Utilization of genetic resources for rice production in Nigeria

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INTRODUCTION

Rice production trends and genetic improvement in Nigeria are closely interwoven. Genetic resources utilization for rice improvement in Nigeria can be broadly divided into phases which coincide with the history of rice research and production in the country. Thus, genetic diversity amounts to a discussion of trends in genetic resource utilization and the history of rice production in the country.

TRENDS IN GENETIC RESOURCE UTILIZATION FOR RICE IMPROVEMENT

In the beginning

Rice cultivation in Nigeria dates back about three-and-a-half-centuries to a period when the indigenous red rices – *Oryza glaberrima* varieties – were the only cultivated rice species, as was the case for other parts of West Africa (Carpenter, 1978). Worldwide, only two of the over 20 known species of the genus *Oryza* are domesticated. Of these cultivated species, one is indigenous to Asia (*O. sativa* L.), while the other is indigenous and endemic to West Africa, (*O. glaberrima* Steud). The latter is distributed mainly in the savannah along the southern fringes of the Sahara desert (Oka, 1988).

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O. glaberrima was first grown as a crop in the central Niger Delta and Sokoto Basin, among other places, but it later spread into the bush fallow upland farming systems of the western forest zones of Nigeria. *O. glaberrima* probably developed independently and was domesticated from a wild progenitor, *O. barthii* (Jacquot, 1977). *O. glaberrima* is believed to have originated or to have first been domesticated in the flood plains of the Niger River (Hardcastle, 1959). Just half a century ago, *O. glaberimma* accounted for up to 60 percent of total rice production in Nigeria (Hardcastle, 1959). The genetic diversity of the species is clear from the wide range of growing conditions that exist from north to south and in which these varieties have thrived for centuries. These conditions range from the floating/very deep to deep waters of the Sokoto-Rima Basin in the northwest along the basins of the River Rima (an important tributary of the Niger River) and the Jere Bowl in the northeast to the lowlands and uplands of central and southern Nigeria. The floating/deepwater conditions in the flood plains were significantly reduced following the construction of the Bakolori Dam in the upper section of the River Rima. Thus, while a number of varieties adapted to the floating/deepwater conditions, others grew well under drought-prone upland conditions. *O. glaberrima* is still cultivated today in the Kebbi and Sokoto states of Nigeria along the Rima Valley flood plain, and as an upland crop in the Zuru area of Kebbi State. It can also be found in mixtures, and almost replaces the *sativa* cultivars in some farmers' fields, both in the shallow swamps of the flood plains of the Hadejia, Kano, Niger, Benue and other rivers, and in dryland rice crops in southern parts of the country. However, as a cultivated rice crop, *O. glaberrima* is fast being replaced by its Asian counterpart, *O. sativa*. That *O. glaberrima* still exists as both a crop and a volunteer, is probably due to its high level of adaptability to African rice ecological conditions. Until the 1960s, the yield of *O. glaberrima* in Sokoto fadama was superior to that of available *O. sativa* floating cultivars (Carpenter, 1978). Two *glaberrima* varieties, Badande and Jatau, outyielded some of the most successful *sativa* cultivars, such as FARO 6 and FARO 7, in Sokoto fadama in 1960 (Oka and Chang, 1964). Similarly, a number of these varieties thrived well in the rainfed lowlands of the country (Hardcastle, 1959). On the basis of studies on genetic diversity in *O. glaberrima,* Jacqout (1977) indicated that there were two major groups: floating and upland.

A number of these varieties can still be found in farmers' fields, particularly in the northern parts of the various rainfed rice ecologies. They are named in many ways, for example: after the cultivation location (Dan Zaria, Godongaji, Katsina Ala Shendam etc. – all of which are towns in Nigeria); or after the farm where or farmer from whom they are collected (Dogo, Baba Hawa etc.). Some of these *glaberrima* varieties were collected and preserved in the short term by the National Cereals Research Institute (NCRI), Badeggi, and in the medium term at the West Africa Rice Development Association (WARDA), Bouake. WARDA's working collection includes about 300 accessions of *O. glaberrima* collected between 1985 and 1990 in Nigeria (Jones *et al.*, 1997). The gene bank of the International Institute of Tropical Agriculture (IITA), Ibadan, has a collection of over 2 000 entries of *O. glaberrima* from 22 African countries, and the International Rice Research Institute (IRRI), Philippines, keeps duplicates of all materials under long-term storage (Singh *et al.*, 1997). At the same time, many of these varieties may have disappeared through the evolutionary processes (Singh *et al.*, 1997; Guei, 2000).

These varieties are characterized mostly by short to medium, red grain types and they shatter very badly on ripening. Under farmers' conditions, grain yields are often very low but stable – probably as a result of the varieties' high adaptability to the ecology (Chang and Vegara, 1975; Fagade and Ayotade, 1978; WARDA, 1992; Jones *et al.*, 1997). *O. glaberrima* varieties have very good early vegetative growth and ground cover and thus compete favourably with weeds, which are major constraints in rainfed rice production in Nigeria and West Africa generally. They also possess acceptable tolerance or resistance levels to many of the prevalent adverse soil and environmental conditions (diseases, pests and weather) in the country. They are considered more resistant to flooding due to their good elongation ability under flooded conditions.

Two recent studies characterized the diversity of *O. glaberrima*. Jones *et al.* (1993, 1997) concluded that there is very wide variability in the important morphological and agronomic traits within both *O. glaberrima* and traditional improved *sativa* accessions.

Breeding methods, varieties and their impact on rice production

There were initially no attempts to improve varieties, despite their possession of the above-mentioned desirable agronomic traits (Abifarin *et al.*, 1972). At best, there may have been some selection process by farmers who tend to look for and plant materials most suited to their environment and tastes. As in other parts of the world, farmers began crop varietal selection and were regarded as pioneer plant breeders. In Nigeria, as in other parts of Africa where *O. glaberrima* was the first rice crop, development of a wide range of *O. glaberrima* cultivars was practised through farmer selection. The selection practice led to the vast diversity of cultivated African rice known today: floating varieties, photoperiod sensitive, photoperiod insensitive, swamp and upland cultivars, short and long duration cultivars, materials with varying levels of pest and disease tolerance, and varieties with all kinds of grain characteristics (Virmani *et al.*, 1978). Unfortunately, these selection practices did not appreciably improve the yield potential of *O. glaberrima*. As a result, the introduced *O. sativa* varieties with superior grain yield were widely adopted and threatened the genetic base of the African rice. However, African rice survived the onslaught thanks to its wide adaptability.

There were attempts to improve *O. glaberrima* and produce hybrids or select cultivars for higher grain yield, adaptability to soil and other abiotic and biotic production constraints. *Sativa/glaberrima* crosses were mostly unsuccessful due to high sterility and continued segregation of progenies up to eighth or more generations (FAO, 1971).

As a result, total national rice production remained low for many years, averaging only a few thousand tonnes and a low productivity rate of about 0.5 t/ha. Rice consumption before 1960 was restricted to the areas of production, and for many years rice in most households in Nigeria was used only for festivals or other special occasions (Ayotade, 1991). Rice was not the national staple it is today. Prices were higher than those of the main staple root, tuber, or of other cereal foods. Rice consumption was regarded as elitist – a special food only for well-to-do and urban consumers. On important occasions, it was a status symbol to serve a rice meal instead of the normal daily staple, such as yam/cassava fufu or a cereal dish. Rice was generally preferred by children, but it was rarely sufficient to satisfy their needs. At Independence in 1960 for example, Nigeria produced only 0.134 million tonnes (Mt) of paddy from 0.156 million hectares (Mha) with an average yield of 0.8 t/ha. *Glaberrima* rices accounted for 60 percent of total national rice production at this time, despite the introduction several years earlier of white-grained *O. sativa*.

The arrival of *Oryza sativa*

O. sativa is believed to have been introduced into Africa some 2 200 years ago (Jacquot, 1977; Gupta and O'Toole, 1986). The route of *O. sativa* into Nigeria is not quite certain; however, Asian rice is known to have reached Africa through Madagascar from Java. It is likely that many African countries, including Nigeria, received their rice via this route. Another possibility is that Asian rice was introduced into Senegal, Guinea Bissau and Sierra Leone by the Portuguese around 150 AD (Porteres, 1950), and Nigeria may also have received the Asian rice by the same route. It should however be noted that Nigeria (like many other West African countries) established contact with the Arab traders and later Arab Islamic Missionaries through North Africa long before the arrival of the Europeans. The same Arabs were already in contact with Asia and could just as well have introduced Asian rice into the country. However, the most significant recorded introduction to Nigeria was in the 1920s when some form of research work started on rice at Moor Plantation, Ibadan (Hardcastle, 1959; Obasola *et al.*, 1981). This period marked the beginning of rapid genetic erosion in the indigenous *O. glaberrima.* Over three-quarters of a century, the white-grained *sativa* varieties almost completely replaced the red rices. These rices of Asian origin had in turn adapted so well to rice-growing conditions that the country and the entire West Africa region became a new centre of genetic diversity (Sharma and Steele, 1978). However, the introduction of these varieties was largely uncoordinated with no significant progress made in rice production.

Breeding methods, varieties and their impact on rice production

Organized rice research activities in Nigeria began in 1953 with the establishment of a rice research unit at Badeggi as a station of the then Federal Department of Agricultural Research (FDAR), Moor Plantation, Ibadan (Hardcastle, 1959). Rice improvement efforts in this period concentrated on improving farmers' yields through the replacement of farmers' traditional varieties with exotic materials. The main breeding strategies of the new station were:

- collection, testing and selection from local varieties; and
- introduction, selection and adoption from exotic varieties.

From 1954, efforts were geared towards the collection of both *glaberrima* and *sativa* rice varieties available or grown in the country. In the first year, nearly 200 accessions were collected and maintained in the gene bank of the station at Badeggi. This collection increased to over 2 000 accessions in the first two decades of the station's existence (FDAR, 1974). Each new collection was entered into a varietal collection nursery and assessed with standard varieties for given agronomic traits, such as duration, height, reaction to diseases (blast, brown spot, onion shoot) and pests (stem borers), grain type and yield. Different nurseries were planted for different ecologies: upland, swamp (rainfed lowlands of varying water depths) and floating rice. Outstanding entries from the varietal collection nursery were moved to station yield trials lasting 2 to 3 years. Materials with superior performance to the standard varieties were then evaluated further in different locations in the country (zonal trials). Materials with higher yield and other desirable traits from zonal trials were then recommended to replace the existing farmers' varieties. It is therefore a lengthy process before a new variety reaches the farmers.

FARO 1 (or BG 79) was introduced from Sri Lanka. It has the FDAR/NCRI (National Cereal Research Institute) genebank accession no. 131 and was later named as FAROE 131-54. FARO 1, recommended for lowlands, was one of the first white-grained varieties to be successfully introduced into the country. Another is FARO 3 (Agbede) recommended for the upland areas. Agbede is a pure line selection from local Agbede 16/56 (Obasola *et al.,* 1981). These two varieties (and others that followed them until about 1966) are late-maturing, poor nitrogen responsive, disease and pest susceptible, and with moderately high-yielding capacity even under the farmers' poor management practices. These earlier recommended, introduced varieties have the good grain qualities sought by consumers and were so widely grown by farmers that they were considered 'local varieties' and given local names by farmers (Fagade and Ayotade, 1978). They were cultivated all over the country in the recommended ecology. Other varieties were: FARO 2, 5, 6, 7 and 8 for rainfed lowland; FARO 11 for upland; and FARO 4 and 9 for deepwater ecologies (Ayotade, 1991) (Table 1).

TABLE 1
Origin and characteristics of varieties released in Nigeria before 1965

FARO no.	Origin	Pedigree/ parentage	Ecology	Year of release	Growth duration (*days*)	Plant height (*cm*)	Yield potential (*t/ha*)
1	Guyana	BG 79	Shallow swamp	1954	135-174	105-120	3.0-5.0
2	Guyana	D 144	Shallow swamp	1957	135-115	100-115	3.0-4.5
3	Nigeria	Agbede	Upland	1958	95-120	95-100	1.5-2.5
4	India	Kavunginpoothala 12	Deepwater	1959	189-220	145-150	2.0-4.0
5	Madagascar	Makalioka 825	Shallow swamp	1960	135-154	111-115	2.0-4.5
6	F/Guinea	Indochinablank (ICB)	Deepwater	1961	176-198	156-160	2.0-3.0
7	Thailand	Maliong	Deep flooded water	1962	160-217	160-165	2.5-3.5
8	Indonesia	Mas 2401	Shallow swamp	1963	155-160	120-125	3.5-4.5
9	Malaya	Siam 29	Shallow swamp	1963	189-220	120-125	2.5-3.0
10	Kenya	Sindano	Shallow swamp (high altitude)	1963	115-162	125-130	2.5-4.5

There was a national need in the period 1966-1970 for early-maturing and high-yielding varieties which could be used for double-cropping in the irrigation schemes that were being established in the country. At this time IRRI was disseminating the 'ideal plant type' for tropical rice varieties. As a result, stiff-strawed, non-lodging, nitrogen-responsive, high-yielding varieties were both introduced and adapted or bred in the country. Prominent among the introduced and adapted varieties were SML 140/10 and IR 8 (recommended as FARO 12 and 13, respectively). High-yielding or modern varieties (not recommended, but found in farmers' fields) include: IR 1416, BG 400-1 and IR 30.

The release and adoption of modern varieties greatly influenced national rice production. Production increased from 135 000 tonnes in 1960 to 308 780 tonnes in 1970. At present, some farmers still grow mixed portions of *O. glaberrima* and *O. sativa* in both upland and floating rice conditions; however, the proportion of *O. glaberrima* has reduced remarkably to around 10 to 15 percent of the total area.

The period from 1970

Restructuring rice research and streamlining germplasm exchange

In the early 1970s, the exchange of germplasm and the development and dissemination of semi-dwarf high-yielding varieties adapted to local conditions were important rice improvement activities in the national research and extension systems in Nigeria. In 1975, FDAR became the National Cereals Research Institute (NCRI) with its headquarters at Badeggi. Rice improvement was accorded higher priority in the NCRI programmes. This period also coincided with the establishment in 1975 of a global network for the systematic collection, evaluation and distribution by IRRI of genetic materials through the International Rice Testing Programme (IRTP). In 1989, IRTP was renamed the International Network for Genetic Evaluation of Rice (INGER). Nigeria has participated in this network since its inception (Seshu, 1986). WARDA (the coordinator of INGER-Africa activities) and IITA (which had a rice mandate for Africa until 1991) also collaborate with Nigeria in the exchange and development of germplasm. The mid 1970s therefore marked the watershed for the systematic exchange, utilization and spread of improved genetic materials in Nigeria. It also greatly increased the range of genetic diversity available for breeding purposes.

Development and spread of high-yielding cultivars

The breeding effort in Nigeria continued to focus on the selection of tall vigorous and photoperiod sensitive varieties for swamp rice ecologies with their varying water depths and growing seasons. These efforts led to the development and release of a number of varieties, such as FARO 12, 15, 16 and 17 (Table 2). FARO 12 was introduced from Suriname. It is a tall long duration variety with narrow long leaves and it was recommended to suit the long growing seasons found in the rainfed swamps of the south, e.g. those in Bende, southeast Nigeria. It has very long and slender grains. FARO 15 has a strong culm, medium-size grain, broad leaves and is more adapted to a medium- to deepwater ecology because of its elongation ability, but lodges heavily when subjected to heavy doses of nitrogen fertilizer. FARO 15 is still very much cultivated in the country in rainfed shallow and deepwater fadamas. There is hardly any trace today of FARO 16 and 17 in farmers' fields, either because they no longer exist or because other names are used by farmers and extension workers.

At this time, the Asian revolutionary development of the semi-dwarf rice plant type (which drastically raised rice yield potential to about 5 to 6 t/ha) was being pursued. This led to the development of high-yielding semi-dwarf IRRI varieties and others from other Asian national research institutes.

Varieties introduced into Nigeria included IR 8 (FARO 13) and Taichung Native 1 (FARO 21). Other IRRI lines were released as FARO 19-23 (Table 2). Seven of the new high-yielding varieties: IR 8, IR 20, BPI-76, TN 1, IR 627-1-31-3-37 and IR 5, were released for cultivation between 1970 and 1974.

At the same time, the breeding programme screened introductions for donors of useful traits, such as high yield potential, adaptability to target environment, and tolerance or resistance to major stresses. Part of the strategy was to incorporate these traits into either local varieties or improved materials. The pedigree method is used to evaluate the lines simultaneously for agronomic traits and resistance/tolerance to different stresses.

From 1976 onwards, greater attention was devoted to developing varieties for the target environment, e.g. early-maturing stress resistant varieties for irrigated ecologies. This culminated in the development and release of a number of varieties, such as FARO 31, 32, 33 and 34 (Fagade *et al.*, 1988; Nkwungu *et al.*, 1990) (see Table 2).

TABLE 2

Released rice varieties in Nigeria, 1965-1986

FARO no.	Origin	Pedigree/parentage	Ecology	Year of release	Growth duration (*days*)	Plant height (*cm*)	Yield potential (*t/ha*)
11	Congo/Zaire	OS 6	Upland	1966	115-120	115-120	1.5-2.5
12	Surname	SML-140/10	Shallow	1969	145	135-140	3.0-4.0
13	Philippines	IR 8	Shallow	1970	135-140	90-100	2.0-4.0
14	NCRI, Nigeria	Chanyza 123 x ICB	Deepwater	1971	170-198	150-160	2.5-4.0
15	NCRI, Nigeria	BG 79 x IR 8	Shallow	1974	145-160	115-120	3.5-4.5
16	NCRI, Nigeria	Mas 2401 x SML 14/10	Shallow	1974	140-160	90-100	2.5-3.5
17	NCRI, Nigeria	Mas 2401 x Tjina	Shallow	1974	145-160	110-120	2.0-3.0
18	Indonesia	Tjina	Shallow	1974	179	145-150	2.0-3.0
19	Philippines	IR 20	Shallow	1974	135-140	90-100	
20	Philippines	BPI-76	Shallow	1974	125-130	90-100	2.5-4.0
21	Philippines	Taichung Native 1	Shallow	1974	90-110	80-90	2.5-4.0
22	Philippines	IR 627-1-31-3-27	Shallow	1974	145-150	90-110	2.0-3.0
23	Philippines	IR 5-47-2	Irrigated/shallow swamp	1974	145-150	90-100	2.0-3.0
24	Viet Nam	Degaule	Irrigated/shallow swamp	1974	135-145	135-145	2.5-3.5
25	NCRI, Nigeria	Jete x Tjina (FAROX 56/30)	Upland	1976	115-120	105-100	2.5-3.5
26	NCRI, Nigeria	TOS 78	Shallow	1982	130-135	105-100	2.5-3.5
27	NCRI, Nigeria	(TOS 103) IR 400-15-12-10-2 x IR 662	Shallow	1982	110-115	90-100	3.0-4.0
28	NCRI, Nigeria	Tjina x IR 8 (FAROX 118°)	Shallow	1982	135-140	125-130	3.0-4.0
29	NCRI, Nigeria	Pesa/TN 1 Remadja (BG 90-2)	Shallow	1984	125-135	100-115	2.5-3.5
30	NCRI, Nigeria	FARO 15/IR 28 (FAROX 228-2-1-1)	Shallow	1986	110-115		5.0

FARO no.	Origin	Pedigree/parentage	Ecology	Year of release	Growth duration (*days*)	Plant height (*cm*)	Yield potential (*t/ha*)
31	NCRI, Nigeria	FARO 15/IR 28 (FAROX 228-2-1-2)	Shallow	1986	110-115	120-125	5.0
32	NCRI, Nigeria	FARO 15/IR 28 (FAROX 228-1-1-1)	Shallow	1986	110-115	110-120	4.5
33	NCRI, Nigeria	IR 28/FARO 12 (FAROX 233-1-1-1)	Shallow	1986	110-115	115-125	4.0-5.0
34	NCRI, Nigeria	FARO12/IR28 (FAROX 239-1-1-1)	Shallow	1986	105-115	115-120	4.0-5.0
35	IITA, Nigeria	ITA 212 (BG 90-2*4/Tetep)	Shallow	1986	120-135	100-115	4.5-5.0
36	IITA, Nigeria	ITA 222 Maushuri/IET 1444	Irrigated swamp	1986	120-135	100-115	4.5-5.0
37	IITA, Nigeria	ITA 306 (TOX 494-3696/TOX 711/BG 6812)	Irrigated swamp	1986	125-140	100-115	4.5-5.0
38	Côte d'Ivoire	IRAT 133 (IRAT 13/IRAT 10)	Irrigated swamp	1986	100-105	100-110	1.0-3.0
39	Côte d'Ivoire	IRAT 144 (IRAT 13/IRAT 10)	Irrigated swamp	1986	100-105	95-105	1.0-3.0
40	NCRI, Nigeria	FAROX 299 (Multiline)	Irrigated swamp	1986	115-120	115-120	1.0-3.0
41	Côte d'Ivoire	IRAT 170 (IRAT 13/Palawan)	Upland	1986	115-120	80-90	1.0-3.0
42	IAR & T, Nigeria	ART 12 (ITA116)	Upland	1986	115-120	110-115	1.0-3.0
43	IITA, Nigeria	ITA 128 (63-83/Iguape Cateto, IET 144, IR 1416-131, Lite 506)	Upland	1986	115-120	110-115	1.0-3.0

Table 2 also includes varieties officially released in the country in the last two decades. These include two each of early- and medium-maturing upland varieties (Fagade *et al.*, 1987a, 1987b). Nineteen percent of the upland varieties released from 1976 to 1995 – i.e. FARO 25, FARO 39 (IRAT 144), FARO 40 (FAROX 299) and FARO 42 – were not grown in any of the country's geopolitical zones. This might be because of the high preference for FARO 11 and FARO 46 (ITA 150). FARO 38 is listed as being grown only in the northeast zone. Similarly, FARO 26 (TOS 78) among the lowland varieties is listed as growing in only one zone, i.e. the southwest. Field surveys, however, are required to confirm that these varieties are no longer planted in farmers' fields, as many released varieties have been renamed using local dialects. The other varieties are widely spread in the country and have made an important contribution to the nation's increased production.

Prior to 1976, only one early-maturing variety, FARO 21 (TN 1), had been released (see Table 2). However, the number of early-maturing varieties released increased from one in 1976 to over ten in 1995 (Table 2). In the 1970s, the Government started to address the constraints to rice production, and large-scale development projects (in the river basins) were among the first attempts to stem imports. Thus, this may have been a reflection of the demand for early-maturing varieties in the irrigated schemes being developed in the upland and lowland areas of the drier north characterized by only 3 to 4 months of rainfall.

A great upland rice discovery (mostly early-maturing varieties) was reported by the River Basin Development Authorities of the northwest zone. It was reported as occupying a significant proportion of the total rice production area in the states, even posing a problem for the early planting of dry season crops (e.g. wheat) (NARP, 1995). The area occupied was, however, not quantified. These areas, known as 'upland rice areas', could also be rainfed lowland rice areas since they were in the river basin schemes.

Farmers adopted some of the improved varieties even without their formal release through the national varietal release mechanism. These varieties included: IR 1416 and Cisadane in the southeast; BG 400-1, IR 30, IR 72 and others in the northern zones. Breeders' seeds of released rice varieties are provided by the research institute to the National Seed Service (NSS) set up in 1975 for further multiplication to foundation seed (Nyanteng, 1986). These are distributed to the ADP (Agricultural Development Project) at state level or to ministries of agriculture for the production of certified seeds which are sold to farmers. The National Seed Service uses the services of the research institutes, NAFPP (National Accelerated Food Production Program) and private seed growers to obtain both foundation and certified seeds (Nyanteng, 1986).

In 1986, the seed multiplication efforts were intensified in Kaduna State with the multiplication and distribution of over 50 tonnes of seeds of ITA 257, FARO 15 and FARO 27 (FACU, 1988); but this was a far cry from farmers' needs. As 1 tonne of seed could plant about 20 ha, some 10 000 ha would have been planted to these improved varieties.

In Kano State, Kano Agricultural and Rural Development Authority (KNARDA) multiplied and sold seeds of ITA 116, ITA 118 and ITA 235 to farmers (FACU, 1988). The area under the authority's rice programme was 40 000 ha. There is thus confirmation of the wide diversity in the use of improved varieties.

Modification of the variety release mechanism

The improved varieties found in farmers' fields could be traced to a number of sources, but research sources were the most predominant. Prior to 1984, the varietal release system in Nigeria was such that rice varieties could reach farmers through many research institutes or channels with a rice component in their programme. At national research level, following two or more advanced yield trials, the most outstanding entries were tested for a further two years in zonal trials. The national research institute then released outstanding varieties to replace existing ones. Other research centres go directly to the farmer. For example, FARO 26 (TOS 78 = IR 269-26-3) and FARO 27 (TOS 103 = IR 790-35-5) were originally introduced into Nigeria by IITA from IRRI. They were used in zonal trials and fertilizer trials between 1976 and 1978, before being released as varieties in 1982 (NCRI, 1978). FARO 28 (FAROX 188A) was developed at NCRI as a cross between Tjna and IR 8 (introduced from Indonesia and IRRI in 1960 and 1967, respectively); it passed through the zonal trials between 1976 and 1978 (NCRI, 1978). Similarly, FARO 29 (BG 90-2), released in 1984, was identified in the IRTP nursery in 1979 and tested in the zonal trial (medium duration) from 1980 to 1982 (Table 2) (NCRI, 1983).

However, as of 1984, outstanding entries from all the research institutions involved in rice research in the country were nominated into a network of Coordinated Rice Varieties Evaluation Trials (CRET) coordinated by NCRI. These institutions included: national institutes, such as NCRI and IAR&T (Institute of Agricultural Research and Training); and international centres, such as IITA, IRRI/IRTP, INGER and WARDA. After two years the best entries from CRET in each ecology were recommended for release to the national varietal release committee. Thus in 1985, IRAT 133, IRAT 144 (from upland short duration CRET), IRAT 170, ART 12 (ITA 116), FAROX 299, ITA 128 (from upland short medium CRET), FAROX 228-2-1-1, FAROX 228-3-1-1 and FAROX 228-4-1-1 (from lowland short CRET) and ITA 212, ITA 222 and ITA 306 (from lowland medium CRET) were recommended by the Third National Coordinating Research Project on Rice for release to farmers and were consequently released by NCRI in 1986 (Fagade *et al.*, 1987a, 1988).

The method of release was modified slightly in 1986, so that between two and five of the most promising materials from any CRET nursery are nominated into NAFPP farmers' field trials and the farmers' choices are released after one or two years of trials. The varieties released in 1986 and 1993 are listed in Table 2. Ninety percent of the varieties released between 1985 and 1995 appeared in the CRET trials. Sixty-seven percent of the varieties released in Nigeria originated directly from IRRI. Eighty-six percent passed through INGER-Africa trials for at least 1 year before release, while all had one or more of their parents originating from IRRI/IRTP or INGER-Africa sources. This showed greater diversity of materials and facilitated the monitoring of varietal types compared to the method previously adopted for varieties released in Nigeria.

Genetic composition of released varieties

Tables 1 and 2 show that the rice varieties released in Nigeria had varying genetic contributions from across the globe. The parentage of the early introductions was not recorded, which places limitations on the discussion of diversity in the genetic make-up of released varieties. However, the spread in the country of origin, diverse morphological and physiological characteristics, adaptation to different ecologies and differences in reactions to environmental stresses are evidence that the varieties have diverse genetic make-up. The high level of resistance to blast in Tjina, for example, was used for developing high-yielding blast-resistant varieties, such as FARO 16 and FARO 25, as well as semi-dwarf FARO 28. The genetic make-up of varieties that were introduced or developed later were traceable. As seen in Table 2 and discussed earlier, most of the varieties bred in the country since 1986 have parents originating from IRRI. IR 28 was used in crosses to incorporate its gene for earliness, traceable from early IRRI lines into:

- FARO 15, a highly adaptable and high-yielding variety, in order to obtain stiff-strawed early-maturing high-yielding varieties. FARO 15 had the high-yielding stiff straw from its IR 8 parent. The other parent of FARO 15 is BG 79, used because of its wide adaptability to the Nigerian ecosystem. This combination resulted in the development and release of FARO 30, 31 and 32 as early-maturing high-yielding varieties for irrigated schemes in the country.
- FARO 12, also a long duration (140-160 days), photoperiod-sensitive variety with long grains. The selected and released lines from this cross (FARO 33 and 34) were weak-strawed (like the FARO 12 parent), but they inherited the long grains of FARO 12 and the earliness of IR 28. They perform well under moderate levels of fertilizer and are grown in most of the irrigated schemes of the north.

Genetic uniformity in rice production in Nigeria is most common in the upland rice-growing zones of the forest zone where farmers stuck to growing only one variety, FARO 11, prior to the introduction of earlier-maturing FARO 46 only a few years ago. There was no serious disease or pest outbreak in this variety, partly because of its tolerance to the most common disease: blast. Farming systems where rice is intercropped with maize, cassava, melon and so on, as well as the fallow system, may have assisted in stemming the incidence of major disease or pest attacks. Genetic uniformity is also found in the Bende irrigation scheme where FARO 12 and 23 are the only common varieties. Again, blast is the major rice disease in this area and the two varieties, particularly FARO 12, are tolerant. The long fallow period due to the insufficient water supplies for a dry season crop may also have helped to reduce serious pest and disease outbreaks. However, in neighbouring Ebonyi State, where gall midge is highly prevalent, there were reports of complete crop failure of all varieties grown in endemic years in the rainfed lowland crops, as no tolerant variety was identified until the official release of tolerant Cisadane just 4 years ago.

New areas of collaborative rice improvement and genetic diversity

Significant to rice development in recent years is the increasingly high level of collaborative research activities from which rice varietal improvement in Nigeria has benefited greatly. The impact is already being felt, but the greater part is to be witnessed in the near future. These activities included the new concept of collaborative research between WARDA and the national programmes within the subregion through task forces. Some production constraints were identified and a task force was allocated to develop technologies aimed at solving such constraints. Rice breeding had three such task forces in which Nigeria actively participated: upland, rainfed lowland and irrigated lowland. Through the task forces, lines bred for different ecological problems were composed into nurseries of nominations from both WARDA and national programmes. The National Agricultural Research Systems (NARS) that share similar production constraints in a given ecology evaluated these nurseries. Part of the funding was undertaken by WARDA and results were discussed at WARDA headquarters at the end of each cropping season. Varieties from these nurseries were identified for national use. WARDA at full incorporation in the CGIAR (Consultative Group on International Agricultural Research) system established a lowland breeding station at IITA when the latter ceased its rice research work. The national programme benefited because scientists could enjoy closer collaboration with their WARDA counterparts at the station.

A recent development is farmer participatory varietal selection (PVS) – a collaboration between WARDA and NARs with the participation of Nigeria. This approach places the farmer first in the varietal selection process, which in turn makes it possible to identify farmer-acceptable rice cultivars, shortens the time lag between varietal development and release (adoption) and utilizes farmers' knowledge to breed acceptable rice varieties.

Another collaborative activity was a national initiative through the now suspended National Agricultural Research Project (NARP), a World Bank assisted project. The project that took off in 1990 brought together all rice scientists within the country to participate in collaborative rice research. The programme contributed by expanding the scope of CRET and bringing the state Agricultural Development Projects (ADPs) and the universities into the mainstream of rice varietal evaluation nationwide.

Most recent sources of diversity through varietal releases

The most recent batch of varieties released in Nigeria were mainly upland with only two lowland varieties (Table 3). The upland varieties were mostly those developed earlier by IITA. Though some of these varieties were developed in the early 1980s, the long process of varietal evaluation meant that they were not released until 1992. They are short-statured varieties, selected to reduce the height of FARO 11 and increase tillering ability. The result was the

TABLE 3
Released rice varieties in Nigeria, 1987 to present

FARO no.	Origin	Pedigree/ parentage	Ecology	Year of release	Growth duration (*days*)	Plant height (*cm*)	Yield potential (*t/ha*)
44	Taiwan	SIPI 692033(SIPI 661044/SIPI651021	Irrigated/ shallow	1992	110-120	95-110	4.0-6.0
45	ITA, Nigeria	ITA 257(IRAT 13/Dourado Precose 689/TOX 490-1	Upland	1992	90-100	90-100	2.0-3.0
46	ITA, Nigeria	ITA 150 (63-83/Multiline	Upland	1992	100-105	80-90	2.0-3.0
47	ITA, Nigeria	ITA 117 (13A-18-3-1/TOX 7)	Upland	1992	115-120	90-110	2.0-3.0
48	ITA, Nigeria	ITA 301 (IRAT 13/Dourado Precose 689/Padipapayak)	Upland	1992	115-120	90-110	2.0-3.5
49	ITA, Nigeria	ITA 315 (IR 43/Iguape Cateto)	Upland	1992	115-120	90-110	2.0-3.5
50	ITA, Nigeria	ITA 230 (BG 90-2*/Tetep)	Irrigated/ shallow swamp	1992	130-135	90-115	3.0-4.0
51	Indonesia	Cisadane (Pelita-1/IR/ 789-98-2-3/IR 2157-3	Irrigated	1997	130-135	100-120	3.0-4.0
52	IITA/WARDA	WITA 4 (TOX 3100-44-1-2 -3-3)	Irrigated/ shallow	2000	120-135	115-120	3.0-4.5

ITA 300 series, of which ITA 301 and ITA 315 were released as FARO 48 and 49, respectively. These two cultivars are of medium maturity and high yielding, particularly under high nitrogen fertilization. They also have good grain type (B type grain), but are susceptible to drought and under the heavy humidity of the moist forest zone of western Nigeria are highly susceptible to leaf scald (*Gerlachia oryzae*) and bacteria blight (*Xanthomonas campestris*).

ITA 117 (FARO 47) is a much taller variety, of medium maturity and with lower yield potential. FARO 48 and 49 are widely adopted in the middle belt zone, especially in Benue and Plateau states. FARO 46 is the most widely adopted improved upland rice variety in Nigeria today. With a moderate yield potential of about 2 t/ha, it is intermediate to tall plant type, depending on the water and fertility conditions of the soil. The paddy grain is golden, easy to thresh and long grained. The variety is even grown in the northern parts of the country: Kano, Adamawa and beyond, where it is intercropped with sorghum, maize and millet. It is also widely grown in the southwest, where two crops a year are cultivated.

The NCRI effort to produce similar upland varieties led to the development of the FAROX 400 series, of which three were nominated into coordinated trials: FAROX 406-1-1, 408-1-1 and 408-1-2. Only FAROX 408-1-1 was finally approved for on-farm trial, but it was not released due to lack of an on-farm performance record.

The two varieties released for swamp ecology in this period were ITA 230 (FARO 50) and Cisadane (FARO 51). ITA 230 has superior grain yield and blast resistance over earlier released ITA lines and it was generally adopted by farmers. Cisadane was introduced through INGER Africa. In 1988, there was a serious outbreak of African Rice Gall Midge (AfRGM) in eastern Nigeria in the Abakaliki area. As a means of finding a solution to the problem through the varietal resistance approach, several cultivars were screened for resistance in the area. All tested lines were susceptible, but Cisadane – although attacked – produced higher grain yields due to its ability to compensate for lost tillers. Subsequent evaluation of the cultivar clearly showed its yield advantage over all local varieties under pest pressure (Williams *et al.,* 1999). The variety was well adopted by the farmers in eastern Nigeria before its release in 1998. WITA 4 (FARO 52), in particular, is widely adapted for both rainfed and irrigated lowland. It combines drought resistance with iron toxicity tolerance, two main constraints limiting rice production in rainfed lowland ecology in Nigeria. It also combines high yield with yield stability even under low input conditions. Its deficiency is its susceptibility to AfRGM.

Promising varieties of the future

There are a few promising varieties expected to make a major impact on rice production in the near future in all rice ecologies in Nigeria. There are a number of IITA-developed but WARDA/NCRI-selected and evaluated lines that are still highly promising in the lowlands, including some WITA lines. WITA 1 and 3 are most promising. Other promising lines currently in coordinated trials include TOX 4004-8-1-2-2-3, TOX 4004-43-1-2-1, TOX 4008-34-1-1-1-2 and TOX 3440-164-3-3-2. In the uplands there are a series of materials, such as WAB 56-50, WAB 35-2-FX, WAB 99-1-1 and WAB 96-1-1, which are developed by WARDA and introduced through the task force programme. These materials are already in CRET. WAB 35-2-FX has already been advanced to on-farm.

Another important development in rice improvement in Africa generally is the successful crosses between *glaberrima* and *sativa* species. This breakthrough by WARDA was made possible through the backcross method and anther culture technique. Progenies of these interspecific crosses are already being evaluated in Nigeria. The varieties have good weed competitiveness, drought tolerance and high yield under the low-input conditions of Nigeria's resource-poor farmers.

Production trends

Several reports – FAO, 1999, 2000; WARDA, 1999a; Yap, 1994; NCRI, 1996 – reveal marked increases in rice production in Nigeria from the 1970s to the present. Production rose from about 0.5 million tonnes (Mt) to over 3.5 Mt. This figure (which accounts for approximately 25% of the region's total rice output) is the single biggest increase in output in Africa (Yap, 1994). The increase in production is sometimes attributed to government policies, such as the introduction of import restriction measures in 1985 (Nyanteng, 1986; Yap, 1994) and the expansion of rice area with rice lands tripling over the 10-year aggregate periods of 1975-1985 and 1986–1995. The release of improved high-yielding varieties, however, is one of the major contributing factors to increased rice production.

The annual growth rate of area (over 10%) is the highest in the world (IRRI, 1995) and the growth rate in output of between 8 and 10 percent is also amongst the world's greatest. These figures surpass the projections in the national agricultural development plans of the Federal Ministry of Agriculture for the period from 1974 to 1985.

POTENTIALS, SUSTAINABILITY, CONSTRAINTS AND UTILIZATION OF RICE GENETIC DIVERSITY

The main sources of rice genetic diversity in Nigeria can be classified into three basic categories: *O. sativa, O. glaberrima* and wild species, such as *O. bathii.*

O. sativa sources

O. sativa germplasm consists of landraces and improved germplasm. Landraces are characterized by tall plant type and strong culm, and usually contain both photoperiod-sensitive and non-sensitive cultivars; they have low tillering potential but heavy panicles. Generally, they are yet to be fully exploited to improve varieties for upland ecology and rainfed deepwater ecologies. The low tillering ability, deep root nature and heavy panicles that combine big and strong culm can be utilized to develop materials for drought tolerance and lodging resistance that characterize upland ecologies, particularly in the high rainfall areas of the rain forest zone. The tall nature of these materials and their photoperiod sensitivity can also make them ideal for the development of rainfed deepwater ecology materials for the flood plains of the Niger, Benue and Kaduna rivers. The rice production potential in these areas is seriously under-utilized. When these materials are crossed with modern semi-dwarf materials, they may result in progenies where intermediate plant types, better tillering and stronger culms are selected. These heavier tillering intermediate plant types are ideal for shallow rainfed ecologies where weed management is a major production constraint.

The improved modern, semi-dwarf germplasm currently used in most irrigated and rainfed inland valleys do not offer much opportunity for improved yield.

Their high dependence on high nutrient input and management levels makes them less attractive to the country's resource-poor farmers. Most of the improved modern varieties are also prone to one stress or another, hence crosses between any two of them do not solve the multiple stress problems typical of the rice production ecologies. For example, the most recently released improved lowland variety in Nigeria (FARO 52 – WITA 4) was developed by IITA/WARDA. It has good stable grain yield potential due to high tillering ability, drought and iron-toxicity tolerance, but is very susceptible to AfRGM. In the 2001 season almost all the nurseries of this cultivar were destroyed by rice blast at Edozhigi, both in research and farmers' nursery beds. Long-term evaluation of new improved varieties by NCRI revealed that new elite lines do not show remarkable yield advantages over materials released in the 1980s, such as FARO 29 and FARO 36 – an indication of yield plateau in the breeding programme.

Use of *O. glaberrima* sources

The second group of germplasm resources is *O. glaberrima*, which did not only originate in but is endemic to the West Africa subregion. Research activities showed that these materials are well adapted to the adverse African rice-growing soils, harsh climatic conditions and biotic stresses, such as drought, RYMV (rice yellow mottle virus), weed competitiveness, acidity and many others (Maji and Singh, 1993; Paul *et al.*, 1995). More attention must therefore be paid to *glaberrima* materials for genetic rice improvement in Nigeria.

O. glaberrima lines are however characterized by very low yield potential, grain shattering before full maturity, grain characters appealing to neither agronomists nor consumers and weak culm that predisposes them to high lodging susceptibility. Other undesirable traits include long awn, black husk at maturity and red seed coat. These limitations are however variable and materials that possess the positive side of these characters are abundant (Maji *et al.*, 1998). They offer great potential for genetic improvement because of their wide adaptation to various rice-growing ecologies, ranging from upland to deepwater. WARDA has pioneered the use of intraspecific crosses between *O. glaberrima* and *O. sativa* and has generated a large number of interspecifics, now code-named "NERICA" (New Rice for Africa). Many of these are currently being evaluated, mainly in upland rice ecologies, although a number of them are now

PLATE 7

A rainfed lowland/swamp rice field in Sierra Leone

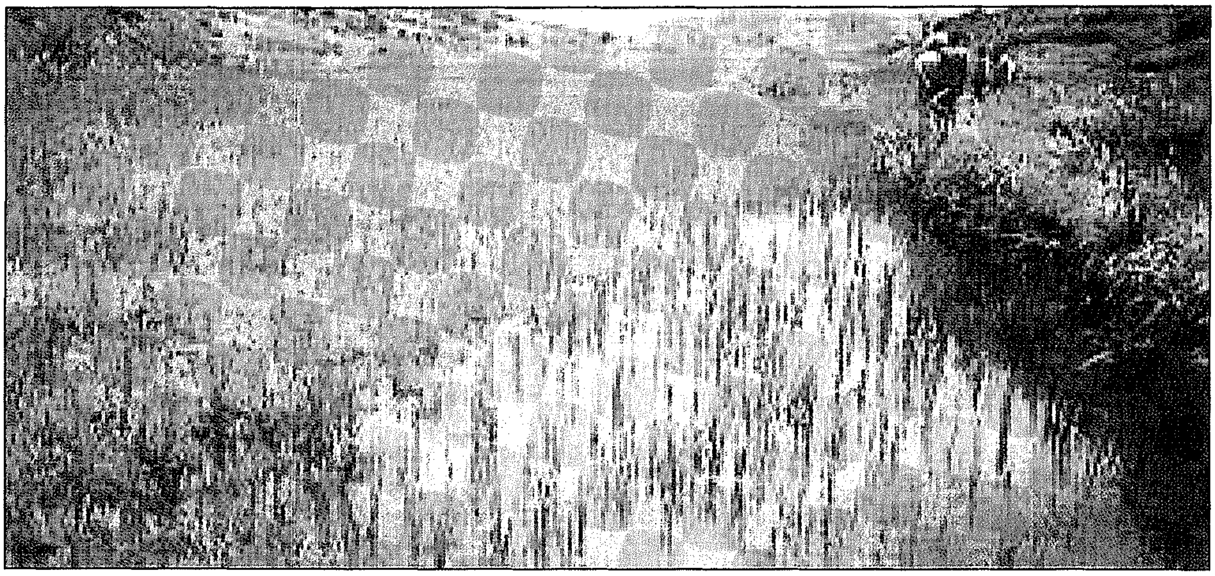

PLATE 8

A field of NERICA rice at a research field of WARDA

Source: WARDA, 1999b.

known to be equally adapted to the lowlands. They are highly weed competitive and suitable for the farmers' low management practices because of their high seedling vigour and intermediate plant height.

However, the use of *glaberrima* germplasm has a major constraint. The F_1 plant in 90 percent of cases is sterile and two or three backcrosses may not have a major impact on the high sterility situation. This is what makes anther culture attractive for the production of double haploids that may be fertile and fixed. The National Cereals Research Institute made a series of backcrosses in its *sativa-glaberimma* interspecific hybridization and discovered that there are only a small number of compatible lines that can give a high percentage of fertile individuals after two or three backcrosses.

Use of wild rice cultivars

Though wild rice cultivars, such as *O. bathii*, abound in Nigeria to the extent that they constitute a menace in some rice fields, especially in flood plains and some inland valleys, their use as genetic resources are constrained by a number of factors.

- Given the wide genetic distance between these wild germplasm materials and cultivated species, particularly *O. sativa*, the success of cross hybridization is quite low and highly technical and therefore requires advanced breeding techniques. Such techniques include embryo rescue, transformation through identification of genes of interest in these wild species, tagging such genes, isolating them and transferring them directly into current varieties.
- There is very little information available concerning these materials and their response to biotic or abiotic rice production constraints in Nigeria, although some information is available at IRRI. It is necessary to identify suitable germplasm materials within these wild species, followed by basic screening activities for various biotic and abiotic rice production constraints.
- The main research institute with the mandate for rice varietal improvement in Nigeria, the National Cereals Research Institute (NCRI), has limited resources in terms of modern research tools to effectively conduct the basic research required for identification of these germplasm. It must

therefore maintain collaborative research with centres that have such facilities in order to optimize the country's abundant sources of genetic diversity.

GENERAL CONSTRAINTS FOR UTILIZATION OF GENETIC RESOURCES AND SUSTAINABLE RICE PRODUCTION

The majority of rice producers in Nigeria are low resource base farmers producing at a subsistence level either as a food crop or as a cash crop. The majority of these farmers have no formal education or a very limited education. The implications of these two factors are the poor resource base and the slow adoption process of rice research improved technology packages. It must be asked whether farmers have access to improved farming techniques, such as rice varieties, farm implements and chemical inputs (fertilizer, insecticides and herbicides), and whether Nigerian rice farmers have access to financial assistance in the form of loans. The answers to these questions are more often than not negative. Although there have been impressive figures showing an increase in production, rice productivity in Nigeria, while not stagnant, has had a very low growth rate. This may be attributed to a number of factors, some of which are explained below.

Available germplasm

A high number of Nigerian rice farmers still depend largely on either *O. glaberrima* germplasm (especially in some northern upland ecologies and deep flood plains) or traditional landraces (as in most of the country). Farmers hold onto these materials tenaciously as they can give substantial grain yields with low management. They have a poor response to fertilizer input but perform relatively better than improved varieties where inputs, such as fertilizer and protection against pests and diseases, are minimal or absent. *O. glaberrima* varieties are generally vigorous in tillering and early seedling growth and better in the exploitation of inherent soil nutrients, and are hence better in weed competition and low input conditions. The traditional tall and strong culm varieties are adapted variously to upland and rainfed lowland ecologies. They are low tillering, but produce heavy panicles. These characteristics also make them attractive to farmers as a result of reduced weeding efforts and there is no need to use fertilizers. The improved rice varieties in Nigeria today are semi-dwarf materials generally bred for irrigated ecologies that constitute less than 10 percent of the rice production ecology (Maji *et al.*, 1999). They are less adapted to rainfed lowland ecologies (which give most of Nigeria's rice output) and they require high levels of nutrients in order to maximize their yield potential. Hence no sooner does a farmer adopt these materials than he forgoes them for traditional types, particularly in rainfed ecologies. However, improved yields require an improved production management package to be developed and propagated.

Adoption rate

The adoption rate is reported to be very low, probably for the reasons given above. There were also complaints that research packages do not take into account farmers' varietal preferences. This has led to the recent research strategy known as farmer participatory varietal selection (PVS), culminating in particular in the development of NERICA rice varieties.

Marginal lands

Some Nigerian rice farmers operate in marginal rice production ecologies where soil problems also aggravate biotic problems. Such soil problems include iron toxicity under rainfed lowland ecologies, acidity in high rainfall upland rice ecologies and salinity in the far north irrigated areas. In some cases, soils are sandy, which worsens the fertility problem. These problems combine to aggravate biotic constraints, such as blast, brown spot, gall midge attack and, in rare cases, rice yellow mottle virus. Traditional varieties give marginal yields under these conditions but improved varieties perform poorly.

Lack of farming tools

Most small-scale Nigerian farmers operate with cutlass and hoes, even in some irrigated ecologies, resulting in high labour demand and exorbitant costs in peak periods with farm holdings reduced to the barest minimum. Irrigation facilities in some of these areas need to be improved to provide for efficient water usage and control. In some irrigated fields water inflow cannot be properly managed, hence some fields have excess water while others within the same scheme have inadequate water supply. These problems of poor crop and water management make the traditional low-yielding varieties more attractive to farmers than the high-yielding, but high management-demanding semi-dwarf improved cultivars.

RECOMMENDATIONS FOR THE MAXIMUM UTILIZATION OF RICE GENETIC RESOURCES

National level

Research and extension

To derive maximum potential from the genetic material available in Nigeria for the benefit of rice production in the country, research must be refocused, more committed and closely monitored. Rice yields – even in research fields – have reached a plateau. What is more, even the plateau cannot be realized by the farmers. To fight this dual problem, genetic improvement effort must look beyond the current semi-dwarf improved materials towards traditional and *O. glaberimma* germplasm for sources of new genes to combat production constraints. Hence, wide hybridization is a key factor in breaking the plateau, if not in the research field at least in farmers' fields. These however will require modern breeding techniques, such as anther culture and biotechnology (molecular genetics), of which national programmes are incapacitated, not necessarily in terms of manpower, but in terms of the equipment and infrastructure needed for such an undertaking.

The current effort and the methodologies required for getting the new cultivars of varieties to farmers need to be doubled and re-examined. The extension efforts are limited, and extension approaches are mostly top-down, which do not work well. Participatory varietal selection has been found to be a better approach. But WARDA's efforts are currently limited because of the wide area in which the farmers that need to be contacted are located. The rate of adoption of research packages is low, due to factors such as low level of farmer education, limited economic capacity, lack of infrastructures and tools. Research packages are usually tailored towards modern farming techniques, such as appropriate spacing, fertilizer usage and other chemical inputs (e.g. herbicides and insecticides). Lack of these facilities hinders the optimum benefits which can be obtained by farmers using new techniques and varieties and so farmers revert to old technologies.

Government role

National governments must invest more in research and implement measures that ensure that such investment is used appropriately. Research is currently seriously underfunded and much of the money provided is not correctly used. In rice-producing countries, governments must invest in the development of irrigation facilities in fadama areas. Irrigation facilities in these states are far below their potential. This effort will extend rice production activities into the dry season when maximum yields are attainable. In addition, the provision of land-preparation equipment, such as rotavators, is important. Use of water and good land preparation will minimize the weed and pest problem. An added advantage will be larger farm holdings – at present limited given that fewer family members are involved in farm work as a result of the urbanization process.

Organizing farmers into cooperative societies facilitates bank loans (for small-scale irrigation facilities, for example) and is an easy way of securing government attention and obtaining other farm inputs from relevant organizations and governments.

The role of international organizations

International organizations can help in exploiting the potential of rice genetic resources in Nigeria in two main areas:

- basic research; and
- research extension services.

Research funding comes in two forms: direct involvement in research activities through the use of experts both outside Nigeria and inside the countries with specific objectives through proposed project funding; and provision of research facilities, such as laboratories and equipment. These laboratories should be equipped with modern research equipment for breeding and other research activities, such as tissue culture facilities, molecular biology equipment for gene mapping, screen houses and greenhouses. The provision of energy sources, such as portable generators in laboratories, is essential for the success of research.

In extension, as highlighted earlier. Nigeria is a vast country with numerous widespread rice-growing ecologies. Extension activities therefore suffer due to lack of funds and transport facilities. Carrying research packages to farmers requires extensive travelling and monitoring; provision of funds or vehicles for research institutions or organization with sponsored projects will greatly improve contact with farmers. Participatory variety selection has been found to greatly facilitate the adoption and dissemination of selected varieties, hence it is a model that can be of great benefit to Nigerian rice farmers.

Training and retraining of officers is of great importance for the exploitation of rice genetic materials in Nigeria. Such training areas will include both formal training (e.g. masters and Ph.Ds) and informal training of technicians in areas of tissue culture and molecular techniques. These are essential for effective management of laboratories and other research facilities provided. Retraining of farmers who have already received training but have little or no experience is required to bring them up to date with new methods and technologies. This may be achieved through attachment to overseas laboratories carrying out similar research activities.

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