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Assessment of the phenotypic variability of rice accessions (*Oryza* sp.) collected in Benin using agro morphological markers

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ABSTRACT

Agro-morphological characterization of plant genetic resources is essential to the success of varietal improvement programs. The objective of this study was to evaluate the phenotypic diversity of one hundred and forty-eight accessions of rice produced in Benin, including seven controls, and to assess the structuring of this diversity on the basis of 12 variables selected from rice descriptors. The experimental system used was a randomized aleatory block installed in a upland and lowland ecologies. The hierarchical ascending classification (HAC) displayed six groups of genotypes, each containing a pool of morphotypes characterized by specific agronomic traits. Comparison of the quantitative parameters in the two ecologies showed no significant difference (p> 0.05) between tillering ability, vegetative cycle durations and the number of panicles per area unit. On the other hand, a significant difference was observed for yield components such as grain yield, spikelet fertility, 1000-grains weight and number of grains per panicle at the threshold of 5%. A great variability was observed within the genotypes for these parameters. The correlation of Pearson, determined between the quantitative variables, revealed a strong correlation of 0.909 between physiological cycles and an average correlation of 0.6726 between grain yield and spikelet fertility. The correlation of Spearman showed a relatively weak relationship between quantitative and qualitative variables. Finally, BEN 11-37-A and BEN 11-68-A accessions have been identified as potentially productive for both ecologies and can, therefore, be used as the lead of potential lines and donors for future breeding and varietal improvement of rice in Benin.

Keywords *Oryza sativa*, phenotypic diversity, productivity, varietal improvement, Benin

INTRODUCTION

Oryza Spp, currently called rice, is a collection of species with annual growing cycles and formerly grown in tropical conditions [1]. This cereal is reported to have the largest germplasm in the world [2]. This collection characterized by diverse cultivated varieties (landraces and its related wild species) largely contribute to rice breeding and play an important role in the local food security [2]. Among this collection, *Oryza sativa* complex includes the cultivated Asian (*Oryza sativa* L.) and African (*Oryza glaberrima Steud*) rice species. This complex is subject to a set of evolutionary factors that support the preserving and the genetic evolution of the rice diversity. This observation is in relation to the evolutionary process of species domestication, their taxonomy and the spatial-temporal diversity origin controversially discussed for this cereal [3-7].

Nowadays, the ecosystem variations characterized by climate changes with conducting to drought, floods, the delay of rains and the importance and emergence of new pests, directly and negatively influenced the productive performance of the farming systems. Under these conditions, the organization, preservation and dynamic management of the diversity of rice genetic resources, as well as the availability of their seeds in rice production systems, underwent many constraints [8]. Since several decades, global rice production has increased because of changing dietary patterns, rapid population growth and the rapid urbanization of human societies, especially African societies [9]. Unfortunately, most African countries rice production is unable to fully meet the needs of the population, leading to an increase of rice importations. To remedy this situation, it is necessary to increase the production of local rice through, the intensification of rice cultivation and the rise in the competitiveness of local rice. Thus, the satisfaction of this condition requires the development and adjustment of new high-performing varieties with appreciable traits. To reach this goal, the study of genetic diversity and the agro-morphological characterization of germplasm are fundamental [10]. Landraces offer a valuable gene pool for rice breeding program [11].

Assessment of genetic diversity is very important in rice breeding from the standpoint of selection, conservation of a different local variety of rice and proper utilization [12]. Several studies on the genetic diversity and the evolutionary relations between the different groups of cultivated and wild species were carried out using the morphological, physiological and molecular descriptors, as well as the use of the ecological criteria, which are a function of the different ecotypes studied [1, 13, 14]. The agro-morphological markers were used in the characterization and study of rice germplasm diversity in India [15-17], Brazil [18], Pakistan [19], Bangladesh [20], Burkina Faso [21]. In Benin, the phenotypic diversity of lowland NERICAs and "interspecific" varieties were reported [22, 23].

The present study aimed to characterize agronomic and morphologic variables of rice accessions (local and introduced) collected in Benin. This can help to identify the variability of the collection and select accurately potential donors for future rice breeding and creation programs.

MATERIAL AND METHODS

Study zone

The trials were conducted at two sites of the Southern Agricultural Research Center (CRA-Sud in French) of the National Institute of Agricultural Research of Benin (INRAB). The two experimental sites are located in the central region of Benin (Figure 1).

The experimental site located in Lèma in the municipality of Dassa is characterized by a lowland ecology with the following geographical coordinates: 4 ° 15'418"N and 8 ° 66'191"E at 193 m of altitude. The average rainfall recorded in 2014 was 168.88 mm distributed over the months of June and November, with maximum rainfall recorded during the months of August and October and the minimum during the month of June (Figure 2).

The experimental site located in Sowé in the municipality of Glazoué is characterized by a upland ecology with the following geographical coordinates: 4 ° 9'002"N and 8 ° 81'296"E at 173 m. The average rainfall recorded in 2014, the experimental period was 128.41 mm spread over six months (June to November) with maximum rainfall recorded during the months of August and September and the minimum during the month of November (Figure 2).

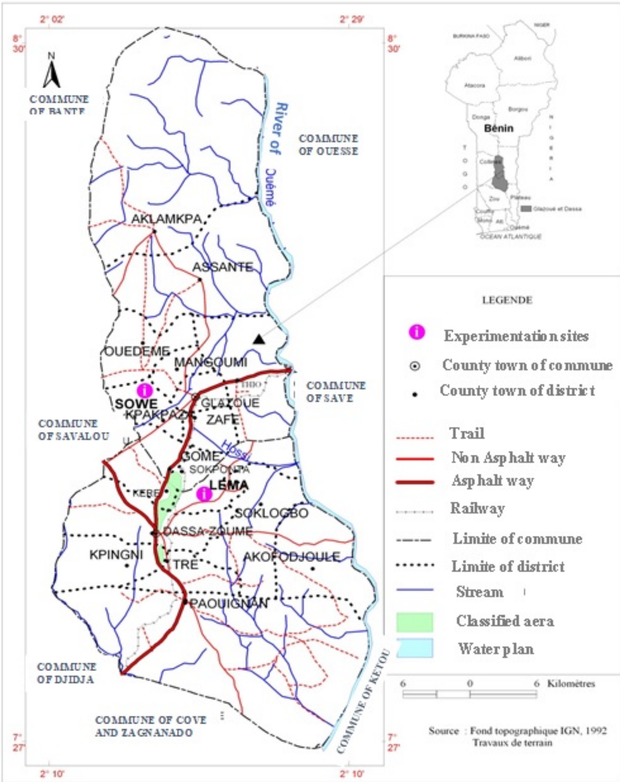

Figure 1: Geographical location of the two (2) experimental sites that hosted the test

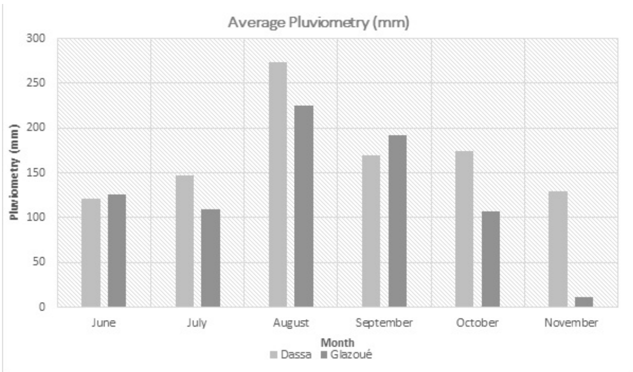

Figure 2: Graph showing average rainfall at both experimental sites in 2014 during the test period.

Plant material

A total of 148 Oryza sp genotypes, including landraces, improved and 7 controls (WAB 32-80, NERICA 1, NERICA-L 19, BL19, ADNY 11, GAMBIAKA KOKUN and WITA 4), were used in this study. The material is composed of Benin rice collections cultivated in lowlands and upland. The choice of the control varieties was made based on their characteristics. Indeed, the varieties WAB32-20 and NERICA are adapted to the rainy ecology; with a maturation cycle varying from 95 to 100 days and an average yield of three t / ha. The NERICA-L 19, BL19, ADNY 11, Gambiaka Kokun and WITA 4 varieties are adapted to lowland ecology with average yields ranging from 3 to 5 t / ha. NERICA-L 19, BL19 varieties have an average maturity cycle of 100 days. Varieties ADNY 11 and WITA 4 have a cycle with an average maturity of 110 days and Gambiaka Kokun a cycle with a late maturity of 125 days.

Methods

The agromorphological characterization of the rice accessions collection was carried out during the wet season of 2014, particularly during the period from July to November.

Experimental system and treatments

The experimental system is a randomized aleatory block of 9 blocks and 23 plots each, as described by Federer [24]. Each block consists of 23 treatments including seven control varieties. Each elementary parcel has an area, of five m^2 (5 m X 1 m) and has five lines of 25 holes each for 125 holes. The distance between the holes was 20 cm. The distance between two parcels is 0.5 m and 1 m for the distance between 2 blocks. This system was chosen because of a large number of samples to be tested.

Two (02) land cultivations between of total herbicide application were made on the experimental parameters. On the site located in the ecology of lowland, dikes of water retention were erected. These operations were followed by flattening and staking of the parcels. Sowings were made at the rate of two seeds per hole. Single (1) seedling per hole was carried out 15 days after germination.

NPK fertilizer (15-15-15) was applied as a manure at the rate of 200 kg/ha. Urea (46%) was fed in maintenance manure, in two fractions of 1/3 and 2/3 of the 100 kg/ha dose. The first fraction was applied to panicle initiation and the second fraction during the grain-filling phase [25]. Three manual weeding operations were performed during the experiment. No phytosanitary treatment was applied. Harvesting was done at rice grains maturity on all elementary plots.

Data collecting

Twelve agro-morphological variables, consisting of eight (8) quantitative variables and four (4) qualitative variables, were evaluated according to accurate measurement methods. The 4 qualitative variables evaluated were: Seedling Vegetative Vigor (Vg); Shape of Plant (SP); Panicle Exsertion (Exs); Flag Leaf Angle (FLA). The 8 quantitative variables were: Tillering Ability (Ti); Semi-Heading Cycle (SHC); Maturity (Mat); Number of panicles per m² (Npan/ m²); Number of grain per panicle (NGP); 1000-grain weight (g) (GW); Spikelet Fertility (SpFert); Grain Yield (Yld) (kg/ha). The measurements were taken according to the methodology and scale of evaluation according to the Standard Evaluation System (SES) for rice developed by the International Rice Research Institute (IRRI) and Bioversity International [26]

Data analysis

The data were entered with the Excel spreadsheet version 2013. Analysis of variance (ANOVA), correlation tests and hierarchical ascending classification (HAC) were performed according to Fenelon [27]. The mean values of the quantitative variables were obtained from the averages of the measurements made on 10 randomly selected plants on the three central lines of each elementary plot. A descriptive analysis based on the calculation of the proportions of the modalities of each qualitative variable within the population of the genotypes studied was carried out. Spearman's correlation analysis finally defined the relationship between qualitative and quantitative variables. The JMP pro version 12 software was used for statistical analysis.

RESULTS

Variability of the quantitative characteristics of rice accessions

Upland ecology

Rice accessions assessed in upland ecology are classified into six (06) genotypes groups based on a hierarchical ascending classification (HAC) (Figure 3). The different morphotypes obtained are distinct on the basis of their agromorphological characteristics (Table 1):

- The group C1 is characterized by medium-tillering genotypes (19.8 tillers), with a medium maturity cycle (122.4 days), a low spikelet fertility rate equal to 35.2% for an average paddy grain yield very low (160.6 kg/ha).
- The group C2 showed very large tillering genotypes (25.7 tillers), an average maturity cycle equal to 122.4 days, a panicle number per m² corresponding to 186.5 and an average spikelet fertility rate 63% for a low paddy grain yield of 669.8 kg/ha.

- The C3 group made up of large tillering genotypes (22 tillers), a short maturity cycle of 104 days, an average spikelet fertility rate of 74% for a low grain yield of 689.6 kg/ha.
- The C4 group formed of genotypes with high tillering of 23 tillers, an average maturity cycle of 115.7 days, an average spikelet fertility rate of 69.6% and a low grain yield of 1.457.5 kg/ha.
- The C5 group counted genotypes also having a medium tillering (18 tillers), a medium maturity cycle of 116.8 days, an average spikelet fertility rate (73.1%) for a low yield of 1.055.5 kg /ha.
- The C6 group is characterized by genotypes having a high spikelet fertility rate (84.8%) and an average grain yield equal to 1873.4 kg/ha.

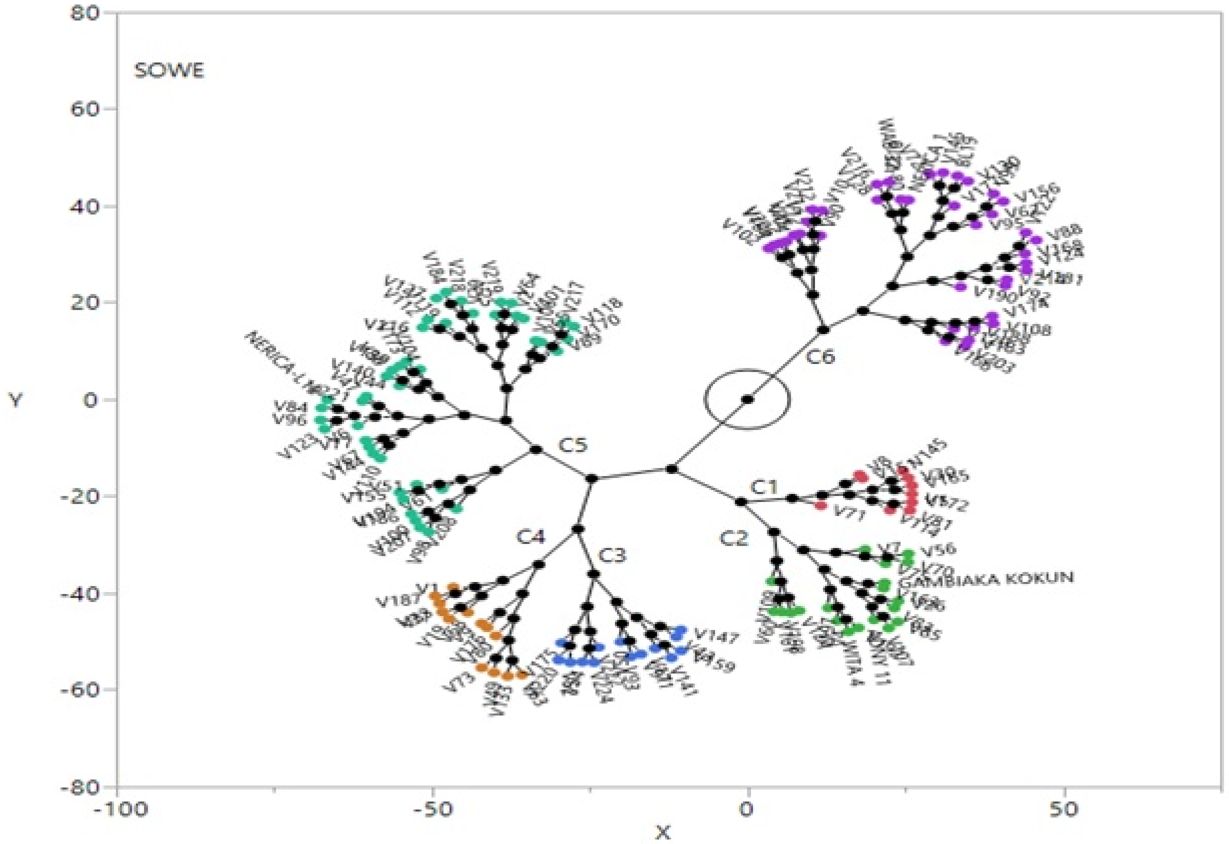

Figure 3: Hierarchical classification of rice accessions in upland ecology.

Among the six (6) morphotypes obtained, the C6 group comprising 3 of the 7 control varieties, is the most productive with a spikelet fertility rate of 84% and a very high grain yield of 1873.4 kg/ha (Table 1).

Table 1: Mean values of the agromorphological quantitative parameters of the individuals of the six morphotypes in the upland ecology;Tillering Ability (Ti); Semi-Heading Cycle (SHC); Maturity (Mat); Number of panicles per m² (Npan/ m²); Number of grain per panicle (NGP); 1000-grain weight (g) (GW); Spikelet Fertility (SpFert); Grain Yield (Yld) (kg/ha).

Cluster	Count	Ti	SHC	Mat	Npan/m^2	NGP	GW	SpFert	Yld
C1	10	19,8 ± 2,3	102,5 ± 7,8	122,4 ± 4,8	152,4 ± 45,4	175 ± 35,3	19,2 ± 2,4	35,2 ± 7,8	160,6 ± 121,5
C2	20	25,7 ± 5,4	104,7 ± 5,3	122,4 ± 3,5	186,5 ± 31,6	155,9 ± 39,8	18,8 ± 4	63 ± 7,9	669,8 ± 296,3
C3	14	22,1 ± 4,9	84,2 ± 6,3	104,9 ± 6,3	184,2 ± 43,1	114,3 ± 35,6	24,9 ± 5,6	74 ± 9,9	689,6 ± 494,4
C4	13	23,8 ± 5,6	95,4 ± 8,2	115,7 ± 7,4	290,5 ± 36	163,6 ± 54	23,8 ± 4,8	69,6 ± 10,3	1457,7 ± 344,7
C5	44	18,1 ± 4,2	97,6 ± 5,1	116,8 ± 4,6	153 ± 40,3	170,3 ± 43,4	25,5 ± 4,2	73,1 ± 8	1055,5 ± 424,3
C6	39	15,1 ± 4,3	82,5 ± 4,9	102,3 ± 5,1	198,6 ± 48,3	177 ± 47,8	27,7 ± 4,7	84,8 ± 7,1	1873,4 ± 527,3

In general, the average paddy grain yield of accessions evaluated in the upland ecology ranged from 2.29 to 3.03 t / ha (Figure 4), while their spikelet fertility rates ranged from 67.53 to 91.7%. The genotype BEN 11-72-A (V166) belonging to the C6 group, is the most productive with a spikelet fertility rate of 82.9%, a good tillering (19 tillers) and an average maturity cycle of 110 days. The average maturity cycle of the top 10 cultivars ranged from 96 to 112 days.

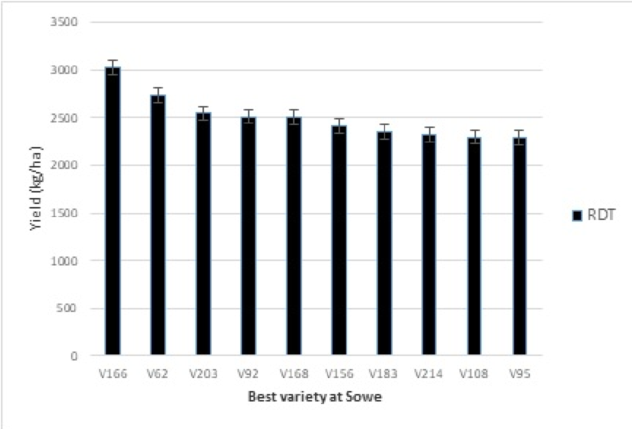

Figure 4: Paddy grain yield of the top 10 genotypes in upland ecology.

Lowland ecology

According to a hierarchical ascending classification (HAC) of the entire assessed rice collection, based on measured agromorphological parameters, six (06) distinctive groups of phenotypes were obtained in the lowland ecology (Figure 5). The characteristics of each of the morphotypes (Table 2) are as follows:

- Group C1 comprising genotypes with a medium maturity cycle (124 days), an average spikelet fertility rate (78.7%), a low paddy rice yield of 1.129.9 kg/ha and a high panicle number (168.3) with a medium tillering (12.6 tillers);
- The C2 group appeared to be the most productive and consisted of genotypes with a medium maturity cycle (118 days), a high number of seeds per panicle (140 ± 27.7 grains on average) and a high spikelet fertility rate (84.3%) for an average paddy grain yield of 2,313.2 kg/ha;
- The C3 group is the least productive and includes high tillering genotypes (24.5 tillers), a short maturity cycle (104 days), a very high panicle count per m² (261.8) and average spikelet fertility (67.5%) for a low grain yield of 1,112.4 kg/ha;
- The group C4, on the other hand, has genotypes that have good spikelet fertility (85.8%), an average paddy grain yield of 1.536.7 kg / ha for a short maturity cycle (114.2 days) , a high number of panicles per m² (225) and a high number of tillers (20.8);
- The C5 group consists of genotypes with medium tillering (14.3 tillers), a short maturity cycle (100 days), a very high number of panicles per m² (266) and a very high spikelet fertility rate (90.6%) for a rice grain yield of 2,097.5 kg/ha;
- The C6 group expresses a good spikelet fertility (88.5%) for an average grain yield of 1890.7 kg/ha, a relatively short maturity cycle (102 days), but showing a weak tillering (9.8 tillers).

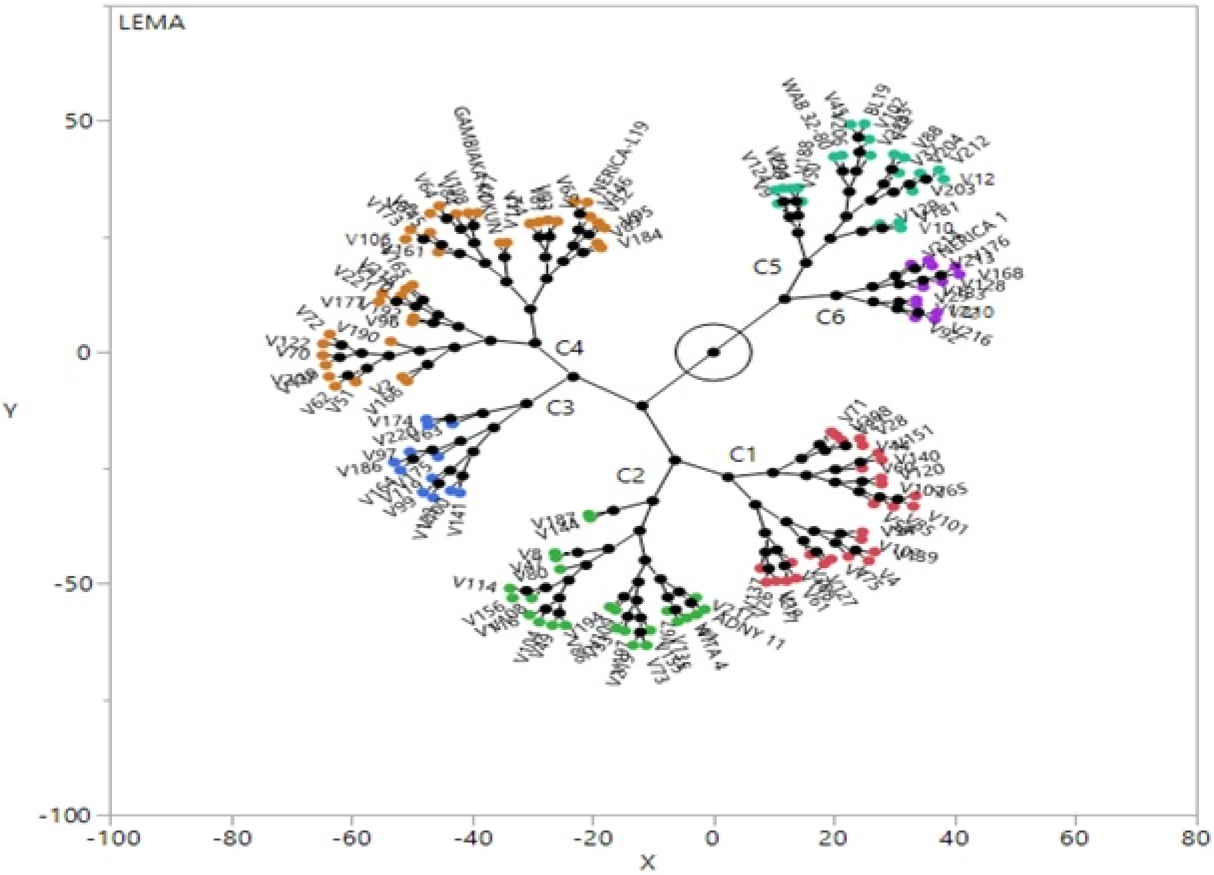

Figure 5: Hierarchical classification of rice accessions in lowland ecology.

Table 2: Mean values of the agromorphological quantitative parameters of the individuals of the six morphotypes in the lowland ecology; Tillering Ability (Ti); Semi-Heading Cycle (SHC); Maturity (Mat); Number of panicles per m² (Npan/ m²); Number of grains per panicle (NGP); 1000-grain weight (g) (GW); Spikelet Fertility (SpFert); Grain Yield (Yld) (kg/ha).

Cluster	Count	Ti	SHC	Mat	Npan/m^2	NGP	GW	SpFert	Yld
C1	28	12,6 ± 4,5	103 ± 4,6	124,1 ± 6,6	168,3 ± 50,3	127,3 ± 30,6	27,2 ± 4,2	78,7 ± 9,5	1129,9 ± 421,1
C2	25	15,8 ± 4	98,3 ± 5	118,4 ± 6,2	176,4 ± 45,8	140 ± 27,7	27,6 ± 2,8	84,3 ± 6,3	2313,2 ± 698,7
C3	12	24,5 ± 10	88,3 ± 6,1	104 ± 9,4	261,8 ± 73,1	98,7 ± 28,3	26,4 ± 4,1	67,5 ± 12,4	1112,4 ± 485,7
C4	39	20,8 ± 5,6	94,4 ± 5,8	114,2 ± 8,5	225 ± 61,2	109,1 ± 29,3	25,4 ± 3,3	85,8 ± 5,3	1536,7 ± 549,5
C5	22	14,3 ± 3,8	81,4 ± 3,9	100,7 ± 3,8	266,2 ± 57,3	97,4 ± 23,7	31,9 ± 4,3	90,6 ± 4,5	2097,5 ± 534,4
C6	12	9,8 ± 3,8	84,3 ± 5,6	102,4 ± 5,5	176,1 ± 36	154 ± 36,1	32,1 ± 4,1	88,5 ± 4,6	1890,7 ± 341,1

The paddy yield values of the ten (10) best genotypes in the lowland ecology ranged from 2,629.79 to 4,537.18 kg/ha. However, the most productive genotype, BEN 11-9 (V187) in group C2, had spikelet fertility by 90.4%, a mean tillering of 16, and a maturity cycle of 123 days (Figure 6).

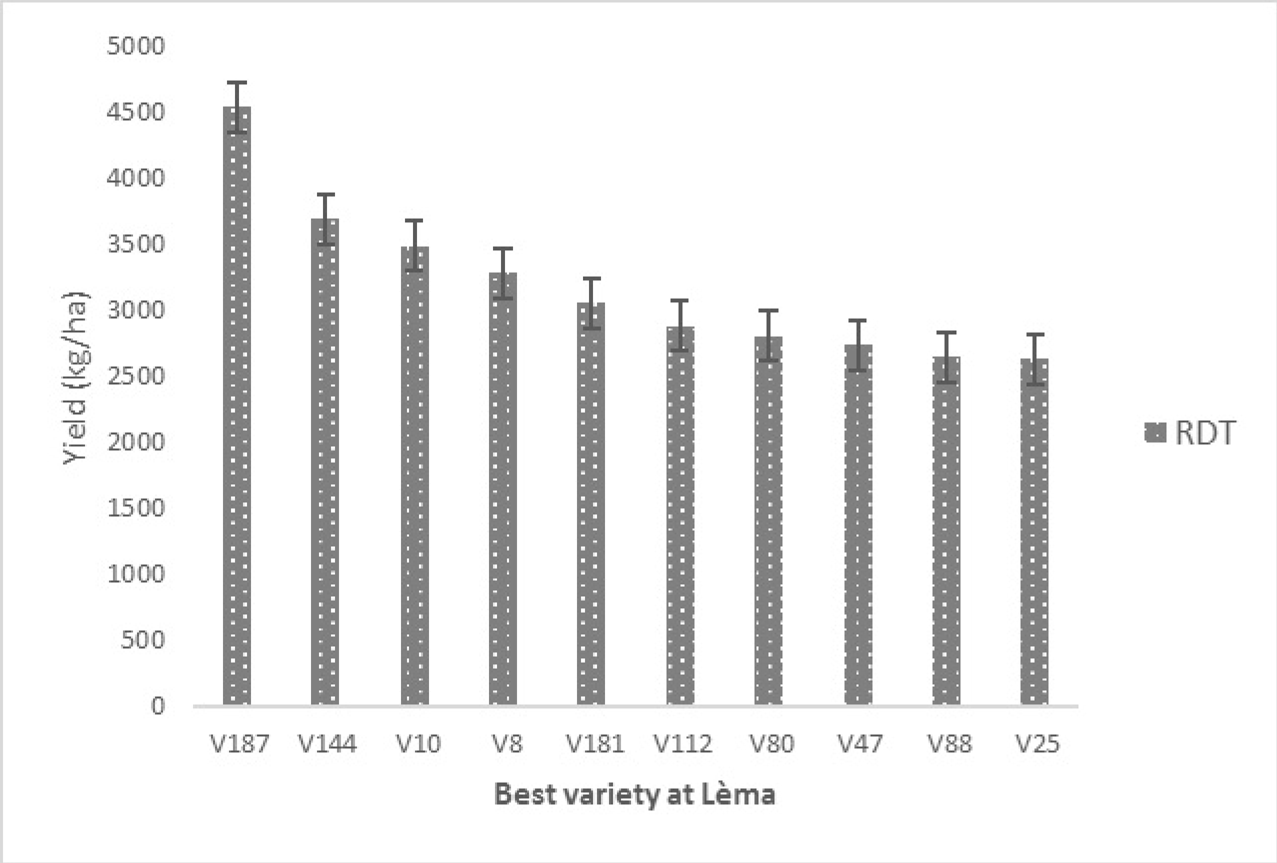

Figure 6: Grain yield of the 10 best genotypes in the lowland ecology.

Variability of qualitative characteristics of rice accessions assessed in lowland and shelf ecologies

The categorization of the accessions studied in the two ecologies for the variable "Flag Leaf Angle (FLA)" permits to subdivide them into four (04) groups. Thus, in the lowland ecology, 52% of these accessions had erected panicle leaves; 40%, presented intermediate panicular leaves; 6.9% had horizontal panicle leaves and 0.69% had to descend panicular leaves. In the upland ecology, respectively, 10.81% and 78.38% of the accessions had erect and intermediate panicle leaves, whereas 0.68% had descending leaves (Figure 7a).

The panicle exsertion (Exs) of accessions has shown great variability in lowland and upland ecologies. Thus, in the lowland ecology, panicle exsertion ranged from 0.69% to 58.62%, while in upland ecology, it ranged from 3.38% (partial panicle exsertion) to 42.57% (very good panicle exsertion) (Figure 7b).

For the shape of the plant (SP), 14.9% of accessions had an erect shape against 18.37% having an open shape in the lowland ecology, while in upland ecology a proportion of 16.22% of accessions had an erect shape versus 1.35% with a very open shape (Figure 7c).

Seedling vegetative vigor (Vg) scores ranged from 1 (extra-vigorous) to 7 (weak-vigorous) for all accessions in the lowland ecology where 52% of the genotypes were very vigorous with very fast growth whereas 0.68% had stunted growth. In upland ecology, however, 98% of accessions grew very fast while the remaining 2% showed rapid growth (Figure 7d).

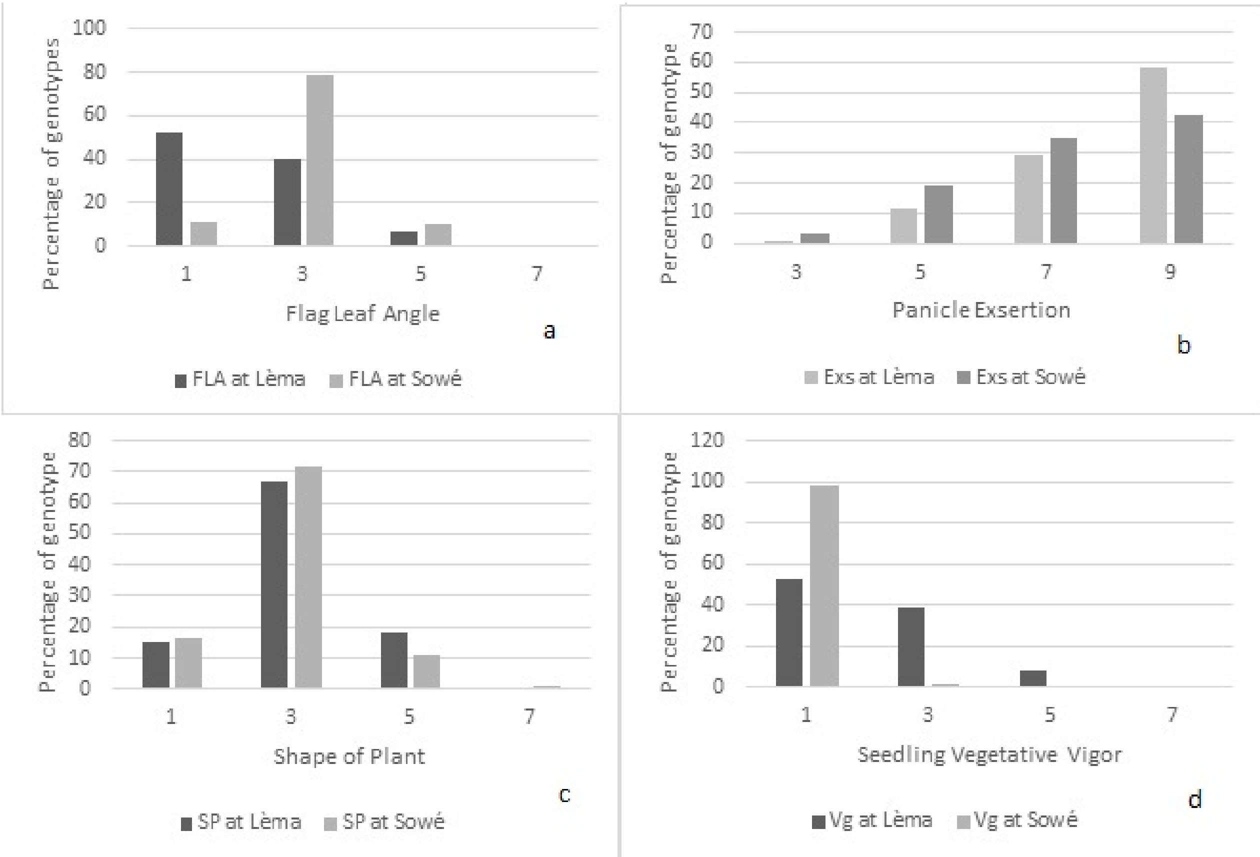

Figure 7: Characteristics of the qualitative parameters of the collection of rice cultivars of Benin; a: Flag Leaf Angle (FLA), b: Panicle exsertion (Exs), c: Shape of the plant (SP), d: Seedling Vegetative Vigor(Vg).

Comparison of agronomic performance of cultivars in lowland and upland ecologies

Table 3: Adjusted average of agronomic parameters evaluated on the collection of rice grown in both ecologies; ns : non significative ; * significative at p<0.05 ; ** highly significative at P<0.01 ; *** very highly significative at P<0.001; Tillering Ability (Ti); Semi-Heading Cycle (SHC); Maturity (Mat); Number of panicles per m² (Npan/ m²); Number of grain per panicle (NGP); 1000-grain weight (g) (GW); Spikelet Fertility (SpFert); Grain Yield (Yld) (kg/ha)

Source	Ti	SHC	Mat	Npan/m^2	NGP	GW	SpFert	Yld
Lowland ecology	17,90 ± 0,9	92,89 ± 0,4	113,51 ± 0,7	210,42 ± 8,3	107,76 ± 5,5	27,75 ± 0,5	82,84 ± 1,6	1664,85 ± 101,2
Upland ecology	18,26 ± 0,9	94,04 ± 0,4	112,83 ± 0,7	184,86 ± 8,0	174,63 ± 5,4	23,83 ± 0,5	71,19 ± 1,6	1085,73 ± 101,2
P- value								
Sites	0,8417 ns	0,1845 ns	0,6221 ns	0,1256 ns	<,0001***	0,0027**	0,0027**	0,0103*
Genotypes	0,0964 ns	<,0001***	<,0001***	0,0433*	0,0568 ns	0,0067**	0,0067**	0,0912 ns

The agronomic performance of the rice accessions evaluated in the two ecologies showed no significant difference ($p > 0.05$) with respect to the following parameters: plant tillering ability, physiological cycle times (Maturity and Semi Heading Cycle) and the number of panicles / m^2. On the other hand, a significant difference ($p < 0.05$) was observed in grain yield average in both ecologies. A highly significant difference ($p < 0.01$) was observed for the following parameters: spikelet fertility, the 1000-grain weight and a very highly significant difference ($p < 0.001$) for the parameter number of grains per panicle (Table 3).

About the variations within the genotypes, no significant difference ($p > 0.05$) was observed in tillering ability (Ti), a number of grains per panicle (NGP) and grain yield in paddy rice (Yld) for all evaluated accessions. However, a significant difference ($p<0,05$) between the number of panicles / m² (Npan / m^2) and highly significant difference ($p<0,01$) between variables such as spikelet fertility, 1000-grain weight and very highly significant difference ($p<0.001$) for the semi heading cycle (SHC) and the Maturity (Mat) were observed (Table 3).

Identification of the best genotypes common to both ecologies

The two potentially more productive and more adapted accessions to both ecologies are BEN 11-37-A (V108) and BEN 11-68-A (V156), with paddy rice yields of 2.20 and 2.50 t / ha, respectively in lowland ecology and 2.30 and 2.41 t / ha in upland ecology (Figure 8). The performances of these accessions were close to those of the NERICA 1 controls (adapted to rice growing) and ADNY11 and WITA 4 (adapted to lowland rice cultivation)

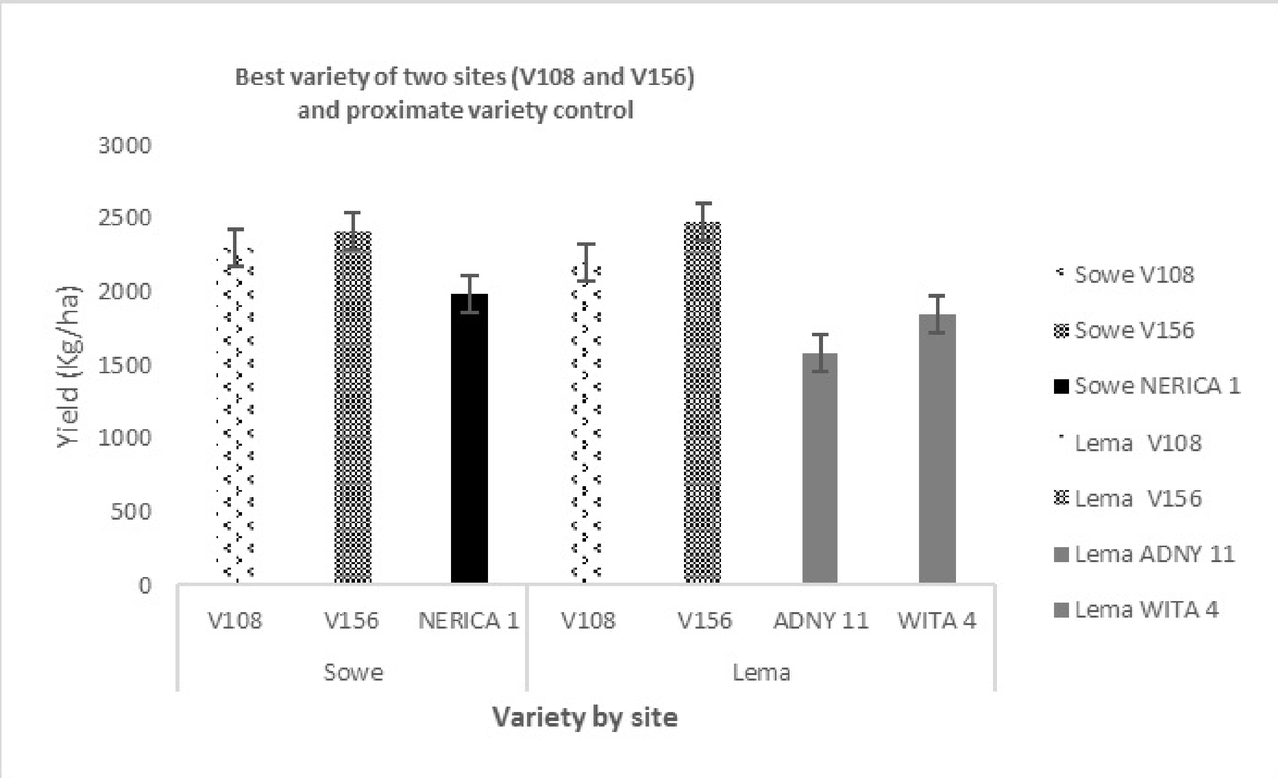

Figure 8: Performance of the two best accessions common to both ecologies with their proximate controls.

Interrelations between agromorphological traits

The correlation of Pearson revealed a strong correlation ($r = 0.909$) between the semi heading cycle (SHC) and the Maturity (Mat) on the one hand, and between grain yield (Yld) and spikelet fertility ($r = 0.6726$), on the other hand. A mean correlation was observed between the 1000-grain weight of (GW) and the spikelet fertility ($r = 0.4922$), on the one hand, and the paddy grain yield ($r = 0.453$), on the other hand. The correlation of Spearman showed a slight correlation between the seedling vegetative vigor of the plant (Vg) and the number of grains per panicle (NGP) ($r = -0.2979$), on the one hand, and the spikelet fertility ($r = 0.2581$), on the other hand. The same correlation was observed between flag leaf angle and paddy grain yield ($r = 0.225$). In addition, panicle exsertion is linked to several quantitative variables including the 1000-grains weight ($r = 0.2565$), the spikelet fertility ($r = 0.2065$) and the paddy rice yield ($r = 0.2209$). No significant correlation was observed for the shape of plant variable, except for the number of grains per plant (Table 4)

Table 4 : Correlation Matrix (Pearson between quantitative variables and Spearman between qualitative variables);Seedling Vegetative Vigor (Vg); Shape of Plant (SP); Panicle Exsertion (Exs); Flag Leaf Angle (FLA); Tillering Ability (Ti); Semi-Heading Cycle (SHC); Maturity (Mat); Number of panicles per m² (Npan/ m²); Number of grain per panicle (NGP); 1000-grain weight (g) (GW); Spikelet Fertility (SpFert); Grain Yield (Yld) (kg/ha)

Pearson Correlation									Spearman Correlation			
	Ti	SHC	Mat	Npan/m2	NGP	GW	SpFert	Yld	Vg	FLA	Exs	SP
Ti	1								-0,0854	0,0348	-0,198	0,0413
SHC	0,2028	1							0,158	-0,08	-0,178	-0,0123
Mat	0,1488	0,909	1						0,1021	-0,058	-0,191	-0,0191
Npan/m2	0,1375	-0,2625	-0,2664	1					0,0528	-0,0008	0,1098	0,0513
NGP	-0,0254	0,159	0,0951	-0,163	1				-0,2979	0,1525	-0,058	-0,1219
GW	-0,2957	-0,3408	-0,268	0,101	-0,1742	1			0,1249	-0,113	0,2565	-0,0159
SpFert	-0,2222	-0,3732	-0,341	0,178	-0,2547	0,4922	1		0,2581	-0,186	0,2065	-0,0021
Yld	-0,1664	-0,3255	-0,2907	0,299	-0,0292	0,453	0,6726	1	0,1689	-0,225	0,2209	-0,0445

DISCUSSION

Genetic diversity in breeding is very important. It is the key of crop improvement. More variability is observed in the basic population, more is the chance of improvement [21]. Phenotypic characterization of plants can provide useful information on the structure and the spatial distribution of the diversity [22]. The phenotypic variability of rice accessions in Benin was evaluated using qualitative and quantitative agro-morphological parameters. This characterization reveals the existence of a large variation within rice accessions according to quantitative variables. The demonstration of this genetic variability for certain morphological characters is the first essential step in the description of genetic resources [28]. This large variation reflects the existence of a diversity of genotypes of rice grown in the different rice production ecologies of Benin. Indeed, the phenotypic variability of rice genotypes is quite high in Benin. Odjo explain this rich diversity by the phenomena of seed exchange between farmers from one region to another and also the strong spread of rice farming systems in Benin [22]. Another possible explanation is the perfect cohabitation existing between the old varieties and the new ones in the same agrosystem.

This diversity has been structured into six groups of morphotype in both ecologies. In a similar study conducted in Madagascar, Radanielina [1] identified three major phenotypic groups organized into six subgroups following a hierarchical ascending classification based on the coordinates of 292 rice accessions. A recent study in Benin categorized a population of 136 rice varieties into three phenotypic groups [22]. This difference can be explained by the difference between the numbers of accessions studied.

The comparison of the agronomic performances of the accessions evaluated shows that the parameters such as tillering, number of grains per panicle do not show a significant difference ($p > 0.05$) between the different accessions. On the other hand, the other variables such as the physiological development cycle and the 1000-grain weight, present a significant difference between the different accessions. The range of variation of the maturity cycle is 55 days (80 to 135 days after sowing), illustrating the presence of early and late genotypes within the collection. These results are close to those obtained by Sarawgi also observed a maturity cycle varying between 86 and 184 days in a population of 782 rice accessions [17]. Similarly, Zafar observed for the same variable a variation of 86 to 100 days in a collection of 124 accessions of rice collection in Punjab, a region of Pakistan [29]. According to the experimental ecology, significant differences were observed in the parameters such as mean grain yield, spikelet fertility, the 1000-grains weight and the number of grains per panicle. Our results are consistent with those of Steel [30] who showed that morphological variations can be observed at the level of the same genotype due to changes in environmental conditions namely nature, soil fertility levels, water regime, light, and temperature. In addition, Morkinyo and Ajibade obtained similar results by using agro-morphological characters and repeating experiments in time and space [31]. Although Jacquot and Arnaud and Sié have demonstrated that panicle variables are not very variable, this study reveals a great variability with respect to panicle number per meter square[32-33] . These observed discrepancies are explained by the environment effect on the growth and development of plants.

The relative stability of the grain yield of paddy rice observed within the genotypes reflects a form of adaptation of these materials at the level of the different ecologies, in contrast with the physiological cycle parameter, which is a character under the strong genetic influence. The interest of these results is that they denote not only a rich phenotypic diversity (qualitative and quantitative) within the Benin rice accessions collection but also a hierarchical structuring of these materials according to their agronomic characteristics at the level of the upland and lowland ecologies. However, the composition of the different classes obtained varies from one ecology to another. According to Yan et al. [34], the change in genotype ranking from one environment to another is an indication of the presence of Genotype X Environment interactions. Moreover, the identification of the ten (10) best cultivars in each ecology, including two (02) identical cultivars (BEN 11-37-A) and (BEN 11-68-A) in both ecologies, demonstrated the adaptation of these cultivars to different ecologies. This stability of paddy grain yield is seen in terms of lowering of the variance in yields, which is a very important selection objective in hard environments [35]. Along the same lines, Ceccarelli and Piepho have indicated that yield stability is perceived by producers as a very useful socio-economic factor that aims to minimize crop losses, especially in tough environments [36,37] . This is contrary to a significant interaction that reflects the inconsistency of paddy rice yield from one ecosystem to another [38,39]. Nevertheless, Kolmodin noted that phenotypic variations of a genotype in different environments are considered as a normal response [40].

Qualitative characters are important for plant description and mainly influenced by the consumer's preference, socioeconomic model and natural selection [10]. Thus, the evaluation of the qualitative variables is important for a study of the agromorphological characterization. Spearman's correlation showed weak correlations between variables seedling vegetative vigor (Vg) and the number of seeds per panicle (NGP) ($r = -0.2979$) on the one hand and spikelet fertility ($r = 0.2581$) on the other hand. The same observation was made for the correlation between flag leaf angle and paddy grain yield ($r = 0.225$). The work being conducted in the lowland and upland ecologies; these results are consistent with those of Hammami stated that when genetic correlations are high and above 0.80, ecosystems are not very different [41]. The accessions studied were subdivided into four (04) groups in both ecologies for the variable “flag leaf angle”. In lowland ecology, 52% of these accessions had erect paniculate leaves, 40% had intermediate panicle leaves, 6.9% had horizontal panicle leaves, and 0.69% had presented descending panicular leaves. In the upland ecology, respectively, 10.81% and 78.38% of the cultivars had erect and intermediate panicle leaves, whereas 0.68% had descending leaves. The presence of panicular leaves at the level of the two ecologies indicates that the collection consists of ecotypes belonging to the Asian species *Oryza sativa* [42]. Thus, the scores of the seedling vegetative vigor varied from 1 (extra-vigorous plant) at 7 (weakly-vigorous plant) for all accessions in the lowland ecology where 52% of the genotypes were very vigorous against 98% of the accessions that showed a very fast growth in upland ecology. These results indicated that the accessions consist mainly of ecotypes belonging to the *Oryza glaberrima* species. Several previous studies have shown that the accessions of the species *O. glaberrima* are vigorous [43, 44] and this vegetative vigor allows them to withstand biotic constraints [45].

The level of correlation between phenotypic traits is important in plant breeding. It can be used as a tool during an indirect selection. The study of correlations assists breeders during selection and provides a better understanding of the different components of yield [21]. A positive correlation is established between the semi heading cycle (SHC) and the Maturity (Mat) on the one hand and between grain yield (Yld), spikelet fertility and the 1000-grains weight of on the other hand. These positive correlations, therefore, reflected a simultaneous evolution of these agromorphological parameters at the level of the evaluated genetic material. This means that a very productive variety (high grain yield) has a high fertility and a medium 1000-grains weight. Moreover, an increase in its semi heading cycle (SHC) systematically reflects an increase in its maturity cycle. A positive correlation was also observed between tillering ability and panicle number per m^2. Some authors have shown that there is a significant correlation between the 50% flowering day, the panicle number and leaf area [21,46,47]. Besides, the grain yield is negatively correlated with the number of tillers. These results are consistent with those of Sié [48] who state that the grain yield is positively correlated with the number of panicles / m^2 and negatively correlated with the number of tillers.

CONCLUSION

The present study has highlighted the existence of a rich phenotypic diversity between rice accessions in Benin. This genetic variability is structured in six (6) morphological groups both in lowland ecology and in the upland ecology. These groups are quite rich in accessions with particular and interesting traits. Especially, BEN 11-37-A (V108) and BEN 11-68-A (V156) accessions have performed fairly well in both ecologies. The knowledge of all these information and the conduct of screening tests against the biotic stress (diseases) of rice cultivation in Benin will make possible to define a better exploitation of the collection and appropriate guide for improvement programs at the national level. In addition, the establishment of a short and medium term conservation strategy for this biodiversity is also necessary. Consequently, the ex-situ conservation of this collection is a first strategy for the preservation of this collection for valorization purposes.

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