GENETIC MARKERS IN THE SPECIES OF RICE (*ORYZA* L.) INDIGENOUS TO NIGERIA.

[1]Nwokeocha, C.C, [2]Bolaji, A.O., [2]Oloyede, F.A., [3]Aladejana, F.O. and [2]Faluyi, J.O.
[1]Natural History Museum, Obafemi Awolowo University, Ile-Ife, Nigeria.
[2]Department of Botany, Obafemi Awolowo University, Ile-Ife, Nigeria.
[3]Institute of Education, Obafemi Awolowo University, Ile-Ife, Nigeria.
*Corresponding Author: Bolaji A.O.; E-mail Address: jesusflower1@yahoo.co.uk
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ABSTRACT

This paper reports the genetics of attributes that have marker values in the body of work done by the Rice Group at Ife in the last 28 years. Baseline works on the morphological and genetic markers in the genus Oryza were carried out in the last 28 years. The two major sources of materials for these studies are selections from local germplasm of peasant farmers (land races), wild relatives of cultivated rice indigenous to Nigeria and collections from the Gene Bank of the International Institute of Tropical Agriculture (IITA), Ibadan, Nigeria. The accessions (both rootstocks and seeds) were collected, planted, screened, and desirable attributes were selected. Inter- and intra-specific crosses were carried out and the F_1 plants generated were monitored to advanced generations. Putative hybrids were collected from a hybrid swarm in the Jebba Fadama and planted alongside suspected parents. The morphological and genetic attributes of these rice plants, including backcross progenies, were studied.

The results showed that certain minor morphological and genetic attributes such as ligule type; sterile lemma type; hairiness on sterile lemma; pigmentation of apiculus/awn, stigma, lower outer leaf sheath; and ripen-hull coloration have good value as markers in the identification of rice species and are also useful in tracing gene flow in a population of hybrid swarm.

The use of these markers by our group has enhanced the understanding of the population dynamics in rice hybrid swarms as species, putative hybrids, and backcrosses can now be easily identified on the field.

Key words: Markers, Indigenous Rice, Gene Flow, Hybrid Swarm, Population Dynamics.

INTRODUCTION

Markers are heritable qualitative attributes of gross morphology, structure or plant organ that remain constant as they are transmitted from generation to generation within the species or when the species are involved in hybridization with related species. They are sometimes minor traits which can easily be overlooked or ignored.

Markers can become important and reliable indices for the identification of the various species, varieties, genotypes, ecotypes and all sorts of intermediates between the species as well as natural and putative hybrids and segregants. Thus markers can aid in the understanding of the population dynamics of the indigenous species of *Oryza*. The species indigenous to Nigeria are *Oryza punctata* Kotshy et Steud., *Oryza barthii* A. Chev., *Oryza glaberrima* Steud., *Oryza sativa* Linn. and *Oryza longistaminata* A. Chev. et Roehr. Two species of the genus (*O. sativa* and *O. glaberrima*) are cultivated while the rest grow in the wild.

The species of *Oryza* is an agriculturally-important genus with a highly diverse morphology. Studies on the genetic and morphological diversity and species relationships are important for the understanding of the genetic structure of the genus and also for breeding purposes such as introgression of useful genes from wild to cultivated crops. Such studies had revealed some high level of polymorphism within and between the genus *Oryza* (Oka, 1964; Faluyi, 1985; Kwon *et al.,* 2006).

Sympatry and Gene Flow

The species of *Oryza* grow in sympatry and cross naturally with one another. Oka and Chang (1961) reported a frequent occurrence of natural hybrids between *O. perennis* and *O. sativa* in tropical Asia, giving rise to hybrid swarms.

Second (1986) discovered that the weedy strains of *O. barthii* show two alleles frequent in *O. sativa* but never found in wild strains of the species or in *O. glaberrima*. He strongly suggested that there is gene flow between *O. sativa* and *O. barthii*. In Zanzibar in Tanzania (East Africa), *O. longistaminata* was found to occur side by side with *O. barthii* (Carpenter, 1978) while in the Fadama plane of northern Nigeria *O. longistaminata* occurs as a weed of *O. sativa*, some of the stocks of which are intermediate plants between *O. sativa* and *O. glaberrima* (Faluyi and Nwokeocha, 1993a; Aladejana and Faluyi, 2007; Aladejana *et al.*, 2007 and Bolaji *et al.*, 2012).

A study of samples of different *O. glaberrima* accessions by Dania Ogbe and Williams (1978) indicated that *O. glaberrima* might be absorbing genes from *O. longistaminata*. Dania Ogbe (1993) thus assumed that the annual *O. barthii* emerged from perennial *O. longistaminata* as biosystematic evidence revealed some *O. longistaminata* plants that were 'glaberrima-like' and 'barthii-like', indicating genetic introgression into *O. longistaminata*.

In Nigeria, various surveys by the authors have shown that there is incidence of cultivated rice in sympatry with *O. punctata* in southwestern Nigeria, *O. longistaminata* with *O. sativa* and *O. glaberrima with O. sativa* in Kwara, Niger and Kogi States and *O. barthii* with *O. sativa* in Bauchi State (Faluyi and Nwokeocha, 1992; 1993; 1993a).This has given room for hybridization especially where inter-fertility exists between the two species in sympatry.

Many minor agronomic characters which have much value as markers in the species of this all-important agricultural genus *Oryza,* are neglected. There is, therefore, the need for sufficient baseline information for on-the-spot field assessment and identification of putative hybrids and their parents using genetic and morphological markers. These markers will also aid subsequent investigations on the population dynamics in the indigenous species of *Oryza*.

MATERIALS AND METHODS

This paper is a compilation of baseline works on morphological and genetic markers in the genus *Oryza* carried out in the last 28 years or so by the authors. The two major sources of materials are selections from local germplasm of peasant farmers (land races), wild relatives of cultivated rice indigenous to Nigeria and collections from the gene bank of the International Institute of Tropical Agriculture (IITA), Ibadan, Nigeria (Table 1). The collections were made as rootstocks and seeds.

The seeds/plant materials were raised in Ile-Ife, Nigeria, for close studies and selection. Crosses were made between contrasting characters within and between species and the F_1 seeds were advanced to the F_2 to determine the modes of inheritance. Putative hybrids from the field were raised alongside suspected parents for characterization. Qualitative and quantitative morphological and genetic characters were recorded and the data were subjected to appropriate descriptive and inferential statistics. BC_1F_1 seeds collected from almost completely sterile F_1 plants between *O. sativa* and *O. glaberrima* were particularly found useful in the genetic analyses of characters.

RESULTS AND OBSERVATIONS

Genetic and agrobotanical studies of species of the genus *Oryza* over a period of 20-28 years have revealed a number of minor characters as valuable markers in the genus *Oryza*. The minor attributes isolated include: ligule shape (type), ripen-hull coloration, shape and hairiness on sterile lemma, sterile lemma type, auricle type, and pigmentation of apiculus/awn, pistil and leaf sheath.

I. Ligule shape (Figure 1)

The ligule type/shape in rice is found to be species-specific. The shape of ligule found in *O. sativa* is linear, long (17-20 mm), 2-cleft with the tip prominently pointed. In *O. glaberrima* and *O. barthii* the ligule is short (4-5 mm and 3-5 mm respectively) and truncate. The ligule in *O. punctata* is linear, of medium length (6-7 mm) but not 2-cleft. In *O. longistaminata* the ligule is similar to that of *sativa* but consistently exaggerated in length (25-30 mm).

The *O. sativa* ligule type showed dominance over all other types such that the hybrids obtained between *O. sativa* and other species always had long, linear, 2-cleft ligule with pointed end. This observation was maintained even in reciprocals (Figure 1F). In the cross between *O. sativa* and *O. longistaminata*, the ligule was exaggerated in length, 2-cleft with pointed end.

This is a good marker that has been successfully used by our research team in hybrid identification and even in tracing introgression of genes in natural hybrid swarms (Table 2).

II. The auricle (Figure 1)

The auricle found in *O. sativa* was very prominent with very long hairs, clasping the culm and persistent till old age. In *O. barthii*, *O. glaberrima* and *O. punctata* the auricle is less pronounced and less hairy, clasping the culm only at seedling stage but usually deciduous at old age. In *O. longistaminata* the auricle is long and partially clasping. A cross between *O. sativa* and *O. barthii,* for instance, produced F_1 plants with sativa-like auricle, showing that the sativa-like auricle is dominant over the other variants. However, this marker is only significant when *O. sativa* is involved in a cross.

Table 1:Materials Used in the Study and their Sources

Accession Number	Collector/Source/Location	Chromosome Number	Habitat Description
Oryza punctata			
Top[1] Ipetu	NWOKEOCHA: Ipetumodu, 7°30"N 4°45"E, Nigeria	2n = 48	Large population on marshy ground around pool of water. Close to human habitation. Location open.
Top Moro	NWOKEOCHA: Moro, 7°33"N 4°45"E, Nigeria	2n = 48	Few stands on the bed of a river, sandy soil. Location under shade of *Alchornea cordifolia*
Top Ikire	NWOKEOCHA: Ikire, 7°23"N 4°12"E, Nigeria	2n = 48	Few stands by pool of water on major road side. Location open.
Top Ede	NWOKEOCHA: Ede, 7°44"N 4°27"E, Nigeria	2n = 48	Few stands on river bed, road side. Location open
Top Sekona	NWOKEOCHA: Sekona, 7°33"N 4°38"E, Nigeria	2n = 48	Fairly large population on marshy ground around pool of water, close to major road. Location open.
Top Rd 7[F]	FALUYI: O.A.U[2] Campus, Ile-Ife. 7°29"N 4°34"E, Nigeria	2n = 48	Along the valley of a river. Location, swampy, open in part, largely under shade.
TOP 15114	IITA[3]: 4°22"N 18°30"E, CAR[4]	2n = 48	Wild on fallow land
TOP 15115	IITA: 4°23"N 18°30"E, CAR	2n = 48	Wild on fallow land
TOP 15116	IITA: 6°53"N 19°07"E, CAR	2n = 48	Wild on fallow land
TOP 15117	IITA: 6°55"N 19°06"E, CAR	2n = 48	Wild on fallow land
TOP 15118	IITA: 7°02"N 18°50"E, CAR	2n = 48	Wild on fallow land
TOP 15119	IITA: 4°20"N 18°30"E, CAR	2n = 48	Wild on fallow land
TOP 8222	IITA: 6°59"N 9°35"E, Nigeria	2n = 48	--
TOP 8221	IITA: 6°59"N 9°35"E, Nigeria	2n = 48	--
TOP 6788	IITA: 6°59"N 9°35"E, Nigeria	2n = 48	--
TOP 13596	IITA:--------Tanzania	2n = 48	--
TOP 13546	IITA: ------- Tanzania	2n = 24	--
TOP 14097	IITA:--------Tanzania	2n = 24	--
TOP 14460	IITA: ------- Nigeria	2n = 24	Wild on fallow land
TOP 5702	IITA: 7°22"N 7°50"E, Nigeria	2n = 24	Wild Vegetation
Oryza longistaminata			
TOL[5] 5655	IITA:--------	2n = 24	--
TOL 7387	IITA:--------	2n = 24	--
TOL JEBBA	BOLAJI and FALUYI: Jebba, 9°8.599"N 4°48.834"E, Nigeria	2n=24	Wild on cultivated field
Oryza barthii			
TOB[6] 8218	IITA:--------	2n = 24	Wild vegetation
TOB 5660	IITA:--------	2n = 24	--
TOB 8226	IITA: 9°30"N 12°10"E, Nigeria	2n = 24	--
TOB 5646	IITA:--------	2n = 24	--
TOB 5658	IITA:--------	2n = 24	--
TOB 7337	IITA:--------	2n = 24	Wild
TOB 7306	IITA:--------	2n = 24	Wild

Table 1 continued

Accession Number	Collector/Source/Location	Chromosome Number	Habitat Description
TOB 7311	IITA:--------	2n = 24	Wild
TOB 7307	IITA: 12°18"N 7°36"E, Mali	2n = 24	Cultivated
TOB 7382	IITA:--------	2n = 24	Wild
TOB 4645	IITA:--------	2n = 24	Wild
TOB 10838	IITA:--------	2n = 24	Wild
TOB KARI – 83	OLORODE – Nigeria	2n = 24	Wild
Oryza glaberrima			
TOG[7] 12082	IITA:--------	2n = 24	Cultivated
TOG 12083	IITA:--------	2n = 24	"
TOG 10985	IITA:--------	2n = 24	"
TOG 12060	IITA:--------	2n = 24	"
TOG 5281	IITA:--------	2n = 24	"
TOG 5282	IITA:--------	2n = 24	"
TOG 5283	IITA:--------	2n = 24	"
TOG 5284	IITA:--------	2n = 24	"
TOG 5236	IITA:--------	2n = 24	"
TOG 3415	IITA:--------	2n = 24	"
TOG 16771	IITA:--------	2n = 24	"
TOG 7454	IITA:--------	2n = 24	"

Table 1 continued

Accession Number	Collector/Source/Location	Chromosome Number	Habitat Description
Oryza sativa			
TOS[8] 15223	IITA:--------	2n = 24	"
TOS purple	IITA: WARDA	2n = 24	"
TOS IJ86-W	FALUYI: Ijesa-Isu, 7°43"N 5°31"E, Nigeria	2n = 24	Upland rice from peasant farmers
TOS IJ86-B	FALUYI: Ijesa-Isu, 7°43"N 5°31"E, Nigeria	2n = 24	,,
TOS AWGU DWARF-W	NWOKEOCHA: Awgu, 6°5"N 7°29"E, Nigeria	2n = 24	,,
TOS AWGU DWARF-B	NWOKEOCHA: Awgu, 6°5"N 7°29"E, Nigeria.	2n = 24	‘’
TOS JEBBA LC2	BOLAJI and FALUYI: Jebba, 9°8.599"N 4°48.834"E, Nigeria	2n=24	Cultivated
TOS JEBBA PSS	BOLAJI and FALUYI: Jebba, 9°8.599"N 4°48.834"E, Nigeria	2n=24	,,
TOS JEBBA TYPICAL	BOLAJI and FALUYI: Jebba, 9°8.599"N 4°48.834"E, Nigeria	2n=24	--
PUT2-PUT9	BOLAJI and FALUYI: Jebba, 9°8.599"N 4°48.834"E, Nigeria	2n=24	Putative hybrids

1 = Tropical *Oryza punctata;* 2 = Obafemi Awolowo University; 3 = International Institute of Tropical Agriculture; 4 = Central African Republic
5 = Tropical *Oryza longistaminata*; 6 = Tropical *Oryza barthii;* 7 = Tropical *Oryza glaberrima*; 8 = Tropical *Oryza sativa;* LC2=Left Corner 2; PSS = Poor Seed Set; PUT = Putative

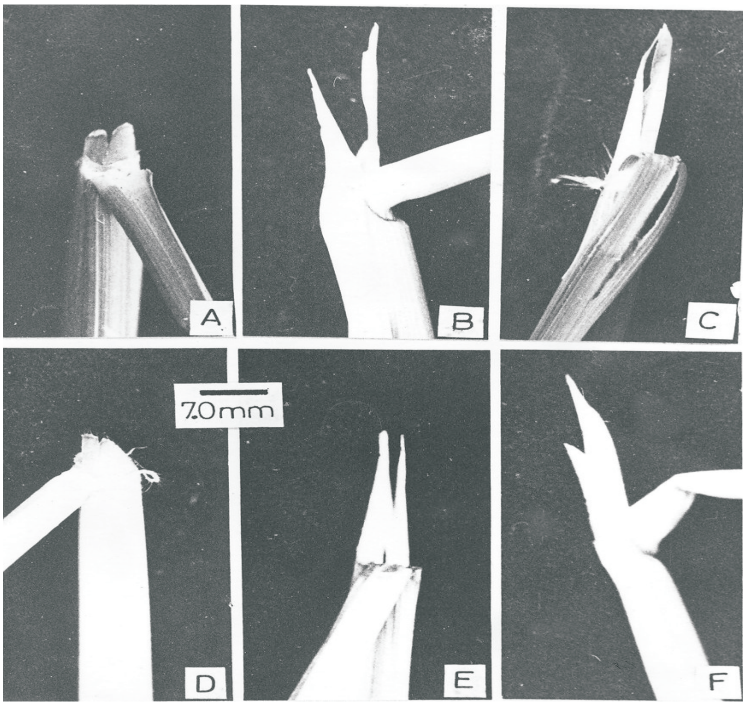

Fig. 1: Ligule Types in the Species of *Oryza* Studied and their Hybrids. A. Truncate in *O. glaberrima*, B. 2-cleft in *O. sativa* × *O. glaberrima* hybrid, C. 2-cleft in *O. sativa*, D. Truncate in *O. barthii*, E. 2-cleft in *O. barthii* × *O. sativa* hybrid, F. 2-cleft in *O.glaberrima* × *O. sativa* hybrid.

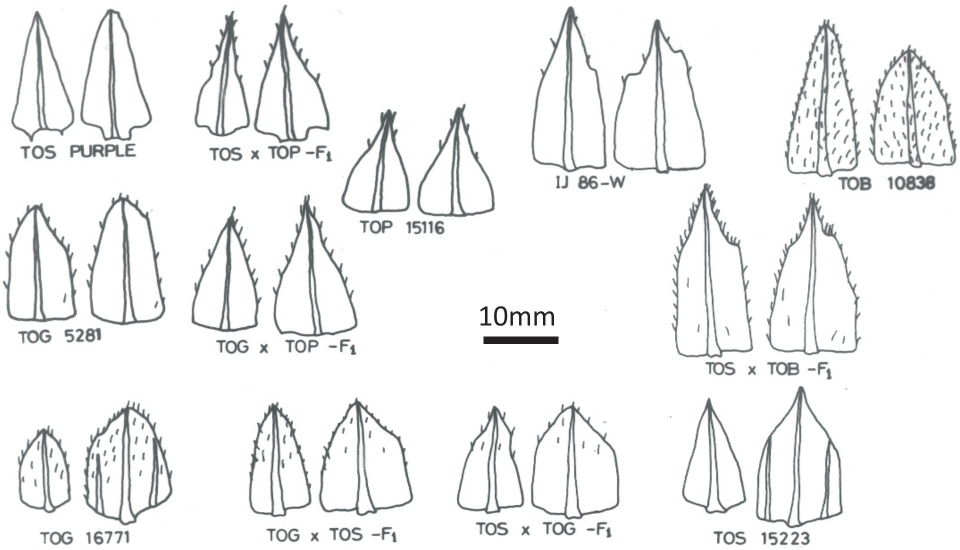

Fig. 2: Forms, Shapes and Hairiness of Sterile Lemma in some Accessions of *Oryza* studied and their Hybrids.

III. Hairiness and Shape of Sterile Lemma (Figure 2)

In all the rice species involved in the current study, long sterile lemma was found only in TOG 12083 and TOG GARKAWA accessions of *O. glaberrima*. All the other accessions possessed the normal sterile lemma. The shape of the normal sterile lemma monitored in the various interspecific and intervarietal hybrids obtained in this study and their parents showed no specific pattern of inheritance. Hybrids, as expected, inherited the shape of the sterile lemma of one of the parents (Figure 2). On the other hand, hairiness on the sterile lemma showed a specific pattern of inheritance. All crosses involving hairless and hairy sterile lemma produced F_1 plants with hairy sterile lemma, showing that hairiness is dominant over hairlessness and can be used as an index in the identification of hybrid plants.

IV. Ripen-hull Coloration

The species of *O. punctata* have black hull colour with no variation and all crosses involving this species produced sterile F_1 plants. All the other accessions of rice species studied had straw hull coloration of palea and lemma except TOB 8218. The F_1 plant of the TOB 8218 (black hull) × TOB 5646 (straw hull) cross and its reciprocal produced spikelets which ripened to black hull showing that black hull coloration is dominant over straw hull coloration. A total of 207 F_2 plants segregated into a ratio of 9 black hulled: 7 straw hulled plants confirming the dominance of black hull over straw hull and showing that the inheritance of black hull coloration in *O. barthii*, is controlled by two genes consistent with the complementary gene interaction model (Table 3). This scenario was also observed in *O. glaberrima,* when crosses between TOG 12083 (black hull) and TOG 16771(straw hull) segregated into a ratio of 9 black hulled: 7 straw hulled plants indicating that the inheritance of hull coloration in *O. glaberrima* is also being controlled by two genes consistent with the complementary gene interaction model (Table 4).

It is important to note that there is no observed effect of straw or black coloration on the caryopsis colour. At full grain filling, the spikelets appear the same colour before blackening commences. Blackening occurs at late grain maturity, beginning at the tip within the panicle and in the spikelet. The black pattern appears first at the tip of prickles on the palea and lemma. The palea and lemma of unfilled spikelets do not blacken but remain straw.

V. Pigmentation of some organs

Purple pigmentation was observed on organs such as lower outer leaf sheath, inner leaf sheath, nodes of culm, pistil, awn, and apiculus of some of the *Oryza* species studied. Close observation revealed that *O. glaberrima* and *O. barthii* have purple pigmentation on their pistil, lower outer leaf sheath, apiculus and awn (where present). *Oryza punctata* has dark-purple pistil but the pigmentation, if present, is not prominent on the apiculus/awn and also on the lower outer leaf sheath.

In *O. sativa*, there were accessions that lacked pigment in all the vital organs (acyanic) and there were those that had pigment in some vital organs (Table 2). At the other end of the spectrum, TOS PURPLE manifested purple pigmentation on all its organs. Figure 3 shows the pattern of inheritance of pigmentation worked out in a cross between TOS PURPLE and TOS 15223.

The result showed that the purple leaf gene PL-imparted colour by pleiotropy on the junction complex (ligule, auricle, colar), node of the culm, sterile lemma, stigma, apiculus; but it inhibited the expression of colour on the inner leaf sheath. The gene for apiculus colour also exerted pleiotropic effect on the stigma, nodal ring, outer leaf sheath, culm (100%); but the major genes exerted complementary on the inner leaf sheath and recessive epitasis on the junction complex.

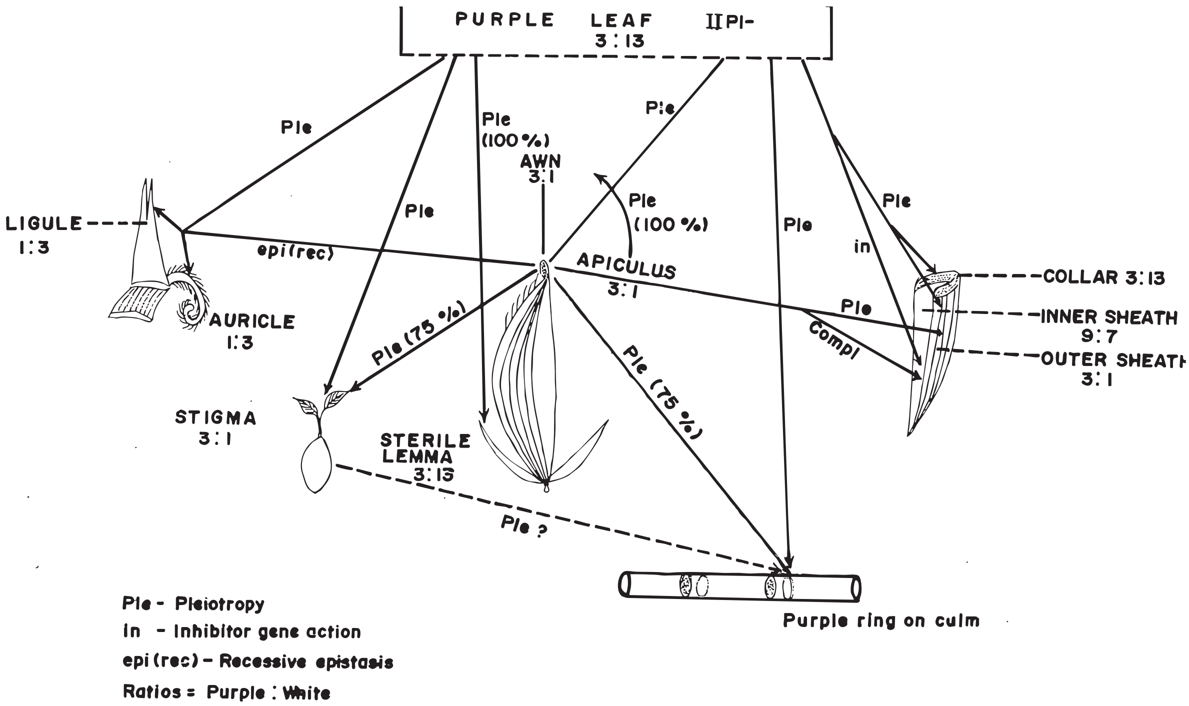

Fig. 3: Gene Systems Controlling Pigmentation in TOS - Purple and TOS - 15223 (Faluyi and Oloyede, 1997)

Table 2: Character State of Markers Encountered in the Study

Species	Flag Leaf Shape	Panicle Type	Ligule Type	Ripen Hull Colour	Stigma colour	Apiculus Colour	Outer Sheath Colour	Auricle	Leaf Pubescence
TOS	Linear	Compact, drooping	Linear, long, 2-cleft	Straw	White	White	Green	Long, clasping till late age	Intermediate
TOL	Lanceolate	Open, erect	Linear, long, 2-cleft	Black	Purple	Purple	Purple	Partially clasped	Intermediate
TOG	Lanceolate	Compact erect	Short, truncate	Straw	White/purple	Purple	Purple	Not prominent, deciduous	Glabrous
TOB	Lanceolate	Open, erect, slightly drooping	Short, Truncate	Straw	Purple	Purple	Purple	Clasping at seedling, not prominent with age	Intermediate
TOP	Linear/lanceolate	Open, erect	Long, not 2-cleft	Black	Purple	White	absent or less prominent	Clasping at seedling	Intermediate
TOB 8218× TOB 5646	Lanceolate	Open	Short, truncate	Black	Purple	White/purple	Purple	Clasping at seedling, not prominent with age	Intermediate
TOP ×TOG	Linear/lanceolate	Open, erect	Acute	Black	Purple	White	Purple	Clasping at seedling	Intermediate
TOS×TOB	Linear	Compact, drooping	Linear, long, 2-cleft	Straw	White	White	purple	Long, clasping till	Intermediate
TOS ×TOG	Linear	Compact, drooping	Linear, long, 2-cleft	Straw	Purple	Purple	Purple	Long, clasping till late age	Intermediate
TOP ×TOS	Linear/lanceolate	Open, erect	Long, 2-cleft	Black	Purple	Purple	absent or less prominent	Clasping at seedling	Intermediate
PUT2	Linear	Compact, erect	Linear, long, 2-cleft,	Straw	White	White	Green	Partially clasped	Intermediate
PUT3	Linear	Compact, erect	Linear, long, 2-cleft,	Straw	White	White	Green	Partially clasped	Intermediate

Table 2 continued

Species	Flag Leaf Shape	Panicle Type	Ligule Type	Ripen Hull Colour	Stigma colour	Apiculus Colour	Outer Sheath Colour	Auricle	Leaf Pubescence
PUT4	Lanceolate	Compact, erect	Truncate	Straw	Purple	Purple	Purple	Partially clasped	Intermediate
PUT5	Lanceolate	Compact, erect	Truncate	Straw	Purple	Purple	Purple	Partially clasped	Intermediate
PUT6	Lanceolate	Compact, erect	Truncate	Straw	Purple	Purple	Purple	Partially clasped	Intermediate
PUT7	Lanceolate	Compact, erect	Truncate	Straw	Purple	Purple	Purple	Partially clasped	Intermediate
PUT8	Lanceolate	Compact, erect	Truncate	Straw	Purple	Purple	Purple	Partially clasped	Intermediate
PUT9	Linear	Compact, erect	Linear, long, 2-cleft,	Straw	White	White	Green	Partially clasped	Intermediate

Table 3: Classification of Plants for Ripened Hull Coloration in the F_2 Population of TOB 8218 (black Hull) × TOB 5646 (straw hull)

Source	Accessions	Number of Plants			χ^2 9:7	P
		Black	Straw	Total		
Nwokeocha (1998)	TOB 8218 × TOB 5646	123	84	207	0.845	0.1≤P≤0.5

Table 4: Classification of Plants for Ripened Hull Coloration in the F_2 Population of TOG 16771 (black Hull) × TOG 12083 (straw hull)

Source	Accessions	Number of Plants			χ^2 9:7	P
		Black	Straw	Total		
Aladejana (2000)	TOG 16771 × TOG 12083	100	60	160	2.540	0.1≤P≤0.5

The genes for outer leaf sheath and stigma colour manifested a single dominant relationship with the genes for the acyanic states while the genes for colour on the ligule and the ligule are recessive to the acyanic states.

DISCUSSION

A number of morphological and botanical markers have been revealed by this study. These markers have been tested and proved reliable in our subsequent agrobotanical studies on *Oryza* and are discussed below.

The long, 2-cleft ligule type (i.e. sativa-type) showed dominance over all the other types encountered. This has been successfully used in hybrid identification and even in tracing introgression of genes in natural hybrid swarms.

The auricle degenerates with age, opening up as the culm increases in diameter. Thus, its prominence and persistence in old age of any rice taxon, as encountered in *O. sativa,* can reliably serve as an identification marker. It can also be used to trace the flow of gene in a hybrid swarm, when *O. sativa* is involved. Its pigmentation is however not reliable.

The occurrence of long sterile glumes formed the basis of the recognition of the varieties; typical (normal glume) and grandiglumis (long glumes) by early systematists. Chao (1928) obtained a 15:1 ratio of short to long glumes, indicating a control by duplicate dominant genes. Jones (1933) reported 3 short: 1 long sterile lemma in the F_2 of his work indicating that long sterile lemma is controlled by recessive genes. Similar results were obtained by Morinaga and Fukushima (1943). The normal sterile lemma was prevalent in all the materials for the current study and did not segregate in hybrids and backcrosses. Thus sterile lemma type connot be considered as a marker. However, the shape of the sterile lemma and its hairiness showed a specific pattern or trend that made hairiness dominant over hairlessness as Figure 2 shows. These characters are therefore reliable markers in the identification of hybrid plants between the two character states.

Black hull coloration in *O. barthii* is a vital genetic marker as it expresses dominance when involved in crosses with plants having the alternate character state. The stage at which the black pigmentation occurs and the pattern of expression on the hull call for caution and utmost care as there is the possibility of misclassification or wrong assessment of the different character states. It has been noted that the brown colour of caryopsis leaches to colour its hull which could have determined being straw. In panicles of brown rice caryopsis, unfilled spikelets are straw, filled ones are brown. Therefore hull colour may not be that reliable when brown caryopsis is involved.

Baderinwa (2004) observed that the brown ripen-hull colour in ERINMO-14 was imparted by the brown caryopsis colour gene and not by an independent gene. The observation of brown and straw ripened hulls corresponding to brown and white caryopsis respectively in the F_1 of a brown × white caryopsis cross support this observations on ERINMO-14. Hull colour may therefore not be a reliable marker. Caryopsis colour may also not be because its inheritance is not simple (duplicate gene with dosage effect as in ERINMO-14); Baderinwa, 2004).

Setty and Misro (1973) and Faluyi and Oloyede (1997) reported that apiculus colour gene exercises absolute pleiotropic effect on the stigma, lower outer leaf sheath and nodal ring. Nagao (1951) pointed out that when only one organ of the rice plant is coloured, it is the apiculus and that it is rare for the stigma alone to be coloured. He also reported that the distribution patterns suggest that the genes concerned in the apiculus pigmentation also control colour expression in these other organs. The green-leafed hybrid plants in this study, obtained from various interspecific crosses involving the TOS PURPLE, have purple tinge on the leaf and glumes but fits into the colour gene-inhibitor gene interaction. Also, the purple colour on the apiculus/awn, stigma and lower outer leaf sheath could be explained on the basis of pleiotropic effect of the colour gene on these organs as reported by Faluyi and Oloyede (1997).

The exploration of the local rice germplasm has shown that purple leaf blade is not common in both wild and cultivated rice. It is therefore not a vital marker. However, various reports, including the results of the present study, show that purple pigmentation of organs such as apiculus/awn, stigma and outer leaf sheath are remarkably distinct and show dominance when they are involved in crosses with plants that are acyanic. The wild rices that are indigenous to West Africa (*O. barthii, O. longistaminata,* and some accessions of *O. punctata*) and the cultivated *O. glaberrima* generally carry these organ colour complexes. Some accessions of *O. punctata,* however, expresses a deep purple colour only on the stigma as against the report of Nagao (1951). These organ colours can therefore be reliably used as markers in identifying putative hybrids between cultivated and wild rices and also between different cultivars. On the other hand, the pigmentation on organs like collar, auricle and sterile lemma are not reliable markers because they are generally not easily observable and according to Tunen and Mol (1991), their inheritance could be recessive and their expression subject to age, internal and external environmental alterations.

The point is obvious that when rice leaf blade is purple, the marker value is more complicated as a result of pleiotropy which modifies the colour expression of the other stake holder genes—the genes for apiculus colour, outer leaf colour and stigma colour. Pigmentation on the culm, auricle and the sterile lemma may not be reliable because there expression is subject to age, environment and they are controlled by recessive genes.

CONCLUSION

Some minor morphological and genetical characters in rice have been shown to possess great value as markers. The valuable markers identified include ligule type; auricle in *O. sativa*, pigmentation of apiculus/awn, stigma, lower outer leaf sheath; hairiness on the sterile lemma; and ripen hull coloration. These markers can be employed in the identification of putative hybrids and also aid in the understanding of the population dynamics of the indigenous species of *Oryza*. The authors have employed these markers, with great success, in their recent investigation of the population dynamics of a hybrid swarm in Jebba Fadama and across other rice ecological zones of Nigeria.

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