International Journal of Development and Sustainability
ISSN: 2186-8662 – www.isdsnet.com/ijds
Volume 6 Number 7 (2017): Pages 479-496
ISDS Article ID: IJDS17052901

Diversity assessment and geographical variability of rice landraces collected from Burkina Faso

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Abstract

The collection of landraces from farmers' fields has received significant attention as a strategy to conserve the genetic diversity of food security crops in farms, villages, or countries. In Burkina Faso, the two cultivated rice species, *O. glaberrima* and *O. sativa*, are grown in farmers' fields. To preserve this diversity, a broad collection of rice landraces was acquired in the four main rice growing regions of the country: Boucle du Mouhoun, Cascades, Hauts-Bassins and Sud-Ouest. Three hundred and thirty rice landraces were collected from farmers' stocks. The collection was evaluated in a field with 20 quantitative and 30 qualitative agro-morphological traits. Fourteen traits were found to distinguish the entire collection, which was dominated by *O. sativa* relative to *O. glaberrima* varieties. The diversity assessment revealed that *O. sativa* accounted for 86% of the collection and was split into four sub-groups. The application of the Shannon Weaver diversity index, to compare the diversity of the collection on a regional scale, showed that the collection from Boucle du Mouhoun Region was the most diversified (*H = 0.63*), although it accounted for only 15% of the overall collection. Attention should be paid to the collection of this region for *in situ* conservation in farmers' field.

Keywords: Collection; Diversity; Rice; Landraces; *O. Glaberrima*; *O. Sativa*

Cite this article as: Kam, H., Ndjiondjop, M.N., Sanou, J., Sow, M., Ouédraogo, I. and Laing, M. (2017), "Diversity assessment and geographical variability of rice landraces collected from Burkina Faso", *International Journal of Development and Sustainability*, Vol. 6 No. 7, pp. 479-496.

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1. Introduction

Two rice species are cultivated in the world. Asian rice, *Oryza sativa* L., is the most popular and widespread in the six continents, whereas the African rice, *O. glaberrima* Steud., is encountered in some West African rice fields (Nayar 2010; Sow et al. 2014). *O. sativa* was introduced in Africa in the 15th century, while *O. glaberrima* is endemic to West Africa. The primary centre of diversification of *O. glaberrima* is in the inner delta of the River Niger (Republic of Mali), with secondary centres of diversification in the Sene-Gambia regions (Portères 1950).

In Burkina Faso, rice landraces have been systematically collected four times. The first collection took place in 1967 and covered 23 villages in the Cascades Region (Sié et al. 1998). In 1976, the second collection was conducted by Second and Bozza from the "Office de la Recherche Scientifique et Technique d'Outre-Mer" (ORSTOM) and the "Institut de Recherches Agronomiques Tropicales" (IRAT), respectively, and lasted two weeks (Bezançon 1993). The third collection, led by the International Institute of Tropical Agriculture (IITA), was carried out in 1978 (Sié 1991). From November 1983 to February 1984, an extensive collection of rice samples across all the regions of the country was undertaken by the International Board of Plant Genetic Resource (IBPGR). During that time, 527 rice samples were collected, including 475 *O. sativa* and 52 *O. glaberrima* (Sié 1984). The collections were undertaken to prevent the disappearance of the African rice *O. glaberrima* and to gather rice genetic material for breeding purposes. However, this collection was not properly conserved in the Burkina Faso National Agricultural Research System (INERA) due to a lack of proper seed stores. The components of this collection may still be conserved casually in farmer's fields. Indeed, most farmers in developing countries such as Burkina Faso still breed and conserve crop diversity at the field and village level (Barry et al. 2007a). Crucially, rice diversity at farmer level, if not formally managed by attentive curators, could be lost owing to farmers' decisions, which are primarily driven by private benefits (Jackson et al. 2010).

A quarter of a century after the first extensive collection, there is interest again to collect local rice and reassess the extent of its diversity in order to develop strategies for *in situ* conservation. Farmers and breeders rely on phenotypical features to characterize and distinguish the varieties they hold. Moreover, the naming of rice varieties by farmers is influenced by the characteristics of the plant (Nuijten and Almekinders 2008). Furthermore, in breeding programmes, characterization of varieties, based on multiple phenotypic traits, can be used as a management tool to validate the identity of an accession (Aghaee et al. 2010). Studies on the variations present in rice germplasm collections have been carried out frequently using characterization of plant morphological attributes (Sié et al. 1998; Bisne and Sarawgi 2008; Sanni et al. 2008). The main objectives of this investigation were to evaluate agro-morphological diversity of collected rice accessions and study their regional pattern.

2. Material and methods

2.1. The collection procedure for the rice samples

Rice collection was conducted in 59 villages of the four main rice cropping regions (Boucle du Mouhoun, Cascades, Hauts-Bassins and Sud-Ouest) of Burkina Faso. The methodology behind the choice of the village was as follows:

i. All villages visited during the IBPGR collection (Sié 1984) were listed;
ii. Villages where more than five varieties were collected during the IBPGR collection were chosen, assuming that they maintained a high level of diversity of rice landraces;
iii. Villages that were not visited during IBPGR collection, but listed by regional agricultural officers as having local rice cropping habits, were also added.

In collaboration with the agricultural extension of each region, agricultural agents of each department of the target villages were contacted. The collection team of each region was composed of INERA technicians and researchers, agricultural agents at the departmental level. The process typically kicked off with the agricultural agent of the target village informing farmers and summoning a meeting. In each village, an inventory of rice landraces was drawn in the presence of a group of farmers. Farmers were asked to list the rice varieties they had cropped for several years, including those that their ancestors had cultivated that the present generation is continuing to grow. Farmers who owned these antecedent varieties were identified and the collection team went and collected the varieties in their stocks. Together, farmers identified the chosen varieties through consensus and information related to each variety. The name, the duration, and the cropping system (upland, lowland, deep water) were noted. Then, a seed sample of each variety was collected in a plastic bag. Modern varieties released through the agricultural and research network channels were not collected. Two rice samples were collected in the market place at Douna, a village in the Cascades Region. Data on longitude, latitude and altitude of each village were also collected with a Global Positioning System (GPS).

For purposes of easy identification, the samples collected in Boucle du Mouhoun, Cascades, Hauts-Bassins, and Sud-Ouest regions were assigned the prefix BM, CC, HB, and SO, respectively.

2.2. Agro-morphological characterization

Agro-morphological characterization was implemented to distinguish between *O. sativa* and *O. glaberrima* samples, and to record vegetative data to facilitate comparison between accessions. Subsequently all of the 330 accessions were sown in an experimental field of the AfricaRice at the Benin station (21 m above sea level) using an Augmented Experimental Design (AED) (Federer 1956). The trial was conducted in upland condition during the rainy season. The plants were watered on rainless days. Seven checks (CG14, Moroberekan, ITA212, B6144, RAM55, Nerica4, and Nerica14) were used to estimate the field's heterogeneity, and were also used as "references" for the grouping. They were repeated in seven blocks.

Plot size for each accession was 4 m x 1 m with three rows of 16 plants each. Each row was spaced by 0.25 m with a border of 0.50 m between plots. After direct sowing, thinning to one plant occurred at 20 Days After Sowing (DAS). Basal application of NPK fertiliser (15-15-15) of 200 kg ha^{-1} was applied during land preparation. At 21 and 42 DAS 30 kg ha^{-1} of urea was applied. Regular weeding was performed as needed.

Agro-morphological evaluation was monitored in the field and in the laboratory, using 20 quantitative and 30 qualitative rice descriptors (Appendices A), in accordance with the method described by Bioversity International et al. (2007). The measurement of the parameters was monitored on five plants of the inner row of the plot.

2.3. Data analysis

The values of the augmented design were adjusted in GenStat 11 using an incomplete design model based on the repeated values of the checks in each block. The 50 traits were analysed using Factorial Analysis (FA). Agglomerative Hierarchical Clustering (AHC) (Ward 1963) was used to construct a dendrogram based on the first four factor scores obtained in FA. Discriminant Analysis (DA) (Jobson 1992; Huberty 1994) was performed on the 20 quantitative and 30 qualitative data to obtain the maximum proportion of samples well classed in each group, identified via the AHC analysis. Furthermore, DA analysis was applied on a regional basis to the 20 quantitative and 30 qualitative variables to ascertain the differences between the morphological variations of the accessions. The multivariate analyses (FA, AHC, and DA) were performed in XLSTAT 2010 (www.xlsat.com). An ANOVA was conducted on the 20 quantitative and 30 qualitative variables to highlight the traits differentiating the samples on the regional scale. The phenotypic frequencies of the 14 significant quantitative and qualitative parameters were analysed by the Shannon-Weaver diversity index (H') (Shannon 1948). Jain et al. (1975) and Sanni et al. (2008) gave *H'* as:

$$H' = -\sum_{i=1}^{k} P_i \log_2 P_i$$

where k is the number of phenotypic classes for a character, and Pi is the proportion of the total number of entries in the ith class.

3. Results

3.1. Sample collection

The rice collection according to regions was as follow: 48 samples were collected in the Boucle du Mouhoun (BM) Region, 83 in Hauts Bassins (HB) Region, 33 in Sud - Ouest (SO) Region, and 166 in the Cascades (CC) Region. In total 330 samples were collected. Half of the rice samples collected was from the Cascades Region. Amongst the 330 samples collected, 46 were in the form of panicles and the rest were bulk grains.

Amongst the 330 samples collected, 229 distinct names of rice varieties were identified. Some names characterized the duration (early or late maturing). For instance, Maloba referred to long cycle rice and Wêrê-wêrê referred to early maturing rice. Names can often describe the grain shape (Missinni for long grain) and the grain or paddy colour (Malowilé refers to red rice). The term "red rice" can be confusing because it may refer to either grain colour or husk colour. Rice can also bear a name which highlights its particular notable trait such as a high tiller number (Djoutchèmin or Troutchèmin means 100 tillers). Some

rice varieties were named after the persons who introduced them in the village, for instance, Mariam, Djénéba, Adama-Sali, Dembélé, etc.

3.2. Agro-morphological diversity

The descriptive statistics on agro-morphological variables highlighted the diversity of the accessions in the collection.

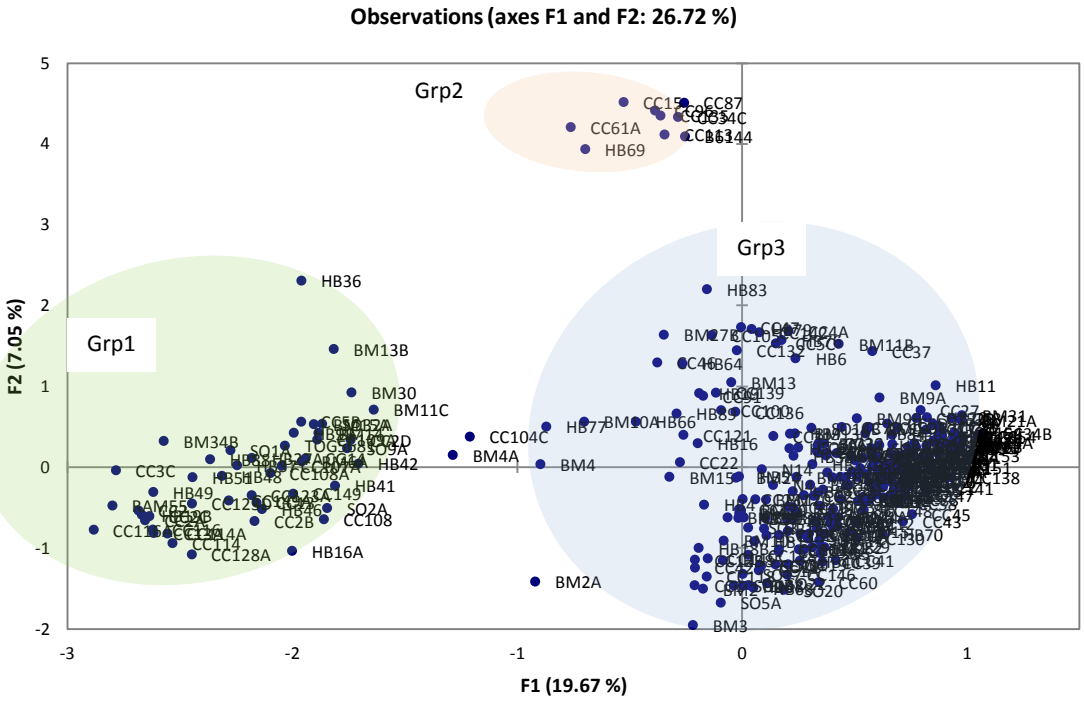

Figure 1. Plan of the two first axes of the factorial analysis on 50 agro-morphological traits applied to 330 rice accessions collected in Burkina Faso in 2008

Grp1, Grp2 and Grp3 refers to the three groups 1, 2 and 3, respectively identified by the factorial analysis

The plan of the two first axes of the factorial analysis highlighted three main groups (Figure 1). Group 1 (Grp1) comprised of the *O. glaberrima* check varieties Tog5681, CG14, and RAM55. The samples of this group were believed to be composed of *O. glaberrima* accessions. Group 2 (Grp2) included the check variety B6144. As with B6144, the samples in Grp2 had anthocyanin in their leaves and culm. The *O. sativa* checks Moroberekan and ITA212, and the inter-specific checks Nerica4 and Nerica14 were located in Group 3 (Grp3). In order to obtain homogeneous classes, the coordinates of the accessions on the four first axes of FA were used with the help of an Agglomerative Hierarchical Clustering (AHC) to build a dendrogram. Five clusters were identified in the dendrogram (Figure 2). Grp3 was split into three clusters (C3, C4, and C5), while Grp1 and Grp2 generated a C1 and C2 cluster, respectively (Figure 2). The *O. glaberrima* checks CG14,

RAM55, and Tog56581 belonged to C1 with 48 other accessions. B6144 was included in C2 with nine other accessions. ITA212 and Moroberekan constituted C3 with 158 accessions. C4 included 51 accessions, while C5 was composed of 64 accessions and the two inter-specific checks Nerica4 and Nerica14.

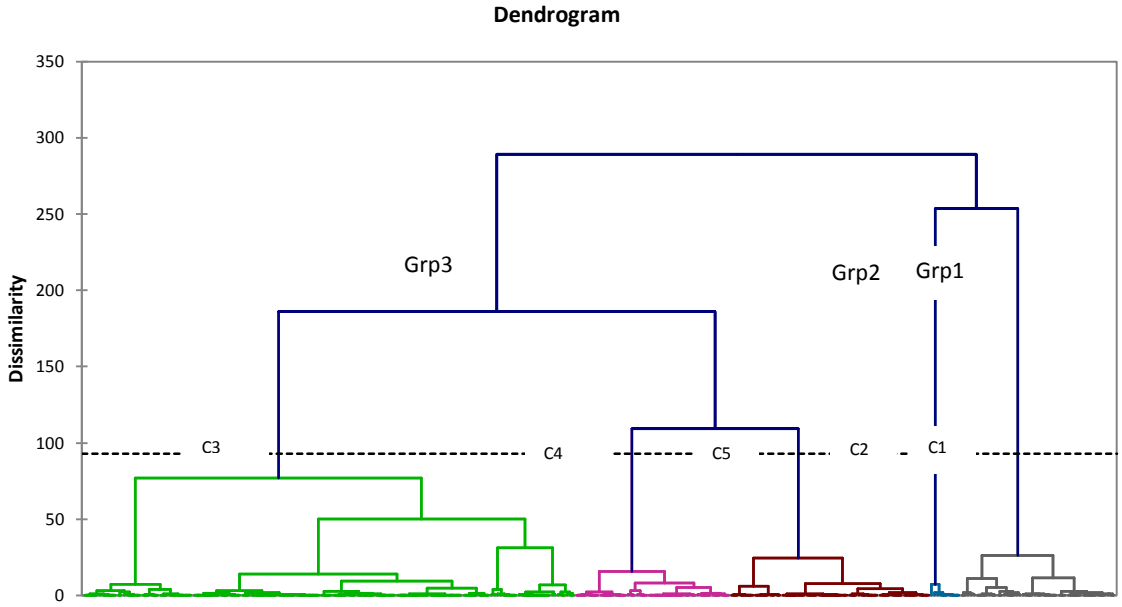

Figure 2. Dendrogram of the 330 accessions from Burkina Faso collected in 2008 and seven checks based on factorial analysis of 50 variables

Grp1, Grp2 and Grp3 are the three groups identified by Factorial Analysis. C1, C2, C3, C4 and C5 refer to Cluster 1, Cluster 2, Cluster 3, Cluster 4, and Cluster 5 identified by the automatic truncation

A scatter diagram obtained through discriminant analysis portraying the five groups highlighted the significant difference between C1 and the four other classes. Axis 2 separated C1 from C2, C3, C4, and C5, while axis 1 separated C2, C3, C4, and C5 (Figure 3).

By avoiding repeats of highly positively correlated variables (Appendices B), the quantitative traits distinguishing the five classes were established and they are: culm length, panicle length, leaf blade length, flag leaf width, ligule length, culm number, number of days to maturity, number of panicle primary branches, grain length and grain width (Table 1).

The accessions in the C1 cluster (48 accessions) were characterized by long panicle length (30 cm), large flag leaf (19 mm), short ligule (4.4 mm), relatively high number of culms (19), relatively high number of panicle primary branches (14), short grains (8.3 mm), breadth of grain (3.0 mm), and early maturing plants (108 days). Furthermore, 90% displayed anthocyanin in their basal leaf sheath, 96% depicted a horizontal to descending flag leaf at maturity, 88% portrayed upright to semi upright panicles, a maximum of one panicle

secondary branch was found in 65% of C1 samples, 96% developed coloured pericarp, and 87% showed low lodging resistance. These are the characteristics of *O. glaberrima* species. The accessions of C1 were grown in lowland and deep water cropping systems. In the C1 cluster, the presence of the *O. glaberrima* checks CG14, RAM55 and Tog5681 confirmed that this was a grouping of *O. glaberrima* accessions.

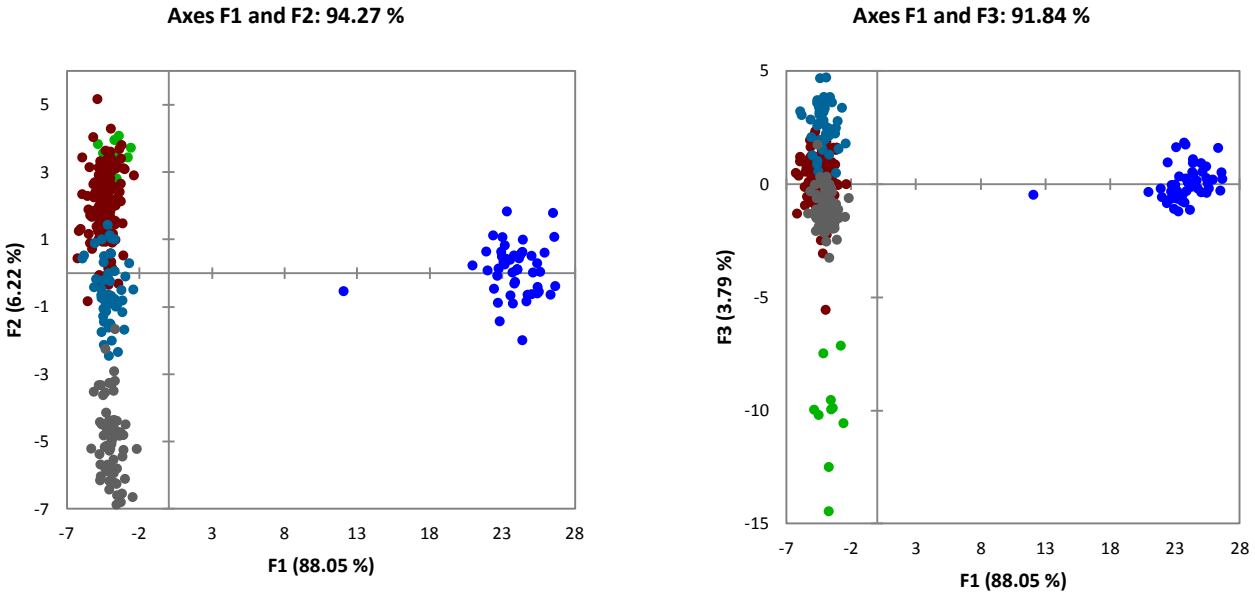

Figure 3. Discriminant analysis performed on axes F1/F2 and F1/F3 on the 5 classes obtained through hierarchical clustering analysis

The Group C1 is set apart from the other four clusters. Blue, green, brown, light blue and grey dots refer to clusters C1, C2, C3, C4, and C5, respectively. C1 is very different from the four other clusters (pv <0.001).

The Cluster C2 (nine accessions) showed strong anthocyanin presence in their basal leaves, their leaves, and their culm in 100% of the samples, 78% grew with erect to semi-erect flag leaf attitude at maturity, 89% depicted a drooping panicle, 99% of the samples developed two to four panicle secondary branches, 78% had a white pericarp and 89% showed a strong resistance to lodging. They were short plants (90 cm) with a medium crop cycle (115 days). The *O. s. indica* variety, B6144, shared these characteristics with the other samples in C2. The accessions of C2 were grown in lowland cropping system.

The Cluster C3 (158 accessions) grew narrow leaves (13 mm), short length of leaves (43 cm), short culm length (93 cm) , longer crop cycle (135 days), and relatively few panicle primary branches (12). In C3, 83% of the samples were without anthocyanin in their basal leaf sheath, 97% showed drooping panicles, while 100% had two to four panicle secondary branches and 88% had a white pericarp. The checks varieties ITA212 and Moroberekan were included in this cluster. The accessions of C3 like those of C2 were grown in lowland cropping systems.

Table 1. Major distinguishing quantitative parameters between the five classes

Traits	C1 ± Sd	C2 ± Sd	C3 ± Sd	C4 ± Sd	C5 ± Sd
Culm length (cm)	95.0 ± 17.2	90.0 ± 12.5	93.0 ± 15.6	**119 ± 13.7**	**89.0 ± 10.3**
Panicle length (cm)	**29.7 ± 2.7**	**23.8 ± 2.9**	25.3 ± 2.0	27.0 ± 2.2	25.5 ± 1.9
Leaf blade length (cm)	48.5 ± 7.1	**41.6 ± 0.7**	43.8 ± 7.2	**55.7 ± 8.2**	46.6 ± 8.2
Flag leaf width (mm)	**19 ± 2**	18 ± 3	**13 ± 2**	16 ± 3	14 ± 2
Ligule length (mm)	**4.4 ± 2.0**	13.6 ± 3.1	17.3 ± 4.9	**19.8 ± 7.3**	15.4 ± 5.0
Culm number	**18.7 ± 5.6**	17.0 ± 4.8	**15.0 ± 3.9**	16.6 ± 5.7	17.6 ± 4.5
Number of days to maturity	**108 ± 12.8**	115 ± 9.4	135 ± 16.3	**138 ± 17.4**	**108 ± 7.9**
Number of panicle primary branches	**13.5 ± 1.9**	**13.5 ± 1.4**	**12.0 ± 1.7**	12.9 ± 1.6	12.3 ± 1.7
Grain length (mm)	**8.3 ± 0.3**	8.3 ± 0.4	8.9 ± 0.8	8.9 ± 0.8	**9.5 ± 1.1**
Grain width (mm)	**3.0 ± 0.1**	2.9 ± 0.2	2.7 ± 0.2	2.7 ± 0.2	**2.5 ± 0.2**

C1, C2, C3, C4 and C5 refer to clusters 1, 2, 3, 4 and 5, respectively, and Sd refers to standard deviation

The Cluster C4 (51 accessions) developed longer culm length (119 cm), longer leaf blades (56 cm), longer ligules (20 mm), and a longer crop cycle (138 days). Anthocyanin was not observed in any of the plants, 96% had a horizontal to descending flag leaf at maturity, and 90% grew drooping panicles. All the accessions developed at least two panicle secondary branches and 96% had a white pericarp. Contrary to C2 and C3, the accessions of C4 were grown in deep water cropping systems.

The Cluster C5 (64 accessions) was characterized by a short culm length (89 cm), early maturing plants (108 days), long grains (9.5 mm), and narrow grain width (2.5 mm). Anthocyanin was not observed on the basal leaf of 95% of the samples, and 80% had a horizontal to descending flag leaf at maturity. Each plant of the group developed at least two panicle secondary branches and 100% had white pericarps. The inter-specific checks Nerica4 and Nerica14 were included in this cluster. Like C2 and C3, the accessions of C5 were grown in lowland cropping systems.

Calculation of the Fisher Distance confirmed the significant differences between each class (p-value < 0.0001). The huge difference between C1 and the other clusters was highlighted. Clusters C3, C4, and C5 were closer in distance compared to C1 and C2. Furthermore, a discriminant analysis performed using both quantitative and qualitative variables confirmed that 99% of the samples were well-classified. Accessions in

clusters C1 and C2 were 100% accurately allotted, while 99%, 96% and 98% of the accessions in clusters C3, C4 and C5, respectively, were accurately allotted.

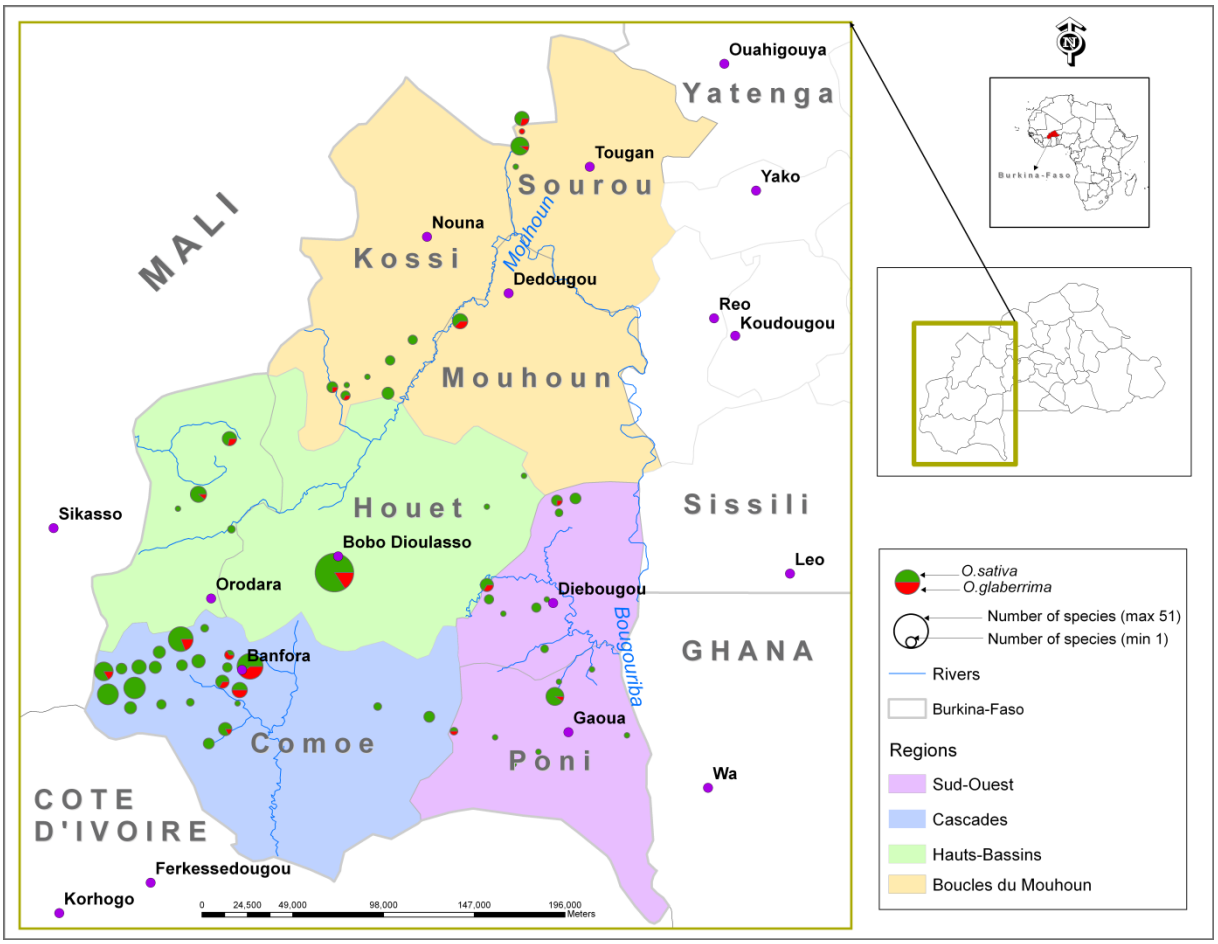

Figure 4. Map of collecting zones showing the different provinces visited where *O. glaberrima* and *O. sativa* were collected in Burkina Faso

Green and red colours in a circle represent the proportion of O. sativa and O. glaberrima, respectively in the place of collection

The agro-morphological characterization helped to distinguish *O. sativa* and *O. glaberrima*. Figure 4 portrays the collection area and the dominance of *O. sativa* over *O. glaberrima* in the collected samples.

3.3. Geographical pattern of phenotypic diversity

Accessions of CC and SO had long culms and CC samples were late maturing. The samples from BM had shorter leaf blade length. Rice plants from SO had longer flag leaves. The samples from CC and HB had more panicles compared to those from BM and SO. SO samples produced more panicle primary branches, which is

an important yield parameter. The grains from CC weighted less compared to those of BM. Samples from BM showed differences in culm habit. Samples from BM also had more anthocyanin in their nodes than CC and SO, while SO samples displayed low anthocyanin in their nodes. CC samples shattered less as compared to those of BM and HB.

The estimate of the Shannon-Weaver Diversity Index (H') of the 14 variables distinguishing the collection (Appendices C) varied from 0.10 to 0.99 according to the region (Table 2). H' is the Shannon-Weaver Index and SE refers to standard error of the mean, and BM, CC, HB and SO refers to Region of Boucle du Mouhoun, Region of Cascades, Region of Hauts Bassins and Region of Sud Ouest, respectively.

The average phenotypic diversity of the collection was 0.6. BM portrayed the highest index of diversity (0.63), while SO showed a low diversity index (0.50). Therefore, the BM Region is the most diversified region, although it accounted for only 15% of the collection. Conversely, the SO Region was the least diversified. Both the CC and HB regions had the same H' (0.59) and occupied the second place of diversification, although 50% and 25% of the collection were collected in those two regions, respectively. The panicle length was the least diversified trait, whereas culm lodging resistance was the most diversified trait across the regions. The discriminant analysis performed on the 50 variables based on the regional scale exhibited the particularity of BM samples (Figure 5).

The Fisher's Distance test did not find any significant difference between CC and SO samples, while BM was strongly differentiated from CC, HB and SO ($p < 0.0001$).

4. Discussion

4.1. Diversity of the collection

The analysis of the diversity of Burkina Faso rice landraces highlighted the dominance of *O. sativa* over *O. glaberrima* accessions (Figure 4). *O. sativa* accounted for 86% of the accessions collected, while *O. glaberrima* represented only 14%. The dominance of *O. sativa* was noted in the previous collection, where 475 of 527 rice samples collected were *O. sativa* landraces (Sié 1991). Analysis of agro-morphological variables demonstrated important differences between the two species. Almost all *O. glaberrima* accessions belonged to Cluster C1, characterized by short ligules and erect to semi-erect panicles (Bezançon 1993; Nuijten et al. 2009; Sow et al. 2014). In the characterization process, some of the *O. glaberrima* accessions developed secondary panicle branches. However, they remained with erect or semi-erect panicles as with all of the *O. glaberrima* accessions. Such *O. glaberrima* cultivars were not identified in rice collection from Guinea (Barry et al. 2007b). Therefore, the *O. glaberrima* cultivars from Burkina Faso developed certain traits found nowhere else, underlining the richness of this collection.

One of the four clusters identified within the *O. sativa* accessions (C2) develops a strong coloration from anthocyanin on their basal leaf sheaths and leaves. In reality, this group appears to be similar to *O. glaberrima* but given the absence of short ligules and drooping panicles, they cannot be considered as *O. glaberrima* plants. C2 included *O. s. indica* accessions and showed strong presence of anthocyanin, and are grown in lowland cropping systems.

Table 2. Estimates of Shannon-Weaver Diversity Index of the 14 most distinguishing characteristics of the rice collection by regional scale

Variable	H' BM	H' CC	H' HB	H' SO	Mean
Culm length	**0.71**	0.65	0.62	0.60	0.68
Panicle length	**0.23**	0.12	0.10	0.14	0.14
Leaf blade length	**0.59**	0.41	0.43	0.53	0.47
Flag leaf width	0.30	**0.38**	0.31	0.21	0.34
Ligule length	**0.57**	0.37	0.55	0.27	0.46
Number of days to maturity	**0.92**	**0.92**	**0.92**	0.74	0.97
Grain length	0.59	**0.72**	**0.72**	0.65	0.71
Basal leaf sheath colour	**0.64**	0.55	0.57	0.26	0.56
Culm lodging resistance	**0.99**	0.96	0.98	0.90	0.99
Flag leaf attitude	**0.95**	0.93	0.88	0.79	0.93
Stigma colour	0.34	**0.36**	**0.36**	0.23	0.35
Panicle attitude of main axis	**0.90**	0.79	0.78	0.77	0.81
Panicle secondary branching	0.61	**0.70**	0.65	0.57	0.68
Pericarp colour of the caryopsis	**0.44**	0.35	0.31	0.30	0.37
Mean ± SE	**0.63 ± 0.07**	**0.59 ± 0.07**	**0.59 ± 0.07**	**0.50 ± 0.07**	**0.60 ± 0.07**

The accessions of clusters C3 and C4 portrayed characteristics of traditional *O. s. indica*, with long cropping cycles. The accessions of C3 with a short culm are all lowland accessions, whereas the accessions of C4 with a long culm are deep water accessions. The accessions of C5 had a short height and were early maturing. They must be improved *O. sativa* cultivars introduced decades ago by NGO and government. Early maturing rice cultivars have been introduced into Burkina Faso since 1959 (Dumont 1966).

4.2. Regional diversity study

The overall diversity of the collection depicted by the Shannon-Weaver Index (0.6) highlighted the diversity of this Burkina Faso rice collection. This index is higher compared to the ones obtained by Nuijten and Treuren (2007) and Sanni et al. (2008), who studied the genetic diversity of upland rice in Gambia (0.31) and the agro-morphological diversity of the *O. sativa* rice landraces of Côte d'Ivoire (0.47), respectively. More than 50% of the accessions were collected in the CC Region. Rice cultivation abounds in this region due to favourable rainfall and the presence of lowland areas. However, the diversity is less than that of the BM Region. This is understandable because 50% of the rice landraces were collected in a small area (18,406 km^2) in the CC Region, whereas 15% were collected over an extensive area (34,333 km^2) of the BM Region. The movement of varieties is facilitated by short distances between villages. Moreover, as in Gambia (Nuijten and Treuren 2007), agriculture is gendered in the CC Region, where women are involved in rice cultivation, transformation and commercialization. Through marriage, women bring their favourite varieties of their mother to the village of their husband or share a valuable variety of their mother-in-law with their sisters. Likewise, in Gambia, when women visit relatives, they often bring new rice varieties back to their village (Nuijten and Treuren 2007). This is supported by the fact that women's names are often assigned to traditional varieties in the CC Region. Consequently, women are more active agents in rice movement than men in CC Region.

Varieties tend to have different names across villages (Nuijten and Treuren 2007). This practice increases rice diversity at village level, but the diversity at the regional level will not change if the varieties come from within the region. The Baguera and Kangoura villages, where the highest number of varieties (19 varieties each) was found, are located in the Cascades Region. However, overlapping of varieties does not contribute to increasing diversification. Hence, this could provide an explanation for the fact that, although half of the collection came from the CC Region, the samples of this region were found to be less diversified than those of the BM Region. The BM Region hosts a large share of the total phenotypic diversity and should be considered to be providing informal in *in situ* conservation. As the NARS of Burkina Faso lack proper infrastructure for long term storage, the identification of a region or an area harbouring the rice diversity of the country would be of great value. The diversity could be conserved in dynamic form in a field and constitute a gene-pool for national and international rice breeders. This requires an active support for the ongoing production of landraces.

There were relatively few landraces and a low diversity in the SO Region. Low diversity in the SO Region could be due to farmers cultivating similar varieties. However, significant differences were not found between landraces from SO and CC. The two regions share the same climatic conditions and are the wettest

parts of the country, with rainfall exceeding 1,000 mm per annum. A variety from CC could be easily introduced to SO and vice versa. Consequently, it is not surprising if there is little difference between the landraces of the two zones. In addition, rice landraces are declining in the SO Region due to the wide-spread adoption of modern varieties. The reports of Projet Riz Pluvial (PRP 2007) and Projet d'Appui à la filière Riz (PAFR 2004) documented that in total 7,531.52 ha; 2,674.40 ha; 1,209.74 ha and 566.88 ha of rice areas have been developed in SO, HB, BM, and CC regions, respectively. These projects introduced modern varieties and encouraged farmers to cultivate them, which contributed to the decrease of the traditional varieties. According to Sié (1984), SO Region was ranked second in terms of the number of rice samples collected (after the CC Region) in 1984. In a quarter of century, the number of rice landraces has decreased drastically. Local rice is endangered in this region. Hence, specific samples collected in this region must be conserved carefully to avoid the loss of landraces coming from this region.

Acknowledgement

The authors thank the USAID for funding the collecting mission. They also thank Nourollah Ahmadi for technical review of the manuscript and AfricaRice Genetic Resources Unit for their support and advice during the planning of the collection.

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Appendices

Appendices A. The 20 quantitative and 30 qualitative traits used to evaluate the rice collection in the field

Code	Quantitative trait measured
7.2.2.1	Number of days from seedling to first heading
7.2.3.1	Number of days from seedling to main heading
7.2.4.1	Number of days from seedling to maturity
7.3.13	Ligule length (mm)
7.3.18	Leaf blade length (mm)
7.3.19	Leaf blade width (mm)
7.3.20	Flag leaf length (mm)
7.3.21	Flag leaf width (mm)
7.3.25	Culm length (mm)
7.3.26	Culm number
7.3.27	Culm diameter (mm)
7.4.14	Number of basal primary branches on panicle
7.4.17	Number of panicles per plant
7.5.1	Panicle length (mm)
7.5.15	Grain length (mm)
7.5.16	Grain width (mm)
7.5.17	Grain thickness (mm)
7.5.18	100-grain weight (g)
7.5.20	Caryopsis length (mm)
7.5.21	Caryopsis width (mm)
Code	Qualitative trait measured
7.3.3	Colour of basal leaf sheath
7.3.8	Leaf blade attitude
7.3.9	Leaf blade pubescence
7.3.9.1	Leaf blade pubescence on blade surface
7.3.10	Leaf margin pubescence

Code	Qualitative trait measured (cntd)
7.3.11	Auricle colour
7.3.12	Collar colour
7.3.14.2	Ligule shape
7.3.22	Flag leaf attitude early after anthesis
7.3.23	Culm habit
7.3.32	Lodging resistance
7.3.33	Culm strength
7.3.34	Flag leaf attitude late at maturity
7.3.35	Leaf senescence
7.4.2	Stigma colour
7.4.5	Lemma and palea colour after anthesis
7.4.6	Colour of apiculus
7.4.8	Awn presence
7.4.9	Awn distribution
7.4.10	Awn colour at anthesis
7.4.19	Panicle attitude of main axis
7.4.20	Panicle attitude of branches
7.4.21	Panicle secondary branches
7.4.22	Panicle exertion
7.4.23	Panicle shattering
7.5.3	Awn colour at maturity
7.5.5	Lemma and palea colour at maturity
7.5.8	Colour of apiculus
7.5.10	Sterile lemma length
7.5.23	Pericarp colour of caryopsis

Appendices B. Correlation matrices of the 20 quantitative variables

	CL	PL	LBL	LBW	FLL	FLW	LL	NPP	FH	MH	cycle	PB	CN	CD	GL	GW	GT	CaL	CaW
CL	1.000																		
PL	0.349	1.000																	
LBL	**0.649**	0.403	1.000																
LBW	0.296	0.424	0.437	1.000															
FLL	**0.508**	0.358	**0.760**	0.330	1.000														
FLW	0.189	0.466	0.413	**0.891**	0.337	1.000													
LL	0.337	-0.207	0.220	-0.355	0.190	-0.456	1.000												
NPP	0.075	0.104	0.057	-0.029	0.067	0.003	-0.053	1.000											
FH	0.438	-0.093	0.172	-0.271	0.050	-0.382	**0.542**	0.059	1.000										
MH	0.434	-0.047	0.178	-0.273	0.067	-0.373	**0.519**	0.052	**0.886**	1.000									
cycle	0.470	-0.007	0.183	-0.245	0.083	-0.357	**0.516**	0.054	**0.858**	**0.934**	1.000								
PB	0.150	0.265	0.282	**0.503**	0.221	0.470	-0.127	-0.107	-0.234	-0.226	-0.203	1.000							
CN	0.071	0.149	0.146	0.188	0.168	0.233	-0.171	**0.570**	-0.120	-0.161	-0.140	0.002	1.000						
CD	0.250	0.112	0.291	0.315	0.225	0.237	0.094	-0.081	0.062	0.069	0.068	0.262	0.016	1.000					
GL	-0.173	-0.226	-0.111	-0.283	0.067	-0.274	0.197	-0.094	-0.104	-0.170	-0.171	-0.143	-0.070	-0.026	1.000				
GW	0.200	0.314	0.165	0.415	0.054	0.453	-0.237	-0.031	-0.096	-0.019	-0.006	0.270	0.071	0.184	-0.481	1.000			
GT	0.234	-0.132	0.067	-0.005	0.003	-0.048	0.247	-0.116	0.179	0.221	0.252	0.043	-0.116	0.272	0.045	0.376	1.000		
CaL	-0.160	-0.195	-0.102	-0.278	0.055	-0.269	0.191	-0.075	-0.094	-0.160	-0.160	-0.144	-0.072	-0.025	**0.977**	-0.487	0.049	1.000	
CaW	0.186	0.321	0.131	0.413	0.026	0.466	-0.286	-0.025	-0.130	-0.071	-0.051	0.263	0.083	0.183	-0.457	**0.962**	0.436	-0.450	1.000
HGW	0.061	-0.088	-0.028	-0.096	0.000	-0.069	0.191	-0.049	0.023	0.010	0.027	-0.009	-0.069	0.157	0.440	0.187	**0.551**	0.465	0.234

CL: Culm length PL: Number of panicle per plant LBL: Leaf blade length LBW: Leaf blade width FLL: Flag leaf length FLW: Flag leaf width LL: Ligule length NPP: Number of panicle per plant FH: Number of days from seedling to first heading MH: Number of days from seedling to main heading Cycle: Number of days from seedling to maturity PB: Number of basal primary branches on panicle CN: Culm number CD: Culm diameter GL: Grain length GW: Grain width GT: Grain thickness CaL: Caryopsis length CaW: Caryopsis width HGW: 100-grains weight

Appendices C. Significant variables out of the 50 discriminating traits of the collection on regional basis

Variable \ region	BM	CC	HB	SO
Culm length (cm)	90.1a	99.6b	92.8a	99.0b
Leaf blade length (cm)	43.2a	47.8b	45.4a,b	50.8b,c
Flag leaf length (cm)	32.8a	35.3a	33.5a	38.7b
Number of panicle per plant	11.5a	13.1b	13.7b	12.3a
Number of days to first heading	81.1a	90.6b	83.6a	83.4a
Number of days to maturity	117.5a	131.1b	120.4a	121.1a
Number of panicle primary branches	12.0a	12.4a	12.5a,b	13.1b
100 grains weight (g)	2.60a	2.41b	2.50a,b	2.46a,b
7.3.23. Culm habit	2.09a	1.59b	1.54b	1.67b
7.4.5. Lemma and palea colour at anthesis	8.04a	6.57b	6.81b,c	7.45a,c
7.5.5. Lemma and palea colour at maturity	2.23a	2.79b	2.67a,b	2.30a,b
7.4.23. Panicle shattering	2.52a	1.52b	2.17a	1.81a,b
7.5.13. Sterile lemma colour	1.83a,b	1.93b	1.77a	1.94b
7.3.29. Underline node colour on culm	1.8a	1.6b	1.7a,b	1.4c

The letters a, b, c and d indicate the significance between variables in a row. BM, CC, HB and SO refers to Region of Boucle du Mouhoun, Region of Cascades, Region of Hauts Bassins and Region of Sud Ouest respectively.