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AGRO-MORPHOLOGICAL CHARACTERIZATION OF AFRICAN RICE ACCESSIONS (*Oryza glaberrima*) IN RAINFED AND IRRIGATED CULTURAL CONDITIONS

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ABSTRACT

African rice is used for its resistance to diseases and stresses, to improve Asian species. Unfortunately, its culture is greatly neglected in favor of Asian varieties and because of this only many African rice varieties is literally on the way of extinction. Due to its potential, it is important to preserve this agricultural resource. This work aims primarily at doing agro-morphological characterization of African rice accessions in the perspective to identify the useful varieties of *Oryza glaberrima* for future exploitation. This study was carried out at the Africa Rice Center sites in Republic of Benin and Senegal, for this 235 African rice accessions including two controls (CG14, NERICA4) have been observed during rainfed (Benin) and irrigated (Senegal) culture using "*Augmented design in randomized complete block*" method. Result of study revealed that all accessions completed their life cycle; among the tested accessions, 22 were reported as *O. sativa* and interspecific accessions while reset 213 accessions were phenotypically identified as *O.glaberrima*. The discriminate variables of PCA (based on the 9 main parameters) of 213 *O.glaberrima* accessions, leaded to a dendrogram with two clusters: cluster I (114 accessions) is characterized by the precocity of their cycle: it can be used as an important

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trait for variety selection. Cluster II (99 accessions including CG14 and NERICA4) is characterized by the strong production yield. These results allow us to have a collection of *O. glaberrima* accessions in order to study not only its genetic diversity but also to evaluate more potential of these varieties for exploiting their genetic and nutritional advantage for the development of new varieties.

1 Introduction

The rice (*Oryza spp)* is a basic food that provides 27% of the energy intake in population of third world countries (FAO, 2004). It is an important agricultural product for food in West Africa, where 40% of needs are insured by the international market (Mendez del Viflar & Bauer, 2013). Two species *Oryza sativa* (Asian rice) and *Oryza glaberrima Steud* (African rice) are mainly cultivated in Africa (Anonymous, 1991; Anonymous, 2002). The African species is composed of several varieties used for a long time in varietal improvement systems because of their potential for resistance to diseases and drought (Africa Rice, 2010).

The introduction and rapid adoption of Asian rice varieties has, on one hand, led to an increase in rice production resulting in a positive impact on producer's income (Obilana & Okumu, 2005), and on the other hand, abandonment of African rice. However, the success of Asian and improved varieties does not fully satisfy breeder's ambitions and the expectations of producers and consumers. There is still an unfavorable difference between improvement varieties and their parent *O. glaberrima* either in the form of resistance, tolerance to cultural constraints (biotic and abiotic), or organoleptic and nutritional quality (Futakuchi & Sié, 2009; Africa Rice, 2010). These observations challenges breeders to improve the abilities of native varieties (interspecific) being created and tested under various growing conditions (rainfed, lowland, irrigated, etc.) so that they can better adapted, more productive and accepted by consumers. The use of parents such as the *O. glaberrima* was therefore indispensable, since they constitute the very basis of the creation of interspecific varieties.

Domestication, gene flow and natural introgression are interspecies phenomena that can affect over time the diversity of rice species. In West Africa, due to its abandonment, very few studies have focused on characterization of the African rice in varied growing conditions. This study would make it possible to better evaluate, with a wide range of agro-morphological indicators, the agronomic potentials of the African rice. This work, in context of a research project about the valorization of African rice, aims mainly to identify the successful accessions of African rice useful for varietal improvement systems, through a hierarchical classification based on agronomic descriptors. The results will not only complete the list of characterized African rice varieties, but also ensure the use of its diversity for the development of new rice varieties.

2 Materiel and Methods

2.1 Test sites

Two sites namely "the Africa Rice station of Cotonou (Benin)" for rainfed test (between October and January) and "the Africa Rice station of Sahel (Ndiaye, Saint Louis, Senegal)", for irrigated test (between September and December) were exploited for testing.

2.2 Materials

It consists of 235 accessions of African rice collected in the villages of Danyi in Togo (in August and December 2008) and two controls (CG 14, NERICA4) having all been subjected to the germination test.

2.3 Experimental Setup

The setup used for the implementation of the two tests is built according to the method "Augmented Design in Randomized Complete Block" described by Nokoe (2001). This test has been used because of the high number of accessions while the quantity of seed is very limited (about 5g). The method consists in designing a device in which only the controls are repeated in each block (Sharma, 1988), to be used for the estimation of the experimental error and the block effect. 24 blocks of 10 entries and two witnesses, totaling 12 entries per block were designed. Each elementary plot has a density of 42 plants 20cm apart between the lines and on the lines. The elementary plots (1.68 m2 of area) are separated by a path of 30cm.

2.4 Agronomic Practices

2.4.1 For rainfed crops (Benin)

Sowing was carried out in a line by a direct method at the rate of 2 seeds per plant, with a separation (after two weeks) at one plant. Only basic fertilizer NPK (10-18-18) is applied at the rate of 100 kg / ha at seeding. Irrigation was carried out with a watering system and weeding was carried out manually.

2.4.2 For irrigated crops (Senegal)

The seeds were pre-germinated at artificial incubator at 30°C for 48 hours. Seedlings were transfer in to pots in greenhouse conditions. Nine (09) days after sowing, the pots were removed from the greenhouse and exposed to natural conditions for acclimatization; this transplanting was carried out in a line. Selective Herbicide, LONDAX 60% (Bensulfuron-Methyl 100 g/kg) was applied for weed control with a recommended application rate of 100g/ha (Africa Rice 2010). This application is accompanied by manual weeding. Three successive applications of fertilizer $NP_2O_5KO_2$ (150-60-60) were carried out for the treatment of the tests. For irrigation, draining system has been developed to allow the management and renewal of water whose level is controlled according to the evolutionary stage of the plants.

2.5 Agro-morphological parameters observed

Observations are related to agro-morphological characteristics of varieties and some characteristics of post-harvest grain. Overall 36 quantitative and qualitative parameters were measured according to the SES (Standard Evaluation System) and the International Rice Research Institute (IRRI) descriptors. However, nine mains parameters viz tillering at 30 days after Sowing (Till30), tillering at 60 days after Sowing (Till60), height 60 days after Sowing (Hgt60), maturity height (Mat.Hgt), flowering date (Flw.Date), maturity date (Mat.Date), number of fertile panicles (NFP), weight of 1000 grains (Wgt.1000g) and yield have been studied in detail.

2.6 Statistical treatment

Since only the witnesses were repeated the effect of the blocks was first evaluated and the adjustment of the averages of the accessions was then realized. For the different parameters, the level of variability and degree of heritability within the collection were studied to ensure homogeneity and absence of the effect of the environmental factor. A simple descriptive analysis was realized with the R software, followed by significance and correlation test of a Genotype-Environment (GXE). Principal Component Analysis (PCA), Hierarchical Ascending Classification (HAC) and study of variance of the different groups were realized using the adjusted averages of the common parameters evaluated at the two sites.

3 Results

The results of germination test of the accessions showed on average of 80%. Within the tested collection, it was observed in the two sites, twenty-two (22) accessions within agro-morphological characteristics widely distinct from others, with a mixture of specific traits (of *O. sativa* or interspecific).

3.1 Presentation of Agronomic Characteristics

The heritability coefficient varies between 0.86 and 0.99 for rainfed conditions and between 0.84 and 0.99 for the irrigated conditions. The coefficient of variability varies between 0.021 and 1.9. The correlation Genotype X Environment of parameters showed a p-value above 0.05 for the yield. The adjusted average of the data of the two sites made it possible to extract the descriptive values from the agronomic parameters (Table 1) and to make a Principal Component Analysis (PCA).

3.2 Identified Phenotypic Groups

The individuals factor map (Figure 1) obtained from PCA showed the distribution of accessions based on their similarity. The two axes of distribution map represent more than 50% of the information in the collection. The selection of the characteristics parameters was made from their value contribution, which informs on the quality of their representation and their contribution to the distribution.

These results made it possible to make the hierarchical classification represented by the dendrogram (Figure 2), this appeared two groups (clusters) phenotypes. Table 2 shows the different values-tests for the variables of each cluster. The fundamental difference between the accessions is related to the variables as: Till30 (4.10), Till60 (16.62), Hgt60 (83.15cm), Mat.Hgt (81.07cm), Flw.Date (≈ 48 days), Mat.Date (≈ 80 days), NFP (19.76), and yield (497.30g/m^2). This grouping made it possible

Table 1 Descriptive values of the agronomic characteristics of the accessions studied.

variables	Moy	Low	Max	Standard deviation
Till30	4.10	1.94	9.10	0.16
Till60	16.62	9.51	26.07	1.97
Hgt60 (cm)	83.15	69.21	100.64	3.25
Mat.Hgt (cm)	81.07	66.16	99.83	1.42
Flw.Date (days)	47.20	41.30	59.10	2.65
Mat.Date (days)	79.80	74.35	90.05	5.47
NFP	19.76	12,10	29.45	5.09
Wgt.1000g (g)	26.61	20.41	36.15	1.98
Yield (g/cm^2)	497.30	297.57	702.25	60.97

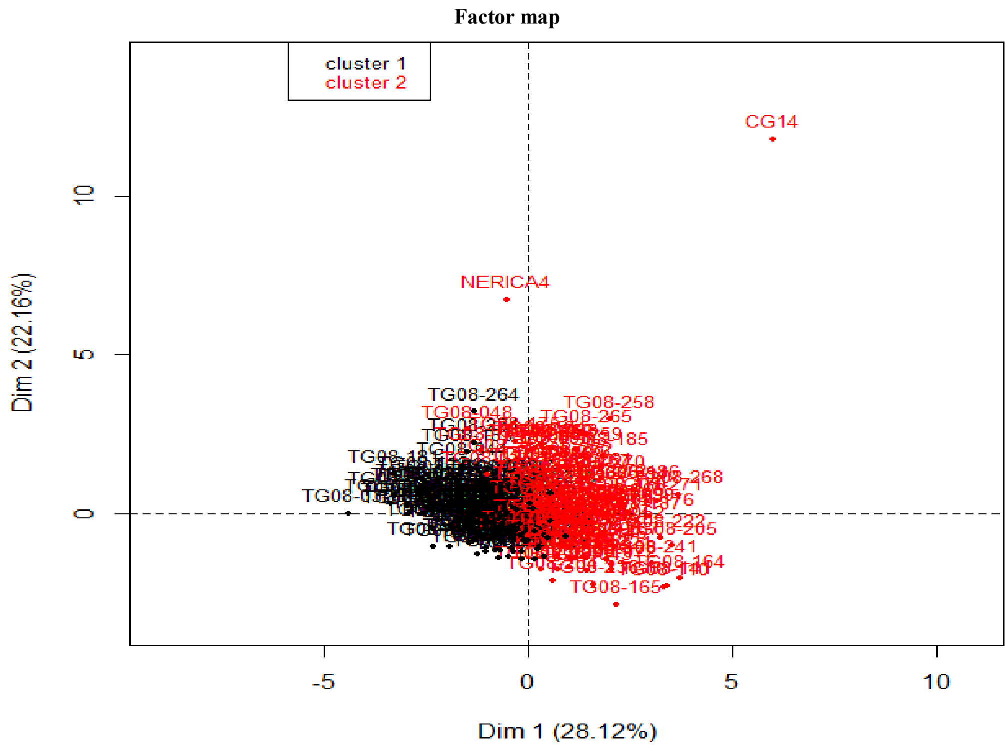

Figure 1 Accessions distribution map

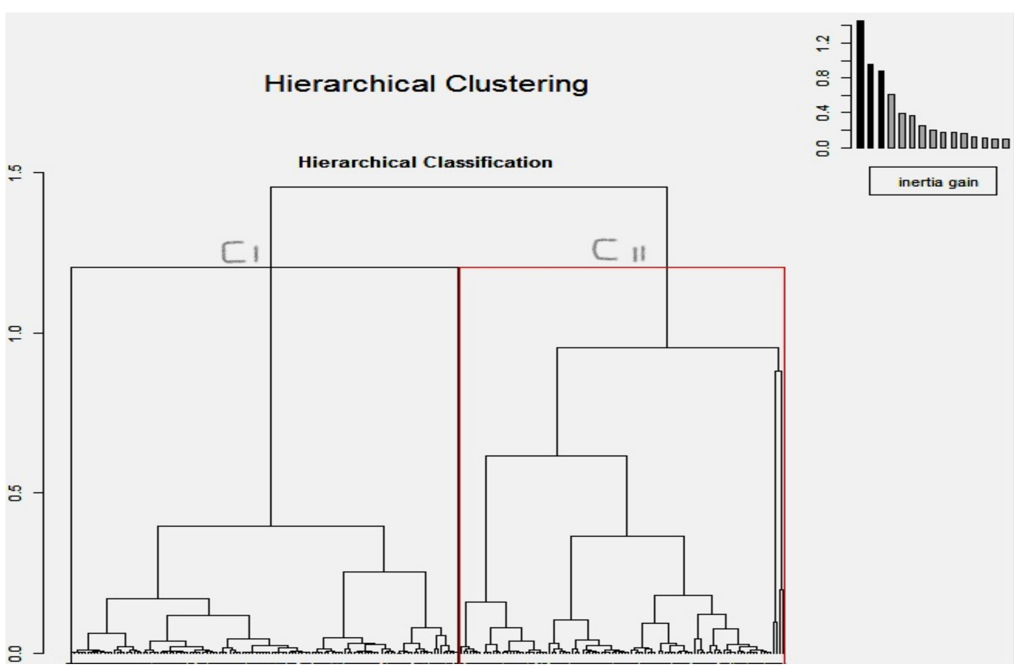

Figure 2 Hierarchical classification of accessions according to their agronomic characteristics

Table 2 Agro-morphological parameters characteristic of clusters

Cluster 1		Cluster 2	
variables	v.test	**variables**	v.test
NFP	4.79	**Hgt60**	8.59
Flw.Date	3.73	**Mat.Hgt**	8.01
Till30	2.82	**Yield**	7.76
Mat.Date	-4.17	**Till60**	7.09
Till60	-7.09	**NFP**	4.79
Yield	-7.76	**Mat.Date**	4.17
Mat.Hgt	-8.01	**Flw.Date**	3.73
Hgt60	-8.59	**TIll30**	2.82

to identify 114 *O.glaberrima* accessions for the cluster1, and 99 *O.glaberrima* accessions for the cluster 2, this included two controls CG14 and NERICA4.

4 Discussion

4.1 Agro-morphological characteristics

All accessions have finished their growth cycle: which gave information on their good germination and vegetative vigor. Values expressing heritability (≈1) explain a very low impact of environmental factors. These observations suggested that phenotypic characters come from genotypic expression. In addition, the analysis of variance revealed a significant effect of the genotype on the studied variables. According to Okeno (2001) and Pliura et al. (2014) genotypic variation is an important factor for the improvement of variability and selection of new varieties.

Absence of Genotype X Environment effects on yield revealed that site variation does not seem to affect the productivity. These results are in agreement with the findings of Gueye et al. (2016) those who reported similar results on inter and intraspecific rice lines by crossing Genotypes X Season factors. Indeed, one might consider this absence of Genotype X Environment interaction for yield as an interesting result; this provides information on the potential of varieties especially with respect to their stability and their ability to give good performance in various conditions. According to Vitaa et al. (2010) modern varieties are characterized by reducing G X E interaction and increasing stability.

The evolution of the data in relation to the number of tillers and height shows a normal growth of the plants. In fact, 30 days after sowing, the average numbers are equal to that of the control CG14, thus indicating a good development of the plants with the minimum cultivation conditions imposed which is a very important characteristic of *O. glaberrima* (Anonymous, 1991; Anonymous, 2002; Aboa et al., 2004; Vido, 2011). The observed variability may depend on other factors related to genotypic traits. In the same order of data, the average number of tillers 60 days after sowing is greater than 16. Based on the criteria of IRRI (2002) & Sanni et al. (2009b) it is realized that this parameter has strongly contributed to the number of fertile panicles of accessions thus indicating for a normal progression of the maturity phase of the plants (Sanni et al., 2009b; IRRI, 2002). Indeed, the number of tillers produced by a variety is related to the stage of plant development (Sanni et al., 2009a), which is strictly related to the variety (Nguetta et al., 2006). In relation to the number of fertile panicles, this parameter is related to the tillering attitude of the plants (Wang et al., 2007), but it does not necessarily determine the yield, because it is important to note that the yield is not directly correlated with the vegetative development of the plant (Guéi et al., 2005), a very strong tillering (in tuft) at the vegetative phase could give way to competition and produce a small number of fertile panicles. In addition, resistant varieties, when threatened with severe attacks (midge for example), emit new tillers that are not all productive (Nwilene et al., 2006). However, a low attitude to tillering presented by some varieties is linked to the low nitrogen supply or perhaps the combined effect, in ground, of the possible deficiency of phosphorus and percentage of acidity (Wopereis et al., 2009; Dewa, 2013). The variability observed in these two studies is certainly not only to the conditions of the test sites but also depend on the genotypic characters of the accessions.

Considering the dates of flowering and maturity, all accessions had a mean of 47 days for the cycle of sowing-flowering 50% that is relatively early compared to NERICA4 (65 days on average). This value also reflects an early cycle of sowing-maturity 80% (79 days), shorter than this same control (92 days on average). These observations explain a good ability to withstand the cold stress observed generally in December (after flowering in the Sahelian conditions). These results are contradictory to the findings of Wopereis et al. (2009) those who reported that cold is an abiotic constraint that delays the growth of rice and increases the duration of its cycle. Varieties used in current study are revealed as early cycle varieties (very interesting aspect for any producer or breeder). Indeed, Bezançon & Diallo (2006) reported that African rice is a species whose life cycle is early and varies between 90 and 100 days. Research conducted by other author has shown that typical rainfed varieties of rice mature between 150 and 170 days and improved varieties mature between 120 and 140 days after sowing (Monty et al., 1997). Given these considerations, the accessions characterized in this study outdo the boundaries and are very interesting from the point of view of life cycle and probably offer a good prospect of study. For the characterized collection, the mean yield evaluated is 497 g/m^2 (in both sites), and is substantially equal to the yield of the control CG14; while more than 70% of accessions have a higher yield than that of NERICA4. These results are in agreement with the assertions of Linares (2002) who estimates the productivity of African rice varieties (*O. glaberrima*) and reported lower yield. These observations explain a relative control of chattering, lodging incidence and pests; these factors being controlled by fillets, bird hunters and border plants during agronomic test. In fact, lodging incidence and chattering are the factors of the low yield potential of African rice (Futakuchi & Sié, 2009). Similar results were observed by Africa Rice (2010) and Aboa et al. (2004), those who suggested that water lodging and chattering are the major limiting factors for *O. glaberrima* varieties. The exsertion panicle also contributes to the reduction of damage. Indeed, a good exsertion of the panicle is a characteristic of weak attack of blast on the neck of the panicle and a good maturation of the spikelets (Jacquot, 1974). This character obviously favored the absence of damage due to blast and maturation of grain that improved yields. This study revealed that there are still accessions of African rice that can have strong yield potential.

4.2 Phenotypic groups identified

The classification of the accessions showed two groups (cluster1 and cluster2). The fundamental difference was reported between the studied accessions. Studied nine characteristics are well discriminating the selected African rice collection. Previous studies conducted on agronomic characteristics revealed that height of plant and tillering ability are essential characteristics which can discriminate rice populations (Ogunbayo et al., 2007; Ojo et al., 2009; Moukoumbi et al., 2011). Current study identified two clusters, among these, cluster I have 114 accessions while cluster II have 99 accession of African rice, this cluster also have two controls CG14 and NERICA4. The values-test (v-test) obtained made it possible to distinguish the variables that strongly characterize the accessions of each cluster. Indeed, cluster 1 groups more than half of the accessions, and the two clusters are strongly characterized by tillering 60 days after sowing (Till60), height of plant (at 60 days after sowing and at maturity) and yield. For these variables, the accessions of cluster 1 have their averages relatively lower than the average of the entire collection; on the other hand, the accessions of cluster 2 are characterized by their average values above the average of the entire collection. Concerning the variable « precocious of the cycle », which is an interesting and exploitable trait for the varietal selection, the accessions of the cluster 1 are revealed very early, with sowing-flowering and sowing-maturity cycles very short compared to the average of the collection. Results of current study are contradictory to the findings of Montcho et al. (2017) those who reported that *O. sativa* has a shorter life cycle than *O. glaberrima.* According to Takeshi (2007), the vegetative cycle is an important factor that can be used as a control parameter for climatic factors and pests. The cycle time of a rice variety is strongly related to its photoperiod sensitivity and depends mainly on the duration of its basic vegetative phase (Dingkuhn & Asch, 1999).

Conclusion

The results of this study reveal that the collection is composed of *O. glaberrima* accessions grouping according to agronomic performance in two clusters. The characteristics of the hierarchical groups show that these varieties present an appreciable agronomic performance with the capacity to develop under several constraints associated with several ecosystems such as the rainfed and the irrigated cultural condition. Globally, the accessions of cluster 1 seem to be the most interesting, owing to their good performance in different conditions (sites and seasons) and their precocious cycle. It is favorable materials for further study because these genotypes have good environmental adaptation, higher productivity, high and stable yields. This collection constitutes a reservoir of interesting genes, which explains its use in variety improvement programs. These results give an opening on the study of the nutritional values in order to reveal over assets for the valorization of the African rice *O. glaberrima*.

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Conflict of interest

There is no conflict of interest for the publication of this article.

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