4.5 with a low water holding capacity. The outstanding cultivars observed were several entries from IRAT (particularly IRAT144) and Dourado Precoce. A Khao Lo/IR8 cross looked very vigorous. 1200 mm of rain were received this season, but due to the low water retention capacity of these soils, 5 d without rain may induce a critical drought. Upland rice production is not presently practiced to a significant extent. Therefore, researchers are investigating the suitability of upland rice technology for these conditions.

Several IRTP nurseries were evaluated under dambo conditions at a third research site. These included the International Rice Yield Nursery-Medium (IRYN-M), International Rice Rainfed Shallow Water Observational Nursery (IRRSWON), and the International Rice Observational Nursery (IRON). Dr. Prasad explained that cultivars with somewhat taller, more vigorous plant type similar to IR5 are the materials which appear most suitable for Zambian rainfed lowland conditions.

The three rice varietal target environments for Zambia appear to be:

1. Irrigated well managed situations: Semidwarf varieties with high yield potential are suitable.
2. Rainfed lowland (including dambo cultivation, partially irrigated situations, and other hyromorphic riceland): Tall semidwarf to intermediate height materials with moderate tillering and good vigor are required.
3. Upland/dryland: Tall vigorous varieties adapted to drought and acid soils are required.

Sources of pure seed are a critical problem in Zambia. The seed certification and production system is at a preliminary stage of development, and the breeder at the national station will play an important role in ensuring that stocks of pure seed of the recommended varieties are maintained properly.

China-Zambia rice project, Camfushi

The China-Zambia rice project is a small rice production project in the vicinity of Lusaka. The farm is a 50 ha rice demonstration project supported by a team of production specialists from Hunan, People's Republic of China. Intensive irrigated paddy cultivation on irrigated rice terraces is practiced with small-scale mechanization and intensive labor inputs. The group visited a field of the cultivar Sindano, a 180-d variety which was being harvested and threshed. The rice farm is located on the sideslopes of the water course of a small creek and receives irrigation from a dam upstream. Approximately 6 ha is under rice cultivation. Since the farm is well managed, it may be an excellent location for the production of certified seed. The production technology, however, appears to have limited applicability to nearby subsistence farmers who necessarily practice more extensive crop production methods. The farm is also involved in the manufacture and sale of tools and small-scale equipment, notably a pedal thresher. These may be of considerable value if extended to farmers on a wide scale.

TANZANIA

Tanzania is the largest rice producer in the eastern and southern African region, excluding Madagascar. About 275 000 ha are planted to rice out of a total cultivated area of 5 million ha. While in Tanzania, the monitoring tour participants visited Dakawa rice farm and the Ifakara Rice Research Station.

Dakawa Rice Farm

The Dakawa Rice Farm, Ltd. is one of the three large rice production schemes in Tanzania that are run by the National Agriculture and Food Corporation. The Dakawa project commenced in 1976 under North Korean assistance and major land development works have been undertaken (pumping stations, canals, structures, and a rice mill) amounting to US$5 million. Irrigation water is being pumped from the Wami River.

About 1000 ha is planted in WS while about 20% of this area is in irrigated rice in DS. The 1984 WS target for area planted was 1400 ha. The main constraint in

planting large areas is the lack of machinery for land preparation. Since 1981-82, WS yields have ranged from 3.7 to 4.4 t/ha using IR8. To date they have not found a variety superior in yield to IR8.

At Dakawa the rice crop is dry seeded in 5 ha plots. Pre- and post-emergence herbicides of Avitasama and Stam F-34 T, respectively, are used for weed control. Urea or ammonium sulfate is applied at about 30 kg N/ha in split doses (20% at the four leaf stage; 20% at tillering; 50% at panicle initiation; 10% at milk stage). Phosporous and potassium are not applied. Insects and diseases are not regarded as production constraints. However, losses due to Quelea birds and elephants can be serious.

Research in Dakawa farm has been undertaken for four seasons at the Dakawa Agro-Scientific Research Center. The group was informed that an international non-alligned research center would be established at Dakawa. Meanwhile, technical assistance for rice research is provided by North Korea. Research trials visited by the monitoring group were in excellent condition, very well laid out and managed. These trials covered varietal improvement (IRTP trials), fertilizer use, crop establishment methods (wet seeding vs. transplanting), time of planting, seedling ages, plant population, farmyard manure and green manure, water management, herbicides, and pest management (particularly for stemborer and *Diopsis*).

The best performing varieties at Dakawa were IR8, BG90-2, and IET2397 (recently released as Katrin). Katrin has yielded up to 7 t/ha and is now being multiplied for major use on the farm.

Most of the production fields at Dakawa farm were harvested. However, those which remained had generally poor stand establishment and high weed populations. This was probably due to inadequate land preparation and water control. It appears that the yield gap between the researcher-managed crops and the production areas is still quite substantial.

Ifakara Rice Research Station

The Ifakara Station was established in 1963 and now serves as the national rice research station for Tanzania. The trials being conducted cover varietal testing of international materials (IRTP nurseries), national varietal trials, weed control, and disease control (blast, sheath blight, brown spot, and Cercospora). The rice hybridization program of Dr. Monyo, which was established in 1972, was interrupted for the past several years. Crossing work began again last year with the return of Mrs. Mgonja from a degree program in the United States.

Two nearby research sites were also visited. At the site of the Tanzania Agricultural Corporation, the national variety trial was being tested under a wet-seeded partially irrigated condition. The national variety trial is composed of 25 lines in 6 replications. It is tested at a range of sites throughout the country.

A fertilizer trial tested three varieties (Supa India, Katrin, and Selemwa) under four rates of nitrogen (0, 30, 60, and 120 kg N/ha) and four rates of P (0, 20, 40 and 60 kg P/ha). An N response was clearly discernible in the trial.

The second substation site was at Lumemo. This was a more typical flood-plain

location apparently representing rainfed lowland drought-prone conditions. Major trials observed at the site were:

- Time of **sowing** experiment. Six varieties were being planted every 10 d to determine the optimum time of planting in relation to the onset of the growing season.
- The national variety trial planted under direct-seeded conditions.
- International Upland Rice Yield Nursery (IURYN). Most entries were stunted by drought stress at the **seedling** and tillering stages.
- **Herbicide trial.** Of four herbicides tested, Propanil + Benthiocarb was performing best.

The Lumemo site was said to be representative of a large part of the Kolembero valley. Farmers in this area commonly intercrop maize with upland rice.

The three research sites available to workers at Ifakara make it possible for them to test cultivars and crop technology under environments ranging from partially irrigated to rainfed shallow to upland conditions. This is one advantage of the location although the remoteness of the station is a major logistical problem to the research workers.

Ministry of Agriculture, Dar Es Salam

The monitoring group had the opportunity to meet with the Principal Secretary of Agriculture, Professor Simon Mbilinyi, and with the Minister of Agriculture, Professor John Matsunda, for indepth discussions on the group's observations concerning the future directions for rice production and research in Tanzania. The Minister spoke at length about Tanzania's problems and potentials for increased rice production. He fully endorsed the workshop recommendations and expressed his commitment to do whatever possible to assist in the speedy implementation of international collaborative assistance to strengthen rice research in Tanzania.

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Acronyms and abbreviations used in this publication

BGA blue-green algae
BL blast caused by *Pyricularia Oryzae* Cav.
BLB bacterial leaf blight
BLS bacterial leaf streak
BPH brown planthopper
BS brown spot
CIAT Centro Internacional de Agricultura Tropical
CW caseworm
DAS days after seeding, sowing
DAT days after treatment
DS dry season
DT days after transplanting
GEU Genetic Evaluation Utilization
GLH green leafhopper
GM gall midge
HLS *Helminthosporium* leaf spot
HYVT high yielding varieties technology
IITA International Institute for Tropical Agriculture
IPM integrated pest management
IRAT Institut de Recherches Agronomiques Tropicales
IRRI International Rice Research Institute
IRTP International Rice Testing Program
MC moisture content
MR moderately resistant
MV modern variety
R resistant
RWM rice whorl maggot
RYMV rice yellow mottle virus
SB stem borer
ShB sheath blight
SR stem rot
UNDP United Nations Development Program
WARDA West Africa Rice Development Association
WAS weeks after seeding
WSB white stem borer
WS wet season