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VARIETAL IMPROVEMENT PROGRAMME FOR PLUVIAL RICE IN FRANCOPHONE AFRICA

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Introduction

This paper summarizes the work of IRAT, in collaboration with national institutes, on the improvement of pluvial (upland) rice in francophone Africa. The topics discussed are 1) genetic resources, 2) selection criteria, 3) breeding methodology, 4) culture of haploids (androgenesis) and 5) drought tolerance.

Historically, the National Institute for the Development of the Congo (INEAC, Zaire) began collecting rice ecotypes in 1933. This resulted in the release of varieties such as R 66 and OS 6. They came from crosses between local varieties and introductions from India, Malagasy and other countries. They remain widely distributed and useful varieties for pluvial rice throughout tropical Africa.

Research on pluvial rice in Casamance, Senegal commenced in the 1950's. Varieties such as 617A were developed from Malagasy stock while other suitable varieties, such as Iguape Cateto from Brazil, were introduced and distributed. IRAT has assumed responsibility for rice research in Senegal since 1960.

Prior to 1966, rice research in the Ivory Coast was conducted by the Ministry of Agricultural Research. Several useful varieties, including Moroberekan, were released. Subsequently, work on pluvial rice was assigned to IRAT. There was some opposition to pluvial rice because it was alleged that its cultivation resulted in soil deterioration. However, considering the topography and the available land in the Ivory Coast, rice cultivation could be extended into regions where pluvial rice was the only possibility.

Genetic Resources

Two major collections have been assembled at Bouaké, Ivory Coast, one of *Oryza sativa* and one of the indigenous African species *Oryza glaberrima, O.barthii* and *O.longistaminata*.

Oryza sativa collection

The entries of *O.sativa* are either old African varieties or introductions from other rice-growing regions. Many of the latter group are from IRRI, Philippines. About 4000 varieties were assembled at Bouake up to 1976. Of these, about 1,150 have been retained as having some suitability for pluvial rice improvement.

The origins of 3,421 varieties introduced up to 1975, and the percentages from each source that have been eliminated because of blast susceptibility, lateness, or other undesirable traits, as evidenced by observation over two years, are shown in Table 1.

The two most important agronomic characteristics of the 1,150 varieties retained through 1976 were the length of the vegetative cycle and plant height. The proportion of varieties in various classes for these characteristics is given in Table 2.

A catalogue has been prepared of the varieties obtained up to 1975, with their characteristics as determined in the field and laboratory. Of these characteristics, those relating to the major diseases are particularly important. Susceptibility to leaf blast was determined, using at first the methods described for the International Blast Nursery. However, it was noted that certain varieties (e.g. Zenith) were severely damaged by neck blast after they had been given a satisfactory rating for leaf blast.

The reaction of the varieties to leaf scald (*Rhyncosporium oryzae*) was also noted. There was considerable genetic variability in the resistance of the varieties.

A sample (260 varieties) of the collection was examined in detail, principally for morphological characters, and evaluated by factorial analysis.

Collection of indigenous African rices

During an IRAT-ORSTOM collecting expedition in Mali and Senegambia in October-December 1974, 1000 samples of *O. glaberrima* and 100 each of *O.barthii* (annual) and *O.longistaminata* (perennial, with rhizomes), were obtained. The samples were grown at Bouaké in 1975 under well-irrigated conditions in order to minimize blast damage. The agronomic characteristics of the samples were observed and, with the aid of factorial analysis and electrophoresis data, the organization and relationships of the groups were defined. This gave valuable information for varietal improvement work using African species and in devising strategies for further collections of indigenous species.

The resistance of 367 varieties of *O.glaberrima* to leaf blast was tested. A few varieties (5%) showed satisfactory resistance. However, these varieties were all field susceptible to leaf scald (*Rhynchosporium oryzae*). Some varieties of *O.glaberrima* were less attacked by *Diopsis* than were varieties of *O.sativa*.

TABLE 1

Numbers and sources of introductions of O.sativa prior to 1975 to Bouaké, Ivory Coast; percentages and causes of elimination

Country of origin	No. varieties	% varieties retained	% varieties eliminated for: blast	lateness	other reasons
Zaire	50	78	0	0	22
Ivory Coast	161	70	2	1	27
Liberia	246	60	35	4	1
Taiwan	75	56	32	7	5
Thailand	107	41	30	10	20
Philippines	86	35	40	13	13
Laos	398	34	27	31	9
India	121	22	45	10	23
U.S.A.	166	21	49	11	19
IRRI	127	17	28	3	53
China	309	9	79	1	11
Senegal	289	9	5	78	9
Malaysia	493	3	9	88	1
Pakistan	100	2	36	2	60
Vietnam	77	1	6	87	5
Others	616	38	28	10	24
Total number	3,421	937	971	982	531

TABLE 2

Composition of the retained collection of 1,150 varieties of Oryza sativa at the end of 1976, Bouake, Ivory Coast, in terms of plant height and length of vegetative cycle

	Late (>135 days)	Medium (110-135 days)	Early (<110 days)	Total %
indica long stemmed (>120 cm)	31%	31%	7%	69
indica short stemmed (<120 cm)	5%	19%	3%	27
japonica	0%	2%	2%	4
Total	36%	52%	12%	100

Other collections

In Malagasy and Senegal, important collections have been assembled mainly for the improvement of aquatic (paddy) rice. However, they may contain useful genetic material for the improvement of upland rice and rice cultivated on soils where phreatic water is present (hydromorphic conditions). In Senegal, the 222 samples of *O. glaberrima* have shown better resistance to borers than varieties of *O.sativa*. Also, the *O.glaberrima* varieties generally showed moderate reactions to blast, while the *O.sativa* varieties frequently were severely affected.

Breeding

The selection criteria established were:

1) *Yield potential*: Varieties with high yield potential under favourable climatic conditions and high inputs were selected. Also, varieties which yield well under variable climatic conditions and/or low inputs are being sought.
2) *Yield stability*: Varieties able to give regular yields despite stresses imposed by erratic rainfall patterns, drought, cold weather, pests or diseases are selected.
3) *Agronomic characters*: Desirable traits include lodging resistance, growth cycles adapted to fit different farming systems, and resistance to shattering.
4) *Grain quality*: Resistance to breakage, good milling quality, desirable grain appearance, palatability and consumer acceptability are sought.

Yield potential

The diverse rice ecologies in Africa necessitate the development of different varieties, each adapted to a particular ecological zone. The yields obtained varied from 1-6 t/ha. The best IRAT selections, growing under favourable conditions, have a yield potential of 7 t/ha, and have yielded 4 t/ha under large-scale cultivation. On marginal lands, they have a yield potential of 5 t/ha, and an average yield of 2.5 t/ha under large-scale cultivation.

Yield stability

Length of the vegetative cycle is of prime importance in most areas. Early maturing varieties (90-100 days; e.g. Dourado Precoce, IRAT 10, IRAT 11, SE 314G) are required for Senegal, Mali, Upper Volta, Niger, north Cameroon and south-east Ivory Coast. In other areas varieties with a longer cycle (130-135 days; e.g. IRAT 13) give more regular yields than early maturing varieties.

In the Ivory Coast, early varieties such as IRAT 10 and Dourado Precoce yield 3-4 t/ha on experiment stations and 2-3 t/ha on local farms. Medium-duration varieties such as Iguape Cateto and IRAT 13 yield on average 3 t/ha. In WARDA multi-location trials throughout West Africa, the short-duration IRAT varieties, gave an average yield of 3-4 t/ha, while those of medium duration averaged 2 t/ha.

Resistance to pests and diseases is important to yield stability. Leaf and panicle blast, caused by *Pyricularia oryzae* are serious threats to pluvial rice in Africa. In Ivory Coast, Upper Volta and west Cameroon, IRAT only releases varieties with resistance to blast. This is preferably horizontal resistance, i.e. moderate resistance to all races of the pathogen.

Leaf scald, caused by *Rhynchosporium oryzae*, is also an important disease, and resistance to it is desirable. There are other diseases of minor importance at present, for which varieties are not selected for resistance. However, any selections which are highly susceptible to a minor disease are discarded. These diseases are being kept under surveillance in case they increase in importance. Similarly, insect pests are being monitored. There are at present no major insect pests of pluvial rice. However, their importance may increase with increased cultivation, especially large-scale cultivation.

Agronomic characters

Lodging resistance. The major disadvantage of traditional varieties is their tendency to lodge when grown under conditions of high fertility. This is a limiting factor in developing more intensive pluvial rice culture. Lodging resistance is being sought. A plant height of 100-120 cm is considered optimal.

Length of cycle. In certain regions with two rainy seasons (e.g. M'Bos plain of west Cameroon), two crops can be grown per year. Early or mid-duration varieties are required. In other areas the length of the cycle must be adapted to different farming systems.

Grain quality

In general, the improved varieties are of acceptable quality in most areas, especially the Ivory Coast, Upper Volta and west Cameroon. Varieties are sought which have a low rate of breakage during milling, long, translucent grains, and taste and cooking qualities as desired by the consumer.

Crossing

Crosses have been made in Ivory Coast, Senegal and Malagasy. (The Malagasy work is presented separately in this volume.) Several methods were used to obtain varieties with reduced plant height, resistance to lodging and other desirable traits.

Indica x Indica. In crosses between traditional African varieties and upland rice varieties from either Africa or Latin America, little transgression was observed. Certain useful lines such as 2243 (Moroberekan x RT 1031-69) and IRAT 8 emerged.

Traditional African pluvial types times upland varieties of diverse origin gave interesting variability. The variety IRAT 10 resulted from the cross 63-104 x Leung Sheng.1. These types of crosses are being continued.

Indica x Japonica. Some interesting variability was observed in crosses of Dourado Precoce, RT1031-69 and 63-83 (IRAT 2) with Chianan 8 (IRAM 1632). F3 and F4 progeny of Dourado Precoce times Chianan 8 and 63-83 times Chianan 8 have been retained, but many of them are susceptible to shedding.

Sativa x Glaberrima. These crosses resulted in some interesting lines which are currently being monitored. Further interspecific crosses are planned after more detailed studies to find suitable parents.

Induced mutations. Gamma irradiation of 63-83 (IRAT 2) from Senegal resulted in short-strawed mutants which not only had increased lodging resistance but also had retained other desirable qualities for upland rice. Varieties IRAT 13, IRAT 78 and IRAT 79 resulted from mutations of 63-83. Moroberekan and IAC 25 were also subjected to mutation and the progeny are being studied in Ivory Coast. Ca1345 and Kagoshima-Hakamuri were used for mutation work in Malagasy.

Crosses using semi-dwarfness. A number of donors of the character of semi-dwarfness (short straw) were indexed, including Taichung Native 1 and others possessing the same gene for semi-dwarfness, including IRAT 9 and IRAT 11. Some interesting selections were made using this gene. However, a limitation was that several undesirable traits, such as excessive tillering and a short and superficial rooting system, were also carried in association with dwarfness. This genetic system was largely abandoned, except in Senegal, where varieties Acorni, Dourado Precoce, Dawn, Mamoriaka, H4 and D25-4 were crossed with Senegalese selections (e.g. IRAT 11), carrying the dwarf gene from TN 1. The progeny of these crosses were at the F4 - F6 stage in 1976.

Three lines, 2243 from Moroberekan x RT1031-69, mutant 312A from 63-83 (IRAT 2) and IRAM 2165 (a mutant of Century Patna 231) carry a recessive gene for semi-dwarfness which is different from that in TN 1. These lines have been used as parents in crosses with Moroberekan, Dourado Precoce and other varieties. The segregating populations are being studied.

IRAT 13, a mutant from 63-83 (IRAT 2) is of medium height (110 cm). It also carries a recessive gene for reduced plant height (but not dwarfness) and it is a good source of other desirable agronomic characters. It has been crossed with several selections, including IRAT 10 which is another short-strawed variety.

Line 13d (*sativa*) and PI 215936 (*japonica*) have polygenic systems for a reduced plant height. They have been crossed with Moroberekan and R75 and the progeny is being studied.

Selection of progeny. Fixed line selections from Bouaké were tested at an early stage in many locations and in several countries. In this way, an early examination of the qualities of the selections and their adaptability was obtained. Early maturing lines from Ivory Coast were tested in northern Cameroon, Upper Volta, Mali and Senegal.

In Figure 1, the regions in which IRAT is involved in testing pluvial rice varieties and lines in Africa, the Indian Ocean (Malagasy and Reunion) and Latin America (Guyana) are shown. The stage of development of pluvial rice cultivation in these regions differs greatly. In some, improved varieties are already widely distributed, while in others, the first new varieties have just been released.

In Table 3, the varietal compositions of each region is given. This includes the varieties presently distributed, those which could be distributed to replace or complement their predecessors and those which have shown good yield potential but which require further testing.

In Guyana, the behaviour of four IRAT selections was compared to that of a traditional African variety and four varieties from Surinam. The results in Table 4 show the potential of the IRAT varieties, which out-yielded the South American varieties in the 1975-1976 trials.

Androgenesis

Research was conducted to obtain haploid plants by isolating the anthers and doubling their chromosomes. When techniques are perfected and put into practice they will be useful for varietal improvement, since fixed lines can be obtained directly from the progenies of the hybrids.

The variety Cigalon was selected for use in this research in 1975. A total of 200 plantlets was obtained

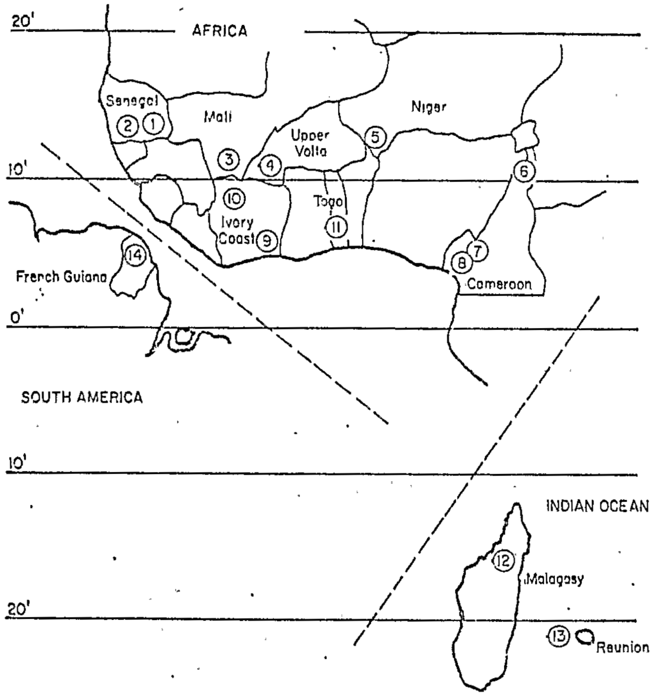

Fig. 1. Regions where IRAT pluvial rice selections are evaluated

at the rate of $3x10^{-3}$ from anthers.

The level of polyploidy of these plantlets was observed on a sample of 110 individuals, by examining root tips. The percentages observed were 80% haploids, 13% diploids, 6% triploids and 1% tetraploids.

The haploid plants were cultivated in a greenhouse in such a manner as to favour tillering. They were later divided and individuals of the clones were then soaked in 2-5% colchicine solution for four to eight hours. The proportion of doubled haploids was relatively low. It is possible that the application of colchicine treatment to very young plants would yield more diploids.

The work on another culture continued in 1976 when a dozen haploids were obtained and doubled by isolating the anthers of F3 plants from the cross IRAT 13 x Moroberekan.

TABLE 3

Varietal composition in regions where IRAT conducts trials

Countries	Regions (see Figure 1)	Varieties distributed	Varieties suitable for distribution	Promising varieties
Senegal	1	TS 123	IRAT 12	Lines of 63-104 x LS 1
Senegal	2	IRAT 11	Se 314 G	IRAT 10
Mali	3		Dourado Precoce, IAC 25	IRAT 10
Upper Volta	4	Dourado Precoce	IRAT 10	
Niger	5			Dourado Precoce, IRAT 10
Cameroon North	6			Daniela, IAC 25, IRAT 10
Cameroon West	7		Shinei	IAC 25
Cameroon West	8	IRAT 2	85 B/1, IRAT 78, IRAT 79	
Ivory Coast	9	Dourado Precoce	IRAT 10	
Ivory Coast	10	Moroberekan Iguape Cateto	IRAT 13	
Togo	11			Ainanthen 14, IRAT 10
Malagasy	12	1345	RS 25 T	Mutants of 1345 Mutants of 1490 1642 2366
Reunion	13			Shinei, Dourado Precoce Lines of 63-104 x LS 1
Guyana	14			IRAT 9, IRAT 10, IRAT 13

TABLE 4

Yield of African and Latin American varieties in Guyana, 1975-1976

Varieties	No.	Origin	Cycle (days)	Yield t/ha
IRAT 9	1716/2/3	TN1 x RT 1031-69	113	3.9
IRAT 10	144 B/1	63-104 x LS 1	114	3.5
IRAT 13	50/2/2	Mutant of 63-83	114	3.4
1345	Ca 345	Central Africa	120	2.8
IRAT 8	1487/9/5/7	Moroberekan x 63-105	113	2.8
Apani		Surinam	125	1.9
Alupi		Surinam	142	1.2
Pisari		Surinam	142	1.2

Resistance to Drought

In improving pluvial rice, drought tolerance can be useful in some ecotropical zones of Africa. Determination of the existence and levels of different resistance/tolerance mechanisms would be useful information for a breeding programme in order to select better parents and progeny. A number of tests have been used to determine the characteristics for drought tolerance in different varieties of rice cultivated under upland conditions. However, since the mechanisms of drought tolerance are not well known, the main criterion is the grain yield obtained after water stress during part of the growth period.

IRAT studies in 1975-76 showed that a deep rooting system and moderate tillering are two characteristics favouring drought tolerance. Two aspects were particularly studied; research on new criteria of selection for drought tolerance; and studies on the physiological aspects of drought tolerance.

The yield of 12 varieties was compared after applying drought periods at various growth stages (Table 5). IRAT 13 (a mutant of 63-83) was shown to have good tolerance to drought, irrespective of when it occurred. The vegetative growth stage of the plant is more sensitive than after heading.

Studies on root systems and root growth have shown that varieties differ in the depth and functioning of their root systems. Drought stress just before heading greatly increases root growth in some varieties.

Other studies have shown that water efficiency as determined through limiting transpiration to one-half, differed little among varieties in terms of dry matter production but did differ in terms of grain production. This may be due to effects on a regulation mechanism giving a shift from vegetative to reproductive growth or to dormancy. A weakness of present varieties is their production

of new tillers under stress, many of which yield no grain.

More research is required before perfection of screening methods for drought tolerance is achieved.

TABLE 5

Yield (g/sqm) of 8 varieties after a three week drought period was applied at various growth stages, Bouaké, Ivory Coast, 1976

Varieties	Initiation to booting	Booting to heading	Heading to filling	Filling to harvest
63-83	*229*	156	*213*	255
Iguape Cateto	191	196	211	303
IRAT 13	*236*	*224*	*227*	*363*
IRAT 9	129	190	151	254
IRAM 1632	193	*256*		
Dourado Precoce	162	160	102	244
Moroberekan	153	158	208	
Palawan	186	133	200	

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