

MORPHO-AGRONOMIC VARIOUSNESS AND ECONOMIC POTENTIALS OF *ORYZA GLABERRIMA* AND WILD SPECIES IN THE GENUS *ORYZA*

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Among the 20 valid species in the genus *Oryza* (Table 1), *O. glaberrima* Steud. and five wild species are indigenous to Africa (Chang, 1976a). The wild species are *O. barthii* A. Chev. (formerly known as *O. breviligulata* A. Chev. et Roehr.), *O. brachyantha* A. Chev. et Roehr., *O. eichingeri* A' Peter, *O. longistaminata* A. Chev. et Roehr. (formerly known as *O. barthii* A. Chev.) and *O. punctata* Kotschy ex Steud. A working key for the identification of the 20 valid species and their geographic races has been proposed by Chang (1976d), but certain problems related to taxonomy and nomenclature of several taxa of doubtful validity are yet to be resolved (Chang, 1964, 1976a, c).

Assemblage of the African rices and the wild taxa in the genus *Oryza* was one of the principal objectives when the International Rice Research Institute (IRRI) began its germ plasm bank project in 1962. IRRI now has 1,372 accessions of *O. glaberrima* and 866 strains of wild species and taxa. The African rices were donated to IRRI principally by Dr. H. I. Oka and his associates in the National Institute of Genetics (Japan), Dr. J. R. Harlan of the University of Illinois, the officers of the Institut de Recherches Agronomiques Tropicales et des Cultures Vivrières (IRAT) and their national counterparts in several West African countries, Mr. Alan Carpenter (formerly of UNDP/FAO) and his associates in Liberia. The wild species and weed forms were collected and donated by Dr. Oka and his associates in the National Institute of Genetics ; Dr. T. Tateoka of the Kihara Institute for Biological Research ; staff and affiliates of the Institute of Botany, Academia Sinica, in Taiwan ; Drs. S. D. Sharma and S.V.S. Shastry, formerly of the Indian Agricultural Research Institute ; Mr. S. Sampath and his associates in the Central Rice Research Institute (India) ; members of the Tottori University Scientific Survey (Japan) ; Dr. Harlan of the University of Illinois ; staff of the National Institute of Agricultural Sciences (Japan) ; IRRI's field advisors on rice collection ; and many other scientists in Australia, Brazil, India, Indonesia, Thailand, U.S.A., and West Africa.

This report summarizes the progress made by the scientific staff of IRRI in assessing and using potentially useful traits in the African rices and the wild taxa in the genus *Oryza* in IRRI's Genetic Evaluation and Utilization (GEU) Program. Preliminary analysis of our work in characterizing the morpho-agronomic traits of 664 samples of *O. glaberrima* in IRRI's Genetic Resources Program will also be presented. The Statistics Department of IRRI kindly assisted us in the summarization and analysis of data.

MORPHO-AGRONOMIC VARIOUSNESS IN THE AFRICAN RICES

MORPHO-AGRONOMIC CHARACTERISTICS

Of the 664 accessions of *O. glaberrima* included in this report, 662 samples came from 10 countries in West Africa, while the geographic origin of the remaining two accessions was not known. Most samples came from Liberia

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(n = 512), Mali (n = 88) and Nigeria (n = 25) (Table 2). For each accession, we have recorded 39 characteristics ; 11 are actual measurements or counts ; the others are coded values 1).

Of morpho-taxonomic interest, none of the 664 samples has completely glabrous leaf blades — all blade surfaces have a few papillae (or are slightly scabrous). Likewise, about 36 percent of the samples have varying degrees of light pubescence on the hulls. Most samples have only a few secondary branches of the panicles. The culm angles vary within a rather narrow range : intermediate to spreading.

Varying intensities of purple pigments are found in several plant parts : basal leafsheaths (81.7 %), leaf blades (0.6 %), ligules (9.2 %), auricles (9.2 %), collars (9.5 %), internodes (0.6 %), sterile lemmas (19.7 %), apiculi (93.1 %), awns (88.3 %) and stigmas (93.4 %). Nearly all (98.9 %) of the samples have red seedcoats.

Panicle exertion is generally partial (67.6 %). Most of the panicle branching belongs to the open type (82.4 %). More than one half of the samples are awnless. Leaf senescence is uniformly quick.

Among physiologic traits showing quantitative variation, the grain length ($x = 8.7$ mm) and width ($x = 2.9$ mm) values are remarkably uniform (coefficients of variation (c.v.) : 5 % and 7 %, respectively). Ligule length varied from 3 to 27 mm., with a mean of about 5 mm., and a c.v. of 32 percent. Blade width (c.v. = 22 %) varied more than blade length (c.v. = 11 %). Culm length measurements were quite uniform (c.v. = 11 %) with a mean of 98 cm. Panicle length was also very uniform ($x = 24$ cm., c.v. = 8.7 %). Maturity showed a very narrow range (93-145 days, $x = 112$) and the second lowest c.v. (6.2 %).

Among the samples from the five countries which contributed 10 or more each, the 88 from Mali showed the largest or the second largest c.v. values for ligule length, blade width, maturity, panicle branching, and panicle type (Table 2). The 10 samples from Upper Volta ranked second in the c.v. values for blade width, maturity, and hull pubescence ; but ligule lengths, 1000-grain weights, and blade lengths slightly exceeded those of the Mali samples. The 25 samples from Nigeria varied more in culm number, 1000-grain weight, blade width, and panicle type than in other traits. The 512 samples from Liberia and 15 from Guinea were less variable and had similar c.v. values, except that hull pubescence was more variable (c.v. = 35 %) in samples from Liberia.

The six samples from Sierra Leone showed high c.v. values for ligule length (104 %), hull pubescence (39 %), panicle type (35 %), and panicle branching (75 %).

While the sample size of our collection is insufficient to indicate the differences in morpho-agronomic diversity between country-groups, it is interesting to note that most of the samples lack the typical features of *O. glaberrima* that were described by Steudel in 1854 : ligule shorter than 8 mm, erect culms, and absence of secondary panicle branches. Some of those traits in our samples also differed from those of the 11 strains studied earlier by Bardenas and Chang (1966). It is most likely that many accessions in our study have been hybridized in the field with the wild race (*O. barthii*) or the weed race ("*O. stapfii*") or both. Our findings support an earlier observation of Chang (1976c) on the two Asian counterparts : "typical specimens . . . are rarely obtainable today even in their adapted habitats because of continuous hybridization among the wild, weed, and cultivated races, ...".

It is apparent from the above summary that the varietal diversity of the African rices is much smaller than would be the diversity of the *O. sativa* cultivars (see IRRI, 1970) for the same number of samples coming from another geographic area of similar size. The data support an earlier observation that *O. glaberrima* has not attained the level of varietal diversity found in *O. sativa* (Morishima et al., 1962b ; Chang, 1976b, c). It appears likely that the genetic differentiation within *O. sativa* predated that of *O. glaberrima* in West Africa (Chang, 1976c). We have not been able to confirm Porteres' postulate that African rices in the central Niger River delta have more dominant features, such as pigmented organs and extreme shattering than those in the Senegal-Gambian center (Porteres, 1976).

The brown rice of 17 *O. glaberrima* samples in earlier studies ranged from 20 to 30 percent in amylose content and from low-to-high in gelatinization temperatures. Other properties related to protein content and amino acid composition were similar to those of *O. sativa* (Bardenas and Chang, 1966 ; Ignacio and Juliano, 1968).

1) We recorded the 37 characteristics used in our systematic characterization of *O. sativa* cultivars and breeding lines (IRRI, 1970). To these, we added hull pubescence and secondary panicle branching.

Earlier, researchers at the Central Rice Research Institute (India) proposed to hybridize *O. sativa* with *O. glaberrima* with the aim of producing types that would have good grain quality and adaptability to low soil fertility (Richharia and Govindaswami, 1962). We recognize that *O. glaberrima* strains with 25 percent amylose content would be in the eating-reference range of most consumers. But their performance at low soil fertility levels needs to be compared with that of those *O. sativa* cultivars which have become adapted to the eco-edaphic environments of West Africa.

REACTIONS TO THE MAJOR DISEASES AND INSECTS OF TROPICAL ASIA AND TO SOIL MOISTURE STRESS

During 1975-76 IRRI entomologists screened 187 accessions of African rices against the green leafhopper (*Nephotettix virescens*). Nearly all of the African rices are resistant to the leafhopper (IRRI, 1976, 1977), although the *Nephotettix* species have not been reported from West Africa except from the Francophone countries (Breniere, 1976). Since early 1976, crosses between the leafhopper-resistant accessions of *O. glaberrima* and the elite breeding lines of IRRI (mainly *O. sativa* germ plasm) have been made to utilize the African gene pools (IRRI, 1976).

On the other hand, nearly all of the African rices are highly susceptible to the tungro virus transmitted by the green leafhopper as well as to the grassy stunt virus transmitted by the brown planthopper (*Nilaparvata lugens*). The African rices are also susceptible to the grassy stunt vector, the brown planthopper (IRRI, 1976).

We and IRRI plant pathologists have tested 189 Liberian strains against the blast pathogen in nursery beds. All of the strains are resistant to the local races of the blast fungus at the seedling stage.

To date, nearly all of the *O. glaberrima* strains tested by different plant pathologists have showed susceptible reactions to bacterial blight when the leaves are inoculated with the pathogen (Goto, 1965 ; Sakaguchi et al., 1968 ; IRRI, 1977). On the other hand, two strains were moderately resistant to bacterial leaf streak (Goto, 1965).

Staffs of the Plant Breeding and Agronomy Departments of IRRI have screened many African rices in the IRRI collection for reaction to water deficit in the field. As shown in Table 3, we found that none of the 790 African rices are highly resistant to drought, but the great majority fall between moderately resistant and intermediate (IRRI, 1975, 1976, 1977 ; Loresto et al., 1976). The agronomists have also evaluated 200 strains in a field test. About 50 percent of the strains had a score of 3 or better, i.e., they fall within the moderately resistant class (IRRI, 1977). The general inference is that the African rices have a higher mean score for drought resistance but a lower maximum score than the combined scores of the lowland and upland cultivars of *O. sativa*. We have also noted that the recovery ability of African rices is generally good when drought is over. The African rices also appear to ratoon well in upland plantings. In earlier investigations, workers in Japan have rated the drought resistance of African rices rather low (Morishima et al., 1962a).

Plant physiologists at IRRI have studied 42 accessions in root boxes. Those 42 African rices generally have higher minimum values for both the total root-to-shoot ratio (mg/g) and the deep-root-to-shoot ratio than 313 *O. sativa* accessions. However, the Asian rices have distinctly higher maximum values for both ratios (IRRI, 1977).

IRRI researchers have yet to test the African rices for their ability to tolerate submergence or to show rapid internode elongation in rapidly rising water. Earlier investigations by Japanese workers indicated that the *O. glaberrima* strains have weak floating ability (Kihara, et al., 1962 ; Morishima et., 1962a).

It appears that very limited research on *O. glaberrima* has been carried out in West Africa (Oka and Chang, 1964 ; Goli, 1976). One recent report indicated that four strains of *O. glaberrima* showed tolerance to iron toxicity of the soil (Virmani, 1976).

USEFUL TRAITS IN THE WILD AND WEED SPECIES

The grain-producing capacity of the wild and weed species is generally so low that yield trials have not been attempted. Nonetheless, the wild taxa offer unique opportunities for rice researchers to exploit certain traits of special significance.

One strain of *O. nivara* from India (IRRI Acc. No. 101508) given to us by Drs. S. D. Sharma and S.V.S. Shastry, was the only source of strong resistance to the grassy stunt virus (Ling et al., 1970) found by IRRI plant pathologists in screening 9,540 *O. sativa* strains and 100 wild forms (Chang et al., 1975). The single dominant gene for resistance in this strain of *O. nivara* (Khush et al., 1971) was the only available source of resistance until 1976, when plant pathologists found resistant lines in IRRI's breeding materials which were not derived from *O. nivara* (IRRI, 1977). The major gene for resistance to grassy stunt virus from IRRI Acc. No. 101508 has been incorporated into IR28, IR29, IR30, IR32, IR34, IR36, IR38, and many promising IR lines of more recent vintage.

Investigations in East Africa indicated that *O. longistaminata* and *O. punctata* were susceptible also to the yellow mottle virus, but the wild taxa showed slower disease development than the *O. sativa* strains (Bakker, 1970). One strain of the American race of *O. rufipogon* ("*O. cubensis*") appeared to be resistant to the dwarf virus (Shinkai, 1962).

O. eichingeri and *O. punctata* were found to be highly resistant to bacterial blight race B1 of the Philippines while other wild taxa ranged from susceptible to resistant. Most of the wild taxa were susceptible to the virulent race B72 of the Philippines (Goto, 1965).

Goto (1965) reported that *O. brachyantha*, *O. minuta*, *O. punctata* and *O. ridleyi* were highly resistant to bacterial leaf streak. Several Australian strains of the annual Asian wild species (*O. nivara*) and one Malaysian strain of "*O. perennis*" were also found to be resistant to bacterial leaf streak (IRRI, (1968)).

A number of wild taxa were reported to be susceptible to false smut, kernel smut, and the stem nematode (see Ou, 1972).

About 60 strains of wild taxa (*O. australiensis*, *O. barthii*, *O. brachyantha*, *O. latifolia*, *O. rufipogon* and *O. punctata*) have been tested against green leafhopper and against different biotypes of the brown planthopper. Ten strains are resistant to all three biotypes of the brown planthopper as well as to the green leafhopper. On the other hand, other strains are susceptible to the brown planthopper. The finding of such a broad spectrum of resistance to the hoppers is certainly encouraging, although similar levels of resistance have been found in 38 cultivars of *O. sativa* collected from Sri Lanka and southern India (IRRI, 1977). IRRI entomologists will continue the search for pest resistance.

A high level of resistance to the stemborers has been reported in *O. ridleyi* from Malaysia (Van and Guan, 1959). IRRI entomologists found that the species has more layers of sclerochymatous tissues and larger and denser silica cells in the stem than *O. sativa* cultivars (see Pathak et al., 1971). Our observation indicated that the extremely small pith of the internodes in this species would make it impractical for borer larvae to grow and to reach maturity.

IRRI plant physiologists have examined the root systems of 37 strains of 10 wild taxa in root boxes. The variations in the total root-to-shoot ratio and deep-root-to-shoot ratio were quite marked. However, none of the wild strains was significantly superior to the best *O. sativa* cultivars (IRRI, 1977).

Geneticists and plant physiologists have examined the ability of several wild relatives of *O. sativa* to withstand rising water levels in tanks. Plants of both *O. rufipogon* (the perennial wild race) and *O. nivara* (the annual wild race) have the potential for producing tillers at the higher nodes and producing many adventitious roots at the nodes when the water depth is gradually increased. The perennial race surpasses the annual race in this respect (unpublished results of Nyat Ng Quat and T. T. Chang). But the elongation ability of seven wild strains under rapidly increasing depth (30 cm/day) was rated poor by plant physiologists. We need to further compare the elongation ability of the wild relatives with that of the floating varieties of tropical Asia.

The grains of 13 wild taxa and 8 strains of the Asian annual weed race were studied by IRRI chemists several years ago. Bardenas and Chang (1966) also investigated the cooking characteristics of eight *O. barthii* strains. In terms of the physicochemical properties of the brown rice, the wild taxa offer no nutritional advantage over *O. sativa* (Ignacio and Juliano, 1968).

Indian workers (Richharia and Govindaswami, 1962) have proposed to use different wild taxa for improving specific traits of *O. sativa* : (1) tolerance of water-logged conditions — from "*O. perennis*", "*O. sativa* var. *spontanea*", and "*O. perennis* subsp. *cubensis*"; (2) tolerance of deep water and flood — from *O. officinalis* and *O. sativa* x

O. perennis" hybrids ; (3) drought resistance – from *O. longistaminata* and "*O. sativa* var. *spontanea*" ; (4) tolerance of saline conditions – from "*O. coarctata*" (now removed to the genus *Sclerophyllum*) ; and (5) resistance to diseases and insects – from unnamed wild species. Again, we are not in a position to comment on the proposals of Riccharia and Govindaswami because they offered no data. We have tested four *O. nivara* strains for drought tolerance. The field reactions ranged between moderately susceptible and moderately resistant (IRRI, 1976). Moreover, nearly all of the wild taxa were susceptible to the tungro and grassy stunt viruses in our field plantings. That has hampered the work of maintaining the wild taxa at Los Baños.

In 1933 Ting reported the successful development of cv. Yatsen 1 which appeared to have improved tillering ability, cool tolerance and acid soil tolerance from a cross between a *O. sativa* cultivar and a strain of "*O. sativa* var. *fatua*" found near Canton.

CONCLUDING REMARKS

The above summary indicates that researchers in different IRRI departments have made a number of limited evaluations of the *O. glaberrima* cultivars and, to a smaller extent, of the strains of various wild species. While it is not anticipated that the yield potentials of the African rices and of the wild species will surpass those of the improved *O. sativa* cultivars, the African rices and the wild taxa appear to offer an array of resistances or tolerances to some of the biotic and environmental stress factors, especially the leafhoppers, planthoppers, and drought. The diversity of the African rices is certainly less than that of the Asian rices, (Morishima et al., 1962b ; Chang, 1976b, c), mainly because the African rices have not been subjected to such rigorous selection pressures as those associated with dispersal and domestication of the Asian rices (Chang, 1976b). The morphological variousness of the African wild annual race (*O. barthii*) also appears to be less than that of its Asian counterpart (*O. nivara*) (Bardenas and Chang, 1966 ; our unpublished observations). On the other hand, the African rices and the wild taxa may provide useful genes for resistance or tolerance that are not found in the Asian rices. Resistance to the grassy stunt virus found in a strain of *O. nivara* is such an example.

We need to broaden our search for useful genes in the African rices as well as in the wild taxa, and to expand the testing of each trait and taxon. We also need to determine if the useful genes found in the above taxa are new or are identical to those in the *O. sativa* cultivars. The assemblage of wild taxa has been made a part of IRRI's field collection (IRRI, 1975, 1977).

The incorporation of useful genes from the African rices and the wild taxa into *O. sativa*'s genetic background would require more time or effort than conventional crosses between *O. sativa* cultivars. Hybrid sterility and aberrant chromosome-pairing in hybrids of *glaberrima* x *sativa* crosses have been described by Belgian, Japanese, and U.S. workers (see Chang, 1964). Certain barriers could be overcome by backcrossing or intercrossing among hybrid progenies. The transfer of genes from *O. australiensis* into an *O. sativa* background has been attempted, but the results have been disappointing (Wu et al., 1967 ; Wu and Li, 1977), primarily because *O. australiensis* has the E genome while *O. sativa* has the A genome. Compatibility between the A and C and between the A and E genomes appeared to be poor (Watanabe and Ono, 1973 ; Watanabe and Wakasa, 1973). Perhaps a more radical approach than chromosome addition or substitution, such as protoplasmic fusion, could be more expedient for truly wide crosses.

While we are discussing the rice germ-plasm of Africa, we should not ignore the thousands of *O. sativa* cultivars that have been grown and become adapted to African conditions following periods of from several decades to more than two centuries of planting and selection (both natural and artificial) in Africa. From the hundreds of *O. sativa* strains recently collected in the Ivory Coast (by IRAT officers) and Liberia (by Alan Carpenter), we have found in our mass-screening tests that many accessions have outstanding sources of drought resistance. Similarly, *O. sativa* cultivars bred in West Africa, such as OS4, OS6, and 63-83, also have outstanding drought resistance, and other desirable characteristics such as heat tolerance at anthesis (Chang et al., 1974 ; IRRI, 1974a, 1977). Under the GEU Program of IRRI, many *O. sativa* cultivars acquired from Africa have been identified to have high levels of resistance to blast, the yellow stemborer, whorl maggot, brown planthopper, and leaf folder (IRRI, 1974b ; Chang et al., 1975). Gissi 27, Socotera 55, and LAC 23 are highly tolerant to iron toxicity of the soil (Carpenter, 1975 ; Virmani, 1976). We should also use such useful and acclimatized germ plasm for the improvement of rices to be grown in Africa or Asia.

Ample opportunities are available for the researchers in international centers (IRAT, ORSTOM, IITA, WARDA, and IRRI) and in national centers of Africa to join in conserving, evaluating, and using the genetic potentials of the

African germ plasm. The staff of IRRI is most willing to collaborate with workers in African countries and Africa-based centers toward the improvement of rices for the farmers of Africa.

Table 1. Chromosome numbers, genome symbols, and geographical distributions of *Oryza* species (adapted from Chang, 1976a, c).

Species name synonym	(x = 12) 2n =	Genome group	Distribution
<i>O. alta</i>	48	CCDD	Central and South America
<i>O. australiensis</i>	24	EE	Australia
<i>O. barthii</i> (<i>O. breviligulata</i>)	24	A9A9	West Africa
<i>O. brachyantha</i>	24	FF	West and central Africa
<i>O. eichingeri</i>	24, 48	CC, BBCC	East and central Africa
<i>O. glaberrima</i>	24	A9A9	West Africa
<i>O. grandiglumis</i>	48	CCDD	South America
<i>O. granulata</i>	24	—	South and Southeast Asia
<i>O. latifolia</i>	48	CCDD	Central and South America
<i>O. longiglumis</i>	48	—	New Guinea (Irian Jaya)
<i>O. longistaminata</i> (<i>O. barthii</i>)	24	A ¹ A ¹	Africa
<i>O. meyeriana</i>	24	—	Southeast Asia, southern China
<i>O. minuta</i>	48	BBCC	Southeast Asia, New Guinea
<i>O. nivara</i> (<i>O. fatua</i> , <i>O. rufipogon</i>)	24	AA	South and Southeast Asia, Southern China, Australia
<i>O. officinalis</i>	24	CC	South and Southeast Asia, Southern China, New Guinea
<i>O. punctata</i>	48, 24	BBCC, BB (?)	Africa
<i>O. ridleyi</i>	48	—	Southeast Asia
<i>O. rufipogon</i> (<i>O. perennis</i> , <i>O. fatua</i> , <i>O. perennis</i> subsp. <i>balunga</i>) (<i>O. perennis</i> subsp. <i>cubensis</i>)	24	AA	South and Southeast Asia, Southern China, New Guinea
<i>O. sativa</i>	24	AA	Asia
<i>O. schlechteri</i>	—	—	New Guinea (Papua New Guinea)

Table 2. Means and coefficients of variation (% in parentheses) of morpho-agronomic traits obtained from 650 *O. glaberrima* samples from West African countries, 1975-76 wet seasons, IRR1 Genetic Resources Program.

Country	Samples (no.)	Blade length	Blade width	Ligule length	Culm number	1000-gr. wt.	Maturity	Hull pubescence a)	Sec. panicle branching a)	Panicle type
Guinea	15	47 (8%)	1.6 (7%)	5.1 (24%)	11 (17%)	20 (15%)	106 (6%)	1.0 (0%)	1.0 (0%)	1.5 (34%)
Liberia	512 (10%)	46 (10%)	1.6 (21%)	4.9 (21%)	11 (27%)	18 (11%)	110 (3%)	1.4 (35%)	1.0 (8%)	1.1 (28%)
Mali	88	47 (11%)	1.0 (50%)	5.3 (43%)	11 (39%)	19 (22%)	119 (11%)	1.4 (35%)	1.2 (33%)	1.8 (48%)
Nigeria	25	47 (13%)	1.3 (37%)	4.8 (14%)	12 (40%)	20 (29%)	116 (7%)	1.0 (0%)	1.0 (0%)	1.6 (44%)
Upper Volta	10	54 (14%)	1.2 (39%)	6.0 (65%)	13 (41%)	21 (31%)	112 (7%)	1.2 (35%)	1.1 (29%)	1.7 (48%)

a) Coded values.

Table 3. Field reactions of *O. glaberrima* samples to moisture stress, 1974-76 dry seasons, Plant Breeding Department, IRR1.

Year	Entries (no.)	Reaction *				
		R	MR	I	MS	S
1974	113	—	2	92	16	3
1975	327	—	118	150	59	—
1976	350	—	208	53	81	8
TOTAL	790	0	328	295	156	11

*) R = Resistant ; MR = Moderately resistant ; I = Intermediate ;
MS = Moderately susceptible ; S = Susceptible.

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