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On-Farm Management of Rice Diversity, Varietal Preference Criteria, and Farmers' Perceptions of the African (Oryza glaberrima Steud.) Versus Asian Rice (Oryza sativa L.) in the Republic of Benin (West Africa): Implications for Breeding and Conservation — Source link

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Short title: "Loko et al: On farm management of rice diversity in Benin"

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Abstract

Rice (*Oryza* spp.) is an important food and cash crop in the Republic of Benin. However, despite its production increase during the recent years, the yield of cultivated varieties remains low, and the introduction of improved varieties threatens the rice diversity existing in the traditional agriculture. Therefore, documenting the on-farm management of rice diversity, farmers' varietal preferences, and their perceptions of the performance of cultivated varieties and species are important prerequisites for the development of on-site breeding and conservation programs. To fill these gaps in Benin, 418 rice farmers, belonging to 21 ethnic groups, were surveyed in 39 villages using participatory rural appraisal tools. Subject to synonymy, 30 improved varieties and

68 local varieties were registered and their folk nomenclature and taxonomy were documented. The north of Benin had the highest diversity of rice with the greatest number of traditional varieties, making this region the best place for an *in situ* conservation program. The number of rice varieties maintained per village varied from 1 to 15 (six on average). The foursquare analysis revealed that the improved variety IR 841 was by far the most popular variety. Most of NERICA varieties were abandoned in the south, while the north still host a wide range of local varieties. Twenty-one reasons explained varietal abandonment by farmers, varying according to geographic areas and ethnic groups. The seed system was both formal and informal in the study area. The participatory evaluation revealed the necessity to create and introduce tolerant/resistant rice varieties to drought and flooding stresses in Beninese agriculture that meet farmers' preferences. Our results showed that the north Benin would be the most suitable place for in situ conservation of local rice diversity.

Key words: Rice, folk taxonomy, on-farm management, varietal diversity, in-situ conservation.

Introduction

Rice (*Oryza* spp.) contributes to food security and poverty reduction in the Republic of Benin, representing the third cereal crop in terms of production, after maize and sorghum, with a production of 459,313 tonnes in 2018 (FAO 2018). Previously considered as a luxury food and consumed only during the festive days (Zanou et al., 2004), rice is nowadays the staple food (a consumption of 74.81 kg per year per person) for millions of Beninese, thus going with an increase importations: from 1,359 thousand tonnes in 2015, to 2,682 thousand tonnes in 2017 (FAO 2018). Indeed, as in many African countries, annual rice consumption in the Republic of Benin is growing faster than its annual production (Akouegnonhou and Demirbaş 2019).

The rice sector has become one of the most dynamic agricultural sectors in the Republic of Benin with production increasing steadily over the years (FAO 2018). This increase in rice production could be due to an increase in cultivable areas and also by the massive introduction into Beninese agriculture of improved rice varieties such as the hybrid NERICA (New Rice for Africa) varieties, resulting from the cross between African (*Oryza glaberrima* Steud.) and Asian (*Oryza sativa* L.) rice (Yokouchia and Saito 2017). However, little information exists on the impact of the introduction of improved rice varieties on the maintenance of local varieties in Beninese agriculture. Indeed, it is well known that a large number of traditional varieties are often supplanted by a small number of improved varieties, which contribute to their disappearance (Joshi and Bauer 2007). The loss of traditional varieties could be accompanied by a loss of unique genes of interest for the breeding of improved rice varieties (Ficiciyan et al. 2018). Therefore, it is important to document rice diversity maintained in the traditional Beninese agriculture and how farmers manage this diversity. This information is a fundamental prerequisite

for the development of appropriate conservation strategies of rice diversity in the Republic of Benin.

A few studies have assessed rice diversity grown in the Republic of Benin (Odjo et al. 2017; Bello et al. 2018). However, none of these studies provides information regarding on-farm management of this diversity and a global vision of diversity across the geographical zones of the Republic of Benin for the development of efficient in-situ conservation strategies. In addition, very little information exists on the local nomenclature and folk taxonomy of rice grown in Benin. Knowledge of local nomenclature and folk taxonomy is essential for systematic germplasm collection and helps to develop an *in situ* conservation scheme for farmers' varieties (Mekbib 2007). These shortcomings need to be resolved to develop an efficient conservation strategies of rice diversity in Benin.

Previous studies have also shown that the Republic of Benin has relatively low quality rice which induces a low competitiveness compared to imported rice (Codjo et al. 2016), and the success of improved varieties have so far failed to meet the expectations of both producers and consumers (Gnacadja et al. 2017). It is, therefore, important that breeders develop new rice varieties adapted to local conditions and that meet the preferences of both producers and consumers in order to boost rice production in the various regions of Benin. However, to ensure their adoption by farmers it is crucial that breeders have a good understanding of farmers' perceptions on the rice diversity maintained on farm and their varietal preference criteria (Sow et al. 2015). As farmers have long experience in evaluating the performance of their own crops (Manzanilla et al. 2011), it is also important to document farmers' perceptions of the agronomic, culinary and technological performance of cultivated rice varieties in order to guide breeders.

The objective of this study was to contribute to the formulation of a strategy for the conservation and breeding of rice genetic resources in the Republic of Benin. Therefore, this

study aim to: (i) document folk taxonomy of rice grown by different ethnic groups; (ii) assess varietal diversity and extent of distribution of rice grown in different zones of Benin ; (iii) evaluate farmers' perceptions of Asian and African rice and varietal preferences in the different production zones of Benin.

Material and methods

Study area

The present study was carried out in the Republic of Benin located in West Africa (between the parallels 6° 30’ and 12° 30’ north latitude, and the meridians 1° and 30° 40’east longitude). With a population estimated at 11 340 504 inhabitants, the Republic of Benin is subdivided into three geographic zones (South, Centre, and North) and three climatic zones (Guineo Congolean zone (6 °25′–7 °30′N) in the south, Sudano-Guinean transition zone (7 °30′–9 °45′N) in the centre and Sudanian zone (9 °45′–12 °25′N) in the north). In the Guineo Congolean zone, the rainfall regime is bimodal with alternating dry seasons (November to March and mid-July to mid-September) and rainy seasons (April to mid-July and mid-September to October). While, the two other climatic zones have a unimodal rainfall distribution pattern characterized by a dry season from November to April and a rainy season from June to September. Three types of vegetation characterize Benin: the savannah with trees in the Sudanese regions of the North; the savannah in the Centre with species like Mahogany and Iroko; and the forest in South Benin. The temperature varies from 24° C to 31°C throughout the study area. The soils are deep ferrallitic or rich in clay in the south Benin, ferruginous in the centre, and hydromorphic in the north.

Ethnobotanical surveys

Thirty-nine villages spread across the north (21 villages), centre (6 villages), and south (12 villages) were surveyed in Benin (Figure 1). These villages were chosen in collaboration with the agents of the Territorial Agencies for Agricultural Development (ATDA), based on rice production statistics and taking into account ethnic diversity, agro-ecological zones, accessibility and the need for good country coverage.

Classical participatory research appraisal tools (individual interviews, focus groups, and direct observations) were used for collected data. In each village, the interviews and discussions were conducted in the local language or dialect with the help of local translators. The focus group discussions (FGDs) in each village comprised 15 to 20 rice farmers, of both genders and different ages. These rice farmers were identified and assembled with the assistance of the local farmers' associations and village chiefs, in order to facilitate the organization of the meetings and the data collection (Kombo et al. 2012). When coming for FGDs, after obtaining the farmers' oral consent to participate, farmers were requested to bring samples of the rice varieties they currently or recently cultivate. During the FGDs, farmers were asked to list (using vernacular names) and display the different rice varieties grown in their villages. The distribution and extent of cultivated rice varieties were assessed using the Four Squares Analysis approach (Loko et al. 2013; Orobiyi et al. 2017). This approach helps to classify the varieties at community level, taking into account the area (large or small) devoted to the variety and the number of households (few or many) cultivating it. The varieties can thus be classified into four groups (varieties cultivated by many households on large areas; varieties cultivated by many households on small areas; varieties cultivated by few households on large areas, and varieties cultivated by few households on small areas). To do this, criteria were established together with the farmers following Kinhoégbè et al. (2020): (i) a variety was considered cultivated by many households when over 50 % of the households of the village grew it; and (ii) a variety was considered

cultivated on a large area if it was cultivated on more than 0.25 ha. Then, free, open discussions with no time limits were conducted with farmers to understand the reasons justifying the cultivation of each rice variety by many or few households and on large or small areas.

During FGDs, information on the agronomic, technological and culinary characteristics of the rice varieties mentioned in each village were recorded. Twelve variables were used to assess the varieties. Among them, eight were agronomic (productivity, drought, flooding, diseases, bird attack, insect attack, weeds, storage insect attack), and three technological and culinary (shelling, cooking features and taste). According to Loko et al. (2015), a simple binary scoring scale was used: the rice varieties were scored 1 when unanimously recognized by the farmers as efficient (very good/ resistant/tolerant), and 0 otherwise. At the end of participatory evaluation, a synthesis was carried out by village in order to avoid duplication of information.

After FGDs, household of rice producers were chosen in each selected village using transect methods for individual interviews (Dansi et al. 2008). At least 10 rice farmers were randomly selected per village, from 29 villages, and eventually a total of 418 farmers participated in the study. The data collected included socio-demographic data (age, sex, household size, years of experience in rice production, educational level, number of workers), local nomenclature, folk taxonomy, abandoned rice varieties, reason of abandonment, varietal preference criteria, desirable and undesirable traits of African and Asian rice, and seed system (seeds origin, seeds supply constraints, seeds quality, seeds cost, conservation mode, seed selection criteria, conservation duration, seeds conservation constraints).

Seeds of each rice variety listed by farmers were collected from the 39 surveyed villages. For each variety, samples were taken from rice farms and presented to a group of village producers to confirm the identity (name given to the seed lot) of the sample and its category (local or improved). Each accession was properly labelled and classified in the laboratory using standard

seed's morphological description characteristics (lemma and palea pubescence, lemma and palea colour, grain length, grain width, caryopsis shape, and pericarp colour), according to Bioversity International et al. (2007). According to Fofana et al. (2011), for each rice variety, 10 paddy grains were randomly selected and their dimensions were determined using a micrometer screw gauge.

Data analysis

Socio-demographic profile data of the interviewed rice producers and the characteristics of their farms were subjected to Pearson Chi-square tests and ANOVA using the statistical software IBM SPSS version 23.0, in order to compare the different regions under study. The level of significance was set at 0.05 (alpha) and the means were separated by the Student Newman Keuls (SNK) test in the case of significant difference using the Statistical Package for Social Sciences (IBM SPSS version 23.0).

Popularity rate of a landrace was calculated according to the formula (1)

$$PRL = 100 \times NVLP/NVLL \times (N_{H+} + N_{A+})/2NVLP \quad (1)$$

with NVLL = Number of villages where the variety is listed; NVLP = Number of villages where the variety is popular (variety cultivated by many households in at least one village); N_{H+} = Number of villages where the variety is cultivated by many households; N_{A+} = Number of villages where the variety is cultivated on large areas.

Rate of threatened varieties (RTLD) at the village level was determined, according to Loko et al. (2013), using the formula (2):

$$RTLD = NLTD /TNL \times 100 \quad (2)$$

NLTD = Number of varieties threatened by disappearance (the number of varieties cultivated by few households and on small areas (H- A-) minus the number of newly introduced varieties); TNL = Total number of varieties.

Shannon-Weaver diversity index (H) was calculated to assess the importance of the varietal diversity in our study area and in the different agro-ecological zones surveyed according to the formula (3):

$$H = - \Sigma Pi \, Log \, Pi \quad (3)$$

Pi = ni / N, with ni = number of varieties in each village and N = sum of ni.

For rice diversity map, Thiessen polygon method was applied to determine the different zones of influence by geometric cutting. The method is based on the Delaunay triangulation using the mediator method between the different rice production fields, using ArCGIS software version 10.2.

Data normality and homogeneity of grain and caryopse dimensions (length and width) of recorded rice varieties were tested using, respectively, Shapiro and Levene's tests, using log-transformation (Ln(x)). The transformed data were then subjected to one-way ANOVA analysis to compare collected rice varieties, using the Statistical Package for Social Sciences (IBM SPSS version 23.0). The level of significance was set at 0.05, and means were separated by SNK test in case of significant.

In order to establish a relationship between the reasons of abandonment (percentage of responses) of rice varieties and the ethnic groups surveyed, a Principal Component Analysis (PCA) was conducted using the software Minitab version 17. To study the rice varietal diversity in terms of agronomic, technological and culinary performances, a synthesis of the information obtained in each village was carried out by gathering the data of the varieties with the same name. Rice varieties were considered as individuals, the participatory evaluation parameters as

variables, and coded 1 or 0 depending on whether the variable evaluated was positive or not. A complete disjunctive table was constructed and used to develop a similarity matrix (simple matching coefficient of similarity) with NTSYS-pc 2.2 software (Numerical Taxonomy and Stastistical Analysis, Rohlf, 2000). The similarity matrix was then used to construct a dendrogram according to the UPGMA method (Unweighted Pair-Group Method with Arithmetic Average).

Results

Socio-demographic characteristics of the households surveyed

Men (74.6%) headed most of the households interviewed in the three surveyed regions (Table 1). Very few, non-significant, differences were observed between the three regions in terms of educational level, with most of the farmers being illiterate (64.4%), and only 1.2% having a university level (Table1). The surveyed farmers were relatively young with an age ranging from 17 to 85 years with an average of 44 years. The surveyed households had large families ranging from 1 to 34 people, and differences in household size were observed from region to another: average size of surveyed households in northern Benin (9.5 ± 0.4 people) was significantly higher than that of southern households (7.5 ± 0.3 people) and central Benin (7.7 ± 0.4 people). In terms of years of experience in rice production, the interviewed producers in the northern (15.1 ± 0.8) and central (15.1 ± 1.9) regions were found to be more experienced than those from the southern region (11.5 ± 0.3). In general, the surveyed producers had good experience in the production of rice with an average of 14 years of practice. The heads of households interviewed were smallholders, with farms averaging 0.9 ha, but average farm size varied considerably between regions, with the south having the largest plots planted by farmers (Table 1). Twenty-one ethnic groups were interviewed across the study area.

Local nomenclature

The common name of rice is not the same from one ethnic group to another, with similarities within ethnic groups belonging to the same socio-cultural groups. For instance, rice was called *Molikoun* among the Aïzo and *Monlikoun* among the Mahi, Fon and Natema ethnic groups; *Irèssi* among the Idaasha and Tchabé ethnic groups, and *Lessi* or *Ressi* among the Ifé ethnic group (Table 2). Ninety-one distinct rice variety names were inventoried across the study area. According to the surveyed farmers, most of these local names (39.3%) were meaningless (Bakilafema, Beris, BL19, etc.), while others mainly referred to the seed colour (29.3% of the responses), seed size (17.2%), plant beauty (6.9%), origin of variety (6.9%) and the length of life cycle (6.9%) (Table 3).

Folk taxonomy

Rice folk taxonomy in the study area had a low level of classification, with two hierarchical levels found in several ethnic groups. For example, in the Biali ethnic group, the generic name of rice Moï was subdivided into seven infra-specific taxa (Moï nihoun, Moï koukourika, Moï lopiro, Moï poga, Moï poria, Moï lague, Moï touanga), while in the Bariba ethnic group, the generic name Mori or Sinvite was subdivided in only two infra-specific taxa (Mori kpika and Mori souan or Sinvite kpika and Sinvite fanrou). Farmers used 13 criteria to differentiate rice varieties (Figure 2), the plant size (54.4% of responses) being the main criteria. For example, many farmers differentiated the local varieties Gambiaka (tall plant) and Toyéta (dwarf plant) by their size in the field. The seed size (17.4%) and caryopsis colour (11.4%), were also among the important criteria, and farmers of Dendi ethnic group identified the local varieties Fondia Ibero (long seeds) and Fondia keno (short seeds) based on their seed size. In the same trend, local varieties Imon ipia (white rice), Imon iwon (purple rice), and Imon soua (black rice) were

differentiated by Ditamari farmers through their caryopsis colour. To identify rice varieties, farmers combined several criteria: for instance, in Dendi ethnic group, some farmers used a combination of the plant size and panicle shape criteria to identify the local varieties such as Djimbo dogo (large plant with panicles facing upwards) and Djimbo gazéré (short plant with panicles facing downwards).

Diversity structuration based on seed characteristics

The FGDs carried out in each village helped identify, subject to synonymy, 30 improved and 68 local rice varieties across the study area (Table 4). A classification of these varieties, based on the seed morphological traits, enabled to group them into 21 morphological groups (Figure 3). There were significant differences between the 21 seed morphotypes, in terms of grain length (ddl = 106, F = 3.106, P <0.000), and grain width (ddl = 106, F = 2.938, P <0.000). The seeds had different lemma and palea pubescence (glabrous, hair on upper portion, hair on lemma kell and short hairs), lemma and palea colour (straw, brown, gold, purple spots straw, purple, reddish to light purple, and gold and gold furrows), caryopsis shape (long spindle-shaped, half-spindle-shaped, and semi round) and pericarp colour (white, red, and brown) (Table 4). The Poinpoua variety collected in Kenkini-Séri village had the longest grain size and Takamorri, Moi koukourika, Timonpéiti varieties, presented the smallest grains (Table 4). On the other hand, the rice varieties Yamaboba, and Gambiaka 5 had the widest grains. Further, 10 and eight rice morphotypes were found in the south (N° 1, 2, 3, 4, 8, 11, 12, 18, 19, 21) and centre (N° 1, 2, 3, 8, 11, 12, 18, 19) of Benin, respectively (Figure 3), while 12 (N° 5, 6, 7, 9, 10, 13, 14, 15, 16, 17, 20, 21) were specific from the northern region. Some morphotypes included both African and Asian rice varieties (Table 4).

Distribution of rice varieties

Subject to synonymy, the number of rice varieties per village varied from 1 (Igbo-Edé village) to 15 (Bagou village), with an average of six (Table 5). The number of rice varieties cultivated per village varied significantly (ddl = 38, F = 3.801, P <0.05) depending on the region: the surveyed village in the northern region (7.2 ± 0.8) grew significantly more rice varieties than the southern (4.5 ± 0.8) and central (4.6 ± 0.6) ones.

The highest diversity indices were detected in the north of Benin varying among ethnic groups: Bariba with 23 different local varieties (highest diversity index of Shannon ISH = 4.26); Dendi with nine (ISH = 2.56) and Ditamari with eighteen (ISH = 1.85). The lowest diversity was identified in southern Benin, where IR841 variety was reported the only cultivated variety at the time of this study (Table 2). Based on varieties cultivated by most households (H +), 40 varieties were identified as popular (Table 6), the popularity rate varying from 6.25% to 100%, at the village level. The improved variety IR841 was by far the most popular variety, found in all the surveyed regions, and cultivated by 43.6% of the surveyed farmers. This was followed by Gambiaka variety, an old variety still cultivated in the Atacora and the Collines departments (Frequency = 2.9%). Subject to synonymy, the rice varieties cited by at least 10 rice farmers were cultivated in the North of Benin: Danrou morri (Atacora), Degaule (Alibori, Borgou), Djimbo gazéré (Alibori), Trial (Borgou), Moï touanga (Atacora), NL20 (Atacora, Donga), R8 (Alibori, Borgou) and Yayi Boni (Borgou, Donga). Many other rice local varieties (N = 37 varieties) were grown by one to five farmers (N = 29 varieties).

The Shannon-Weaver index varied in function of regions, with a value of 5.08 bits for the complete studied area, with a high variation of rice diversity in northern Benin (H = 4.25 bits), while the central Benin was the area with the average diversity (H = 3.04 bits), and the south the area with the lower (H = 2.90 bits). This trend was shown in the Figure 4, figuring a great diversity of rice varieties in the north of Benin, mainly in the Alibori and Atacora departments.

The Shannon-Weaver index was also varied with ethnic group, with the highest value for Bariba ethnic group (H = 4.26 bits) and the lowest (H = 0.05 bits) for the Ifè and Holli ethnic groups (Table 2).

The rate of threat of disappearance ranged from 0% to 100%, with an average rate of 49.8%: Koungarou, Totorou and Igbo-Edè were the villages with the lowest rate of threat of disappearance while Bamè was the only one with a 100 % threat of disappearance. Regarding the rate of threat of diversity disappearance per climatic zone, central Benin had the most threatened varietal diversity (73.7%) followed by the south (51.5%), while, the north had the lowest threat rate (39.9%).

Abandoned rice varieties

The synthesis of information from individual and group surveys made it possible to determine the number of varieties abandoned in each village (Table 7). The number of abandoned rice varieties per village, considering the 36 remaining villages, varied from 1 to 12 (Table 7). The villages, Madécali (12 abandoned varieties), Houéyogbé (9 abandoned varieties), Dévé-Homey (9 abandoned varieties) and Bamè (8 abandoned varieties) were the villages where the number of abandoned varieties was higher, while only one variety has been abandoned in Sewahoué, Kode, Gbeko, Koungarou and Loulè villages. Farmers in most of the surveyed villages abandoned the improved varieties of NERICA (48.7% of surveyed villages), and also the local rice varieties of Gambiaka (38.5% of surveyed villages). At the regional level, the NERICA varieties were the most abandoned varieties by farmers in the southern Benin, while Gambiaka varieties were among the most abandoned by farmers in northern Benin; the two were also the main varieties abandoned in the centre of Benin.

Reasons for varietal abandonment

Twenty-one reasons were reported for the abandonment of rice varieties in the study area (Table 8). Among these, the most important were low productivity (25.4% of responses), lack of aroma (14.4% of responses), lack of sales market (13.4%) and long life cycle of some rice varieties (12.4%). The number of reasons for abandonment and their importance varied from one region to another: 19 were identified in the north, 10 in the centre and eight in the south. The lack of aroma was the main reason for rice varieties abandonment by farmers in southern Benin, while, in north, the long life cycle of some rice varieties was the most important reason. The low productivity, the lack of sales market, the bad taste of some rice varieties, and the lack of seeds were common constraints for the surveyed farmers in the three regions (Table 8).

The number of reasons for rice varieties abandonment and their importance also varied from one ethnic group to another (Figure 5). For instance, seven were listed by farmers of the Adja ethnic group, while three and seven by the surveyed famers of Aïzo and Bariba ethnic groups, respectively. (Figure 5a). The principal component analysis of reasons for rice varieties abandonment in relation to ethnic groups allowed categorising the 21 ethnic groups in nine groups (Figure 5b). The lack of market and aroma were the main reasons for abandonment for farmers from the group constituted by Fon, Mahi, Sahoué, Ouémé, Savé, Ifé, and Tchabé ethnic groups. While, the difficulty of farming practices required by some rice varieties was the main reason for farmers from Idatcha and Mokolé ethnic groups. Whereas, the lack of seeds, their high cost and bad taste were the main reasons for farmers from Wama and Germa ethnic groups; the long life cycle for farmers from Adja and Biali, the low market value, susceptibility of seedlings to lodging, and the high cost of agricultural inputs for Yom farmers. On the other hand, sensitivity to flooding, and damage to fish during flooding were the main reasons for varietal abandonment among farmers of the Dendi ethnic group; poor quality of dough and too much breakage of some rice varieties during shelling among the Ditamari ethnic group;. long cooking

time of some rice varieties and water-intensive varieties were the main reasons for abandonment among farmers of the Lokpa ethnic group; and the falling of paddy grain before harvesting, the lack of time to take care of rice production, and the high content of starch in rice grains were the main reasons for abandonment by farmers of Bariba ethnic group.

Farmers' perceptions of Asian versus African rice

For most of the surveyed farmers (59.6%), there was no difference between African and Asian rice. The remaining surveyed farmers (40.4%) used eight criteria to differentiate African from Asian rice: plant size (78.7% of responses), long life cycle (6.3%), productivity (5.7%), seed length (4.1%), and lodging of rice plants (3.4%) were generally cited, although few surveyed farmers used the taste (0.6%), leaf width (0.6%), and seed colour (0.6%). Farmers revealed 14 and 10 undesirable traits of African and Asian rice, respectively (Table 9) and 13 and 10 desirable traits (Table 9). For the farmers in southern and central Benin, the flooding adaptation and the resistance to diseases were the main desirable traits of the African rice while good taste dominated among the northern farmers (Table 9). Throughout the study area, the most undesirable trait of African rice mentioned by farmers was its long life cycle (5-6 months), and susceptibility to flooding of fields and diseases for the Asian rice (Table 9).

Seed system

Seeds of the rice varieties cultivated by the surveyed farmers had various origins, with the majority coming from the previous harvests (58.6%) and from the Territorial Agency for Agriculture Development (ATDA) (27.3%). Some farmers bought their seed from the local markets (6.1%), and at the National Institute of Agricultural Research of Benin (INRAB) (4.7%). Further, some seed came from some program or projects such as the Service Company and

Producer Organization (ESOP) (1.7%), the Project for Agricultural Development Support (ProCAD) (1.1%) and the German International Development Cooperation Agency (0.5%).

Regarding the constraints related to the supply of rice seed, 63.8% of the surveyed farmers reported that they had no difficulty accessing this agricultural input. The rest of the surveyed farmers mentioned the high cost of seed sold at formal seed markets (12.9%), the lack of financial resources (9.9%), bad quality seeds (5.8%), the delay in supplying producers with quality seed (5.3%), the difficulty of obtaining pure seed from their own harvest (1.6%) and the absence of seed structures (0.7%).

Almost all the surveyed farmers (96%) revealed that the seed they used was of good quality, while few (2.9%) considered that the seed was of an acceptable quality. Most of the surveyed farmers (80.1%) reported that they did not make any selection of seeds for the following season, whereas the remaining (19.9%) selected seed to obtain good quality seeds. To select seed, the farmers used four criteria: seed uniformity (45.5% of responses), seed size (42.2%), seed colour (11.7%) and seed purity (0.6%).

Most of the surveyed farmers (60.1 %) were unable to estimate the cost of seed they used per hectare, only 39.9 % of them could do so. Among those that make estimations, the cost of seed per hectare varied from 6,000 FCFA to 21,000 FCFA and 7,500 FCFA to 8,750 FCFA for farmers that practiced direct sowing (52.5 %) and intensive rice system (7.4 %), respectively.

Farmers' varietal preference criteria

Ten varietal preference criteria were recorded across the study area. All the 10 criteria were listed by the surveyed farmers in the North of Benin, while the surveyed farmers in the south and centre of Benin listed, respectively, seven and five of them. High productivity was the main criterion across all the surveyed regions, followed by the good culinary quality of the variety

(Table 10). Interestingly, the aroma of the variety remained an important criterion in the central and southern Benin.

Evaluation of agronomic, technological and culinary performances of rice varieties

Subject to synonymy, the participatory evaluation of rice varieties led to the identification of 1 to 65 performant varieties per evaluated parameters (Table 11). Tolerance to insect storage attacks (61 varieties), high productivity (47 varieties), tolerance to insect attack in the fields (42 varieties), and tolerance to diseases (38 varieties) were the parameters for which more performant varieties were found. Very few performant varieties were identified for drought tolerance (1), flooding tolerance (6 varieties), and easy shelling (9 varieties). Several rice varieties were found to be well performing for more than one parameter (Table 11).

The 97 rice varieties identified, subject to synonymy, were clustered in 69 agronomic and culinary units at 100% similarity (Figure 6). At 51% of similarity, the 97 rice varieties were structured in three groups with various characteristics (Figure 6). Group 1 (G1) comprised 79 rice varieties that performed well for most of evaluated parameters, group 2 (G2) comprised two rice varieties characterized by their good culinary characteristics but susceptible to drought, and the third group (G3) contained 16 rice varieties that were reported susceptible to flooding.

Discussion

Through the surveyed ethnic groups, 91 names of rice varieties were recorded, indicating the long history of rice production in Benin, but also a quite considerable rice diversity. Similar to the Malagasy (Radanielina et al. 2013), Nepalese (Bajracharya et al. 2010), and Lao (Appa Rao et al. 2002) rice producers, most of the names given to rice varieties had significant meanings, and reflected, for the majority, the rice morphological characteristics. Thus, the knowledge of the meanings of the rice names did not only facilitate communication and knowledge exchange

between researcher or agricultural extension workers and farmers, but could also help the researcher in the visual identification of some rice varieties based only on their name. The local nomenclature of rice varieties varied across ethnic groups, and sometimes from a village to another within the same ethnic groups. These observations are common in folk nomenclature, and have been reported on many crops, such as *Manihot esculenta* Crantz (Kombo et al. 2012), *Sorghum bicolor* (L.) Moench (Dossou-Aminon et al. 2015), *Macrotyloma geocarpum* (Harms) Maréchal et Baudet (Assogba et al. 2015) and *Phaseolus vulgaris* L. (Loko et al. 2018). The great majority of criteria used by the surveyed farmers to identify rice varieties are also used by Indian farmers (Wangpan et al. 2019; Laishram et al. 2020), and are among the main descriptors used for morphological characterization of rice, showing the abundance and distribution of farmers' knowledge of their rice germplasm.

Our results regrouped the rice accessions in 21 morphological groups based on seed characteristics. This diversity is very low compared to those found in Guinea (387 rice varieties; Barry et al. 2008), in Bangladesh (670 unique rice varieties; Tiongco and Hossain 2015), and in Madagascar (346 rice varieties; Radanielina et al. 2013). However, as in Lao (Appa Rao et al. 2002), we noted that the same rice variety could be called by different names and different varieties could have the same name. Both agro-morphological and molecular characterization are required for clarification of problems of synonymy and homonymy.

Relative to the other regions, the northern region of Benin showed the greatest diversity of seed morphotype with 12 specific local ones. This could be explained by the antiquity of African rice production in this region, which pre-dates the colonial era (Vido 2012), the local eating habits of the populations of the north, and by the importance of African rice in their sociocultural life. Indeed, as rice producers in Burkina-Faso (Kam et al. 2003) and as revealed by Gnacadja et al. (2017), farmers in northern Benin prefer the taste of local rice varieties, considered as having a

good taste. In addition, according to Barry et al. (2008), the high proportion of local varieties in a region reflects the predominance of subsistence production systems with low intensification. The fact that many morphotypes are found specifically in the north can support also a low exchange of seeds between northern producers and those from other regions of the country, or even within the region itself. This implies that for *in situ* conservation of local rice diversity in Benin, the north would be the most suitable place.

The average number of varieties cultivated per village in the study area is low compared to that found in the villages of the island of Madagascar (10.9; Radanielina et al. 2013), Guinea (24.6; Barry et al. 2008), and in the Kumaun region of Indian Central Himalaya (11; Agnihotri and Palni 2007). However, the diversity maintained at the household level (2.2) is almost similar to that held by Malagasy (Radanielina et al. 2013), and Indian farmers (Laishram et al. 2020), but lower than those held by Nepalese farmers (Bajracharya et al. 2010). The low diversity observed at Igbo-Idé village could be explained by the fact that farmers of this village began to grown rice after recent sensitization campaigns carried out by government extension services and NGOs to promote the crop in the area considering that it is suitable for rice production: therefore, farmers grow only the recent rice varieties with high market value. In the case of the villages with a high diversity such as Bagou (15 varieties), Madécali (14 varieties), or Kounadogou (14 varieties), farmers have been growing rice for centuries, and the high diversity observed in these areas could be explained by the fact that farmers cultivate both local and improved rice varieties. Indeed, this allows them to maintain their socio-cultural habits, while meeting standardized market needs (Orozco–Ramírez et al., 2014). However, in these villages, only a few of the surveyed farmers maintain high rice diversity on their farm. Unfortunately, most of these villages with high rice diversity also show a high rate of threat of diversity disappearance. Nevertheless, Tchakalakou, Angaradébou and Founougo villages from northern Benin can be considered as conservative

villages in which conservation programs could be implemented because of their high rice diversity and low threat of diversity disappearance.

The IR841 variety selected at IRRI (International Rice Research Institute) was the most popular improved variety grown in the Republic of Benin, because of its rainfed lowland cultivation, the main rice production system used by Beninese producers, and its high level of appreciation by producers and consumers for its grain fragrant aroma and its good yield (Totin et al. 2003). The Gambiaka variety, which is a traditional cultivar of the *O. sativa* species, as opposed to farmers of the Tillabéry region of western Niger (Sow et al. 2015), is abandoned by most of the surveyed farmers both in the northern and central regions of Benin, because of its long life cycle and water requirement.

The predominance of NERICA hybrid varieties among the improved rice varieties recorded in the study area could be justified by their massive introduction into Beninese agriculture due to the presence, until a few years ago of the temporary headquarters of the Africa Rice Center in Benin. According to Barry et al. (2008), the government agricultural policy and the openness of farmers to innovation could also justify the presence of improved rice varieties in traditional agriculture. However, farmers abandoned NERICA varieties in the subsequent years. According to Yokouchia and Saito (2017), the main cause of abandonment could be the combined effects of low yields, lack of access to credit, lack of aroma, and lack of training on NERICA cultivation practices. The fact that the lack of aroma was among the most important reasons of variety abandonment by surveyed farmers in the southern and central regions of Benin could be explained by the fact that the aroma of cooked rice is an important consumer criterion in Benin (Kiki and Agli 2007), leading to a loss of sale for these varieties. Indeed, the two regions are close to the Cotonou Port, which transits various high quality rice varieties coming mostly from Asian countries. The main reasons of rice variety abandonment listed by the surveyed farmers

must be taken into account in breeding and varietal introduction programs, and we highly recommend that future programs take into account the specificity of each ethnic group.

Most of the surveyed farmers who do not distinguish any difference between African and Asian rice were those surveyed mainly in South Benin. This could be explained by the fact that rice production in southern Benin is very recent, and is mainly based on the cultivation of improved varieties. The concordance of the farmers' perceptions of desirable and undesirable traits of both rice species with scientific data reveals the good knowledge they have of their rice materials. For instance, the surveyed famers mentioned as undesirable traits of African rice its long cycle, low productivity, big seed, and unscented grain, which are corroborated by the observations made Bezançon and Diallo (2006). The adaptation to flooding (Kawano et al., 2008), frequent lodging (Sarla and Swamy 2005), high swelling (Gayin et al. 2017), and easy shelling/dehusking without breaking of the grain (Nayar, 2010) of the African rice have been widely reported in scientific literature. The diversity of desirable traits of the African rice listed by the surveyed farmers in northern Benin reflects the preference of this population for this particular rice species.

The farmers' preference criteria registered in the study area are similar to those of many rice producers around the world (Cuc et al. 2008; Manzanilla et al. 2011; Kangile et al. 2018): high yield (as for Vietnam; Cuc et al. 2008; Tanzania; Kangile et al. 2018; southern Asia; Manzanilla et al. 2011), culinary characteristics (such as grain swelling when boiled) and good quality dough were also crucial preference criteria for rice farmers in the study area. Breeders could also take into account the precocity of rice varieties as an important criterion for the selection of varieties to be introduced in the northern and southern regions of Benin; while the resistance to pests and diseases must be taken into account as an important criterion for all the surveyed regions. According to the surveyed farmers, the aroma and swelling are also important selection criteria,

as for Tanzanian farmers (Kashenge-Killenga et al. 2014; Kangile et al. 2018). Breeders developing new varieties for each region of Benin ought to consider the documented farmers' preference criteria.

The participatory evaluation of rice varieties grown by surveyed farmers showed the existence of highly performing rice varieties in traditional Beninese agriculture. However, very few rice varieties were perceived by farmers as tolerant to drought and flood. Breeders must urgently develop resistant/tolerant to flooding and drought rice varieties, to strengthen the pools of varieties resistant to these abiotic stresses. The emergency of this action is supported by the fact that lowland rice cultivation is nowadays confronted with the impact of climate change that is manifested by increased irregularities in rainfall, onsets of extreme floods, and long-lasting droughts (Bossa et al. 2020). The classification of rice varieties in pool of performance will be useful in future rice breeding programs. According to Odjo et al. (2017), the development in Republic of Benin of a concerted national rice-breeding program is required to create novel varieties responding to farmers' preference criteria that will boost national production.

The preference of farmers for using seed from the previous harvests signifies the current state of the rice sector in Benin, which is still essentially traditional. The same trend was observed in Tanzania (Kangile et al. 2018; Gebeyehu et al. 2019), Guinea (Okry et al. 2011), Indonesia (Lakitan et al. 2018), Nepal (Sapkota et al. 2013), and Indian Himalayas (Pandey et al. 2011). It is, therefore, important to enhance farmers' skills in seed selection and maintenance for boosting rice production (Gebeyehu et al. 2019). Nevertheless, more and more farmers obtain rice seed from public institutions and NGOs; unfortunately, they are faced by numerous seed supply constraints. Similarly to Nepalese farmers (Sapkota et al. 2013), the unaffordable price, and inadequate seed were the most common registered constraints among the surveyed farmers in Benin. In agreement with Dossouhoui et al. (2017), it is imperative to establish a partnership

between private seed distribution companies and seed producers in order to facilitate affordable access to quality seeds for rice producers in Benin. These constraints of seeds supply must be taken into account to facilitate the adherence of all producers to the services of private or public seed structures.

Conclusion

Our study revealed that 30 improved varieties and 68 local rice varieties, classified in 21 morphotypes, are grown by farmers throughout the 39 surveyed villages in the Republic of Benin. The local nomenclature and folk taxonomy of these rice varieties were mainly based on seed morphological characteristics. Both agro-morphological and molecular characterization are required for clarification of synonyms and homonyms. The north of Benin showed the highest diversity of rice with the greatest number of traditional varieties making this region the best place for an *in situ* conservation program. The IR841 variety was the most popular rice grown in the Republic of Benin. Farmers abandoned many varieties and the reasons of abandonment must be taken in account in the future breeding programs. The desirable and undesirable traits of the Asian and African rice revealed by the farmers should serve as bases for selection by breeders in possible varietal development. An integration of formal and informal seed systems is required for improving the efficiency of the rice seed system in Benin. Likewise, the development of resistant/tolerant rice varieties to drought and flooding stresses is recommended. The pool of performant rice varieties in this regard will be useful in future rice breeding programs.

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Compliance with ethical standards

We obtained the oral consent of the surveyed village chiefs and rice farmers to share their knowledge after presenting them the objectives of our study.

Disclosure of potential conflicts of interest

The authors declare that they have no conflict of interest.

Data availability

Raw and treated data generated during study are available from the corresponding author on reasonable request.

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Figure captions

Figure 1: Map of Benin showing the surveyed villages

Figure 2: Criteria used by surveyed farmers to identify rice varieties

Figure 3: Morphotype of the inventoried rice folk varieties grown in traditional Beninese agriculture

Figure 4: Map showing the repartition of rice diversity in Republic of Benin

Figure 5: (a) Graphic representation of contribution of each variable to the contribution of the first and second component (axes 1 and 2). (b) Two-dimension plot of Principal Component Analysis (PCA) clustering based on the reason of rice varieties abandonment in the study area in function of ethnic groups.

Figure 6: Dendrogram showing the relationship between the rice varieties grown in Republic of Benin basing on participative evaluation

Table 1: Sociodemographic characteristics of surveyed households in the Republic of Benin.

Characteristics	North (N= 227)	Centre (N=53)	South (N=138)	Study area (N = 418)	X^2-test	F-test
Gender (%)						
Male	74.9	69.8	76.1	74.6	0.809ns	-
Female	25.1	30.2	23.9	25.4		
Education level (%)						
No formal education	69.2	62.3	57.2	64.4	12.482ns	-
Primary	20.1	24.5	19.6	20.5		
Secondary	9.8	13.2	21	13.9		
University	0.9	-	2.2	1.2		
Age (years)						
Average	43.6 ± 0.8	43.1 ± 1.1	47.6 ± 1.8	43.9 ± 0.6	-	2.648ns
Range	[18-85[	[25-78[	[17-76[	[17-85[		
Household size (%)						
Average	9.5 ± 0.4	7.7 ± 0.4	7.5 ± 0.3	8.6 ± 0.2	-	6.009**
Range	[1-34[	[2-15[	[1-24[	[1-34[		
Experience (years)						
Average	15.1 ±0.8	15.1 ± 1.9	11.5 ± 0.3	13.9 ± 0.8	-	3.479**
Range	[1- 66[	[1-37[	[1-60[	[1-66[		
Farm size (hectare)						
Average	0.9 ± 0.0	1.2 ± 0.2	1.6 ± 0.3	0.9 ± 0.0	-	27.581***
Range	[0.05-16[	[0.25-5[	[0.25-8[	[0.05-16[		
Ethnic groups (%)						
Bariba	29.8	-	-	16.4		
Adja	-	-	25.8	8.5		
Fongbé	-	9.4	21.8	8.3		
Wémègbé	-	-	21.8	7.2		
Lokpa	12.6	-	-	7		
Dendi	11.9	-	-	6.5		
Aïzo	-		14.9	5		
Ditamari	8.6	1.9	-	5		
Biali	8.6	-	-	4.7		
Germa	8.6	-	-	4.7		
Yom	8.2	-	-	4.5		
Idaasha	-	35.8		4.3		
Sahouè	-	-	8.2	2.7		
Holli	-	-	7.5	2.5		
Wama	4.5	-	-	2.5		
Ifè	-	18.9	-	2.2		
Mbermin	4	-	-	2.2		
Tchabè	-	18.9	-	2.2		
Mokolé	3.2	-	-	1.8		
Mahi	-	13.9	-	1.6		
Natéma	-	1.9	-	0.2		

N= Number of surveyed households. Statistically significant at *P < 0.05, **P < 0.01, ***P < 0.001; ns = not significant.

Table 2: Common names and diversity parameters of rice varieties grown by different ethnic groups in the Republic of Benin

Ethnic groups	Common names of rice	R	ISH
Adja	Monlou	2	0.19
Aïzo	Molikoun	1	0.14
Bariba	Mori, Sinvite	23	4.26
Biali	Moï	6	0.68
Dendi	Mo, Djimbo	9	2.66
Ditamari	Imon, Imouhon	18	1.85
Fon	Monlikoun	1	0.28
Germa	Mo	6	1.26
Holli	Irèssi	1	0.05
Idaasha	Lessi, Ressi	2	0.95
Ifè	Iyessi, Iressi/agnessi	1	0.05
Lokpa	Mwahang, Man'	5	1.09
Mahi	Monlikoun	3	0.39
Mbermin	Imoïri	4	0.80
Mokolé	Mouyé, Sikafa	7	0.61
Natema	Monlikoun	8	0.91
Sahuè	Monlou	3	0.64
Tchabè	Iressi	3	0.56
Wama	Mori, Baaki	12	0.82
Wémègbé	Lessi	1	0.09
Yom	Mouli, Mori, Mli	8	1.19

R = total varieties, ISH = diversity index of Shannon

Table 3: Names and meanings of some rice varieties recorded in the Republic of Benin

Naming criteria	Percentage of responses	Name of varieties (Ethnic groups)	Meaning of the vernacular name
Age of variety and seed colour	3.4	Kpantcho blanc (Ditamari) Timonwonti (Ditamari)	Old variety with white seeds
Plant's beauty	6.9	Wondia (Mokolé) Fondia keno (Dendi)	Beautiful like young lady
		Fondia Ibero (Dendi)	Beautiful like tall lady
Cooking strategy	1.8	Samoussagouni (Dendi)	The woman that don't have the experience cannot cook it
Cycle duration	6.9	Moï lague (Biali) Moï touanga (Biali)	Early variety
		Moï nihoun ou Moi Manga (Biali)	long-cycle variety
		Toyéta (Yom)	Variety of three months
Seed colour	29.3	Lobelobe Koussènou (Lokpa) Imon Iwon (Ditamari)	
		Su itara kpikpa (Wama)	
		Mli piri (Yom)	Rice with purple seeds
		Mori Souan (Bariba)	
		Kpantcho tèro (Wama) Sinvite fanrou (Bariba)	
		Lobelobe doberome (Lokpa)	
		Imon Ipia (Ditamari)	
		Mori kpika (Bariba)	Rice with white seeds
		Moï poria (Biali)	
		Sinvite kpika (Bariba)	
		Imonsoua (Ditamari)	Rice with black seeds
		Toukouchèti (Ditamari)	Rice with red seeds
		Suru ftore kpika (Wama)	
Seed shape	5.2	Yamaboba (Wama)	flat grain variety
		Pointinini (Ditamari)	Long and pointed seeds
Seed size	17.2	Sountam (Dendi)	Rice suitable for flooding
		Mli lèbèlèbè (Yom) Gbéga (Bariba)	Rice with long seeds
		Moï koukourika (Biali)	Rice with short seeds
Institution and strategy of introduction	1.8	ITA 3 (Tchabè)	The third rice variety created and introduce by IITA
		Carder (Bariba)	Introduce by CARDER
		PROCAD (Mokolé)	Introduced by a PROCAD project
		Essai (Bariba)	The evaluation tests have been performed in this village
Origin	6.9	Burkina (Bariba)	Variety coming from Burkina-Faso
		Commonkounkounka	Variety coming from Common village
		Yoncommon (Mbermin)	Variety coming from Common village
		Senegal (Ditamari)	Variety coming from Senegal
		Chinois (Dendi)	Variety coming from China
		Gambiaka (Ditamari, Bariba, Idaasha, Yom, Mbermin)	Variety coming from Gambia

plant habit	3.4	Debout (Wama)	Variety with straight Plants
		Timonsoti (Wama)	Variety with curved plants
Plant size	3.4	Djimbo dogo (Dendi)	Djimbo variety that the plants have a long size
		Degaule (Mokolé)	Long plants variety like president Degaule
		Djimbo gazéré (Dendi)	Djimbo variety that the plants have a small size
		Bakikrouma (Wama)	Rice with short plants
The name of Benin Republic President when the variety has been introduced	3.4	Yayi boni (Bariba, Lokpa)	Introduced when Mister Boni Yayi was the president
Productivity	1.8	Doga (Mokolé)	variety of poor
Relief of the production field	3.4	Takamorri (Bariba)	upland rice, rice planted between the yam mounds
		Danroumorri (Bariba)	variety of lowland
Target population	1.8	NERICA (Wama, Bariba, Tchabè)	New rice for Africa
The first producer of the variety	3.4	Wahabou (Biali)	Variety introduced by Wahabou
		Woroukarimou (Bariba)	Variety introduced by Woroukarimou

Table 4: List of rice varieties recorded in the Republic of Benin and their seed characteristics

N°	Seed's morphological description (mm)						Varieties as perceived by the surveyed farmers	
	LPP	LPC	CS	PC	GL	GW	African rice	Asian rice
1	HUP	S	HSS	W	7.3 ± 0.4abcd	2.2 ± 0.1abcd	Djimbo dogo, Kanwaka, Iressi Olotchoumédji, Gambiaka1, Samoussagouni, Bakilafema, Yoncommon, Mli pori	Tricos
2	SH	S	HSS	W	7.4 ± 0.5abcd	2.2 ± 0.0abcd	Djimbo gazéré, Timonsoti, Sinvite kpika, Toléfa, Moï poga, Lobelobe doberome	IR 841, Procad, Burkina, IR15, Yayi Boni1, Essai, R8, Chinois, 11365, 8 à 8
3	G	S	LSS	W	7.5 ± 0.6bcd	2.1 ± 0.0abcd	Toukouchèti, Doga, Mli Lèbèlèbè, Bakini	Yayi Boni2, Beris 21, Dégaule, Tox 4008, Woroukarimou, Adny 11
4	HUP	B	HSS	W	8.1 ± 0.2d	2.1 ± 0.0cd	Pouinpoua	-
5	HUP	Go	HSS	W	7.7 ± 0.3cd	2.1 ± 0.4cd	Moï lague, Kpantcho blanc, Imon ipia, Bagnéguila	-
6	HLK	PSS	SR	R	6.9 ± 0.1abcd	2.5 ± 0.0cd	Imonsoua, Mori souan, Gambiaka2	-
7	HUP	Go	LSS	W	6.6 ± 1.2abcd	2.4 ± 0.0cd	Comonkounkounga, Bakikrouma, Wahabou	
8	G	Pu	SR	R	7.7 ± 0.2cd	2.1 ± 0.0cd	Timonwonti	-
9	HUP	S	LSS	W	5.9 ± 0.8a	2.2 ± 0.2a	Takamorri, Moi koukourika, Timonpéiti	-
10	HUP	RLP	HSS	Br	5.9 ± 0.3abcd	2.3 ± 0.1abcd	Sinvite fanrou, Antonoumon	-
11	HUP	S	LSS	W	6.7 ± 0.6abcd	2.1 ± 0.1abcd	Gambiaka3	Gbéga1
12	SH	GGF	HSS	W	6.3 ± 0.6abc	2.0 ± 0.0abc	Moï nihoun, Lobelobe koussèmou, Gambiaka4	-
13	HUP	S	LSS	W	6.0 ± 0.5ab	2.2 ± 0.0abcd	Méada, Morri doenoun, Takparakpassé	Debout
14	SH	GGF	SR	W	7.3 ± 0.3abcd	2.5 ± 0.1cd	Moï touanga, Mori kpika, Mli piri, Wondia	
15	HU	S	LS	W	7.2 ±	2.2 ±	Fondia keno, Danroumorri, Moi poria,	Senegal

	P		S		0.7abcd	0.0abcd	Lobèlobè kouholome,	
16	SH	S	HSS	W	7.2 ± 0.5abcd	2.3 ± 0.1abcd	Wobaga, Fondia ibero, Sountam, Aise, Maga, Kpantcho poriwo, Toyéta	-
17	HUP	S	LSS	W	7.5 ± 0.0bcd	2.6 ± 0.1d	Yamaboba Gambiaka5	-
18	HUP	S	LSS	W	6.9 ± 0.7abcd	1.9 ± 0.0abcd	-	Pointinini
19	HUP	GGF	HSS	W	7.3 ± 0.9abcd	2.2 ± 0.1abcd	-	ITA 3, Nerica L14, Carder, Nerica L19, Nerica L8, Yayi Boni3, Nerica L20, BL19, Nerica 6, Inaris 88, Nerica L41, Nerica 16, Gbéga2
20	SH	RLP	HSS	R	7.5 ± 0.9bcd	2.1 ± 0.0bcd	Kpantcho tèro, Suru ftare kpika	-
21	G	Go	HSS	R	7.6 ± 0.0cd	2.4 ± 0.0cd	Moi lopiro, Imon iwon	-

LPP: Lemma and palea pubescence, LPC: Lemma and palea colour, GL: Grain length, GW: Grain width, CS: Caryopsis shape, PC: Pericarp color, HUP: Hair on upper portion, S: Straw, HSS: Half-spindle-shaped, W: white, SH: Short hairs, G: Glabrous, LSS: Long spindle-shaped, B: Brown (tawny), Go: Gold, HLK : Hair on lemma kell, PSS: Purple spots straw, SR: Semi round, R: Red, Pu: Purple, RLP: Reddish to light purple, Br: Brown, GGF: Gold and gold furrows. Means followed by different letters within the same column are significantly different at 0.05 level as determined by the Student Newman-Keuls test.

Table 5: Varietal diversity at the level of villages and rate of threat of landrace disappearance in the Republic of Benin

Village	TNL	Distribution and extent				NNIL	NLD	RTLD
		(H+A+)	(H+A-)	(H-A+)	(H-A-)			
Koungarou	5	3	0	0	2	2	0	0
Totorou	3	1	2	0	0	0	0	0
Igbo-Ede	1	1	0	0	0	0	0	0
Tchakalakou	10	4	0	0	6	5	1	10
Angaradébou	8	2	3	1	2	1	1	12.5
Founougo	9	4	3	0	2	0	2	22.2
Bèkè	4	2	1	0	1	0	1	25
Onklou	4	3	0	0	1	0	1	25
Kounadogou	14	4	3	0	7	3	4	28.6
Koudengou	7	2	1	0	4	2	2	28.6
Kotchessi	6	2	1	0	3	1	2	33.3
Dokomey	3	1	1	0	1	0	1	33.3
Gourouberi	8	3	1	0	4	1	3	37.5
Kenkini-Seri	5	2	0	0	2	0	2	40
Bétérou	5	0	3	0	2	0	2	40
Birni(Gorobani)	4	0	2	0	2	0	2	50
Bori	6	2	0	0	4	1	3	50
Houala	4	1	0	0	3	1	2	50
Loulè	2	1	0	0	1	0	1	50
Kodé	2	1	0	0	1	0	1	50
Gbéko	2	1	0	0	1	0	1	50
Bagou	15	7	0	0	8	0	8	53.3
Nanagadé	7	2	1	0	4	0	4	57.1
Okouta-ossé	7	1	0	0	6	2	4	57.1
Tchalinga	5	2	0	0	3	0	3	60
Gamia	8	1	1	0	6	1	5	62.5
kikele-lokpa	8	1	1	0	6	1	5	62.5
Séwahoué	3	1	0	0	2	0	2	66.7
Gnanlin	3	1	0	0	2	0	2	66.7
Awokpa	4	1	0	0	3	0	3	75
Allahè	4	1	0	0	3	0	3	75
Yaoui	5	1	0	0	4	0	4	80
Agbaboué	5	1	0	0	4	0	4	80
Dévé-Domé	5	1	0	0	4	0	4	80
Houéyogbé	10	1	0	0	8	0	8	80
Hokpamé	5	1	0	0	4	0	4	80
Kpataba	6	1	0	0	5	0	5	83.3
Madécali	14	1	1	0	12	0	12	85.7
Bamè	10	1	0	0	10	0	10	100
	6.05	**1.69**	**0.64**	**0.03**	**3.67**	**0.54**	**3.13**	**49.77**

H: household; A: area; +/-: many or large / few or small; TNL: total number of landraces; NNIL: number of newly introduced landraces; NLD: number of landraces threat of disappearance; RTLD: rate of treat landraces disappearance

Table 6: Popularity of some rice varieties grown in the Republic of Benin

Varieties	NVLL	NVLP	$N_{H+} + N_{A+}$	PRL
Bakikrouman	1	1	2	100
Toukouchèti	1	1	2	100
Burkina	1	1	2	100
Danroumorri	1	1	2	100
Djimbo gazéré	1	1	2	100
Gbega	1	1	2	100
IR 15	1	1	2	100
Kpatcho poriwo	1	1	2	100
Kpatcho tèro	1	1	2	100
Lèbèlèbè dobèrome	1	1	2	100
Lobèlobè koussèmou	1	1	2	100
Moï lague	1	1	2	100
Moï touanga	1	1	2	100
NERICA L20	1	1	2	100
Samoussagouni	1	1	2	100
Takamorri	1	1	2	100
Toyéta	1	1	2	100
Tricos	1	1	2	100
Woroukarimou	1	1	2	100
Yoncommon	1	1	2	100
IR841	31	30	54	87.10
Yayi Boni	3	3	5	83.33
Essai	2	2	3	75
Moïnihoun ou Manga	2	2	3	75
R8	5	3	6	60
Common-Kounkouga	1	1	1	50
Kpantcho blanc	1	1	1	50
Mli lèbèlèbè	1	1	1	50
Mli piri	1	1	1	50
Moï poua	2	1	2	50
Timonsoti	2	1	2	50
Wobaga	1	1	1	50
Wondia	1	1	1	50
Gambiaka	15	6	11	36.67
Degaule	4	2	2	25
Méada	2	1	1	25
Yamaboba	2	1	1	25
BL 19	8	2	3	18.75
Takpara kpassè	6	1	1	8.33
BERIS 21	8	1	1	6.25

NVLL: Number of villages where the variety is listed; NVLP: Number of villages where the variety is popular (variety cultivated by many households in at least one village); NH+ = Number of villages where the variety is cultivated by many households; NA+ = Number of villages where the variety is cultivated on large areas.

Table 7: Abandoned varieties per village in the Republic of Benin

Regions	Villages	Number of varieties	Abandoned varieties
North	Koungarou	1	Gambiaka
	Bétérou	2	Gambiaka, Degaule
	Birni	2	Mlimorri, Gambiaka
	Nanagadé	2	NERICA L20, Common Kounkounga
	Onklou	2	Lèbèlèbè-molli, toyéta
	Tchakalakou	2	Gambiaka, NERICA L20
	Bori	3	R9, montchré, Degaule
	Founougo	3	Adny-11, Tox, Gambiaka
	Tchalinga	3	Takparakpassé, lobolobo kounlone, ketouketou
	Kenkini-Séri	3	Moïlopiro, Moïpoua, Moïnihoun
	Kikele-lokpa	3	BL19, lobolobo, IR841
	Kotchéssi	4	Moïlopiro, Moïpoua, Moïnihoun, moïkoukourika
	Angaradébou	5	R8, BÉRIS 21, Méada, Tricos, Wita
	Béké	5	NERICA L20, IR841, Gambiaka, BL19, NERICA 1
	Kounadogou	5	Yamaboda, gambiaka, Imonsoua, Imon-iwon, Inaramoumoua
	Bagou	6	Gambiaka, pisséré, Nerica, Batonoumori, Autonomon, Banikoara
	Gamia	6	Gambiaka, yayi boni, NERICA L20, IR22, IR8, IR4
	Gourouberi	6	Djimbo, Tox, Adiny11, Dassagarbi, soukézo, yaléyouti
	Madécali	12	Méada, Impotoga, Fondia, Damba, Sommonce, R8, Bagnéguila, Batché-éri, goudigoudi, Manyimanza, kouatérizé, sobsob
Centre	Okouta-Ossè	6	BL19, NERICA 1, NERICA 2, BÉRIS 21, NERICA 4, Djodo Ogboyin wabo
	Yaoui	2	ITA2, Gambiaka, NERICA 4
	Houala	2	Gambiaka, NERICA L20
	Kpataba	2	Gambiaka, BÉRIS 21
	Agbaboué	3	Gambiaka, NERICA 2, BÉRIS 21
	ILoulè	1	Gambiaka
South	Sewahoue	1	NERICA L24
	Gbeko	1	NERICA L20
	Dokomey	2	NERICA L20, TOX Long
	Gnanlin	2	BL19, NERICA L20
	Allahè	3	NERICA L20, BÉRIS 21, TOX
	Awokpa	3	NERICA L20, NERICA 4, TOX
	Hokpame	4	NERICA 1, BERIS 21, NERICA L14, NERICA 8
	Bamè	8	NERICA L19, NERICA 1, NERICA 4, NERICA L14, NERICA L41, NERICA 3, Gambiaka, NERICA L20
	Dévé-Homey	9	ITA4, NERICA L20, NERICA L42, NERICA L45, NERICA 1, NERICA L14, IR841, 11365, NERICA 4
	Houéyogbé	9	NERICA 4, Gambiaka, 11365, Adny, ITA212, BÉRIS 21, INARIS 88, NERICA L20, NERICA 1
	Kodé	1	NERICA L20

Table 8: Reasons for abandoning landraces and their importance in the Republic of Benin

Reasons of diversity loss	Percentage of responses			
	North	Centre	South	Benin
Low productivity	23.64	32.26	18.92	25.36
Lack of aroma	-	24.19	40.54	14.35
Lack of sales market	7.27	19.35	21.62	13.40
Long life cycle	20.91	4.84	-	12.44
Bad taste	4.55	4.84	8.11	5.26
Low market value	9.09	-	-	4.78
Lack of seeds	6.36	3.23	2.70	4.78
Water-intensive variety	5.45	3.23	-	3.83
Too much starch	3.64	3.23	2.70	3.35
Susceptible to plant lodging	4.55	-	2.70	2.87
Poor quality of dough	3.64	1.61	-	2.39
Sensitivity to flooding	2.73	-	-	1.44
Grains not appreciated by their red colour	0.91	-	2.70	0.96
Too much breakage during shelling	1.82	-	-	0.96
Difficult farming practices	-	3.23	-	0.96
fall of paddy grain before harvest	0.91	-	-	0.48
Fish damage due to flooding	0.91	-	-	0.48
High cost of seeds	0.91	-	-	0.48
High cost of agricultural inputs	0.91	-	-	0.48
Lack of time to take care of rice production	0.91	-	-	0.48
Long cooking time	0.91	-	-	0.48

Table 9: Farmers' perceptions of desirable and undesirable traits of African and Asian rice throughout the production zones of Benin Republic

Traits	Characteristics	African rice (*O. glaberrima*)				Asian rice (*O. sativa*)			
Desirable		South (N=25)	Centre (N=17)	North (N=188)	Study area (N=230)	South (N=34)	Centre (N=23)	North (N=188)	Study area (N=245)
	Flood adaptation	65.4	10.5	32.4	33.8	-	-	-	-
	High productivity	-	10.5	30	26.5	39	39.1	12.6	21
	Good taste	-	-	24	20.7	-	6.5	11.2	8.4
	Disease resistant	30.8	79	0.4	7.3	-	-	-	-
	High storage time of rice dough (up to 3 days)	-	-	4.9	4.3	-	-	-	-
	Swelling of grains during cooking	-	-	4.6	4.1	-	-	-	-
	Resistance to birds	-	-	0.7	0.6	-	-	-	-
	Fit for transformation	-	-	0.7	0.6	-	2.2	-	0.3
	Variety adapted to climatic hazards	3.8	-	0.4	0.6	-	-	-	-
	Large grains	-	-	0.7	0.6	-	-	-	-
	Easy deshelling without breaking the grain	-	-	0.4	0.3	-	-	-	-
	Large plant size	-	-	0.4	0.3	-	-	-	-
	Easy to cook	-	-	0.4	0.3	-	-	1.1	0.7
	Dwarf plant	-	-	-	-	9.8	15.2	1.8	4.9
	Short cycle (3-4 months)	-	-	-	-	37.8	32.6	63.5	54.8
	No lodging	-	-	-	-	12.2	2.2	3.6	5.2
	Perfume grains	-	-	-	-	1.2	2.2	4.7	3.7
	Good for cooking fatty rice	-	-	-	-	-	-	1.2	0.7

	Less water demanding	-	-	-	-	-	-	0.3	0.3
Undesirable		(N=34)	(N=23)	(N=187)	(N=244)	(N=24)	(N=15)	(N=187)	(N=226)
	Long cycle (5-6 months)	30.8	32.7	57.9	49.8	-	-	-	-
	Frequent plant lodging	20.5	8.2	17.7	17.1	-	-	-	-
	Low productivity	11.5	2	9.2	8.8	-	-	5.7	4.7
	Big plant size	30.8	12.2	-	7.3	-	-	0.5	0.4
	Large grains	6.4	24.5	-	4.1	-	-	-	-
	Water-demanding plant	-	2	3.9	2.9	-	-	-	-
	Susceptibility to pests	-	-	3.9	2.7	-	-	23.8	19.8
	Susceptibility to flooding	-	-	3.5	2.4	-	-	0.5	0.4
	Bad taste	-	10.2	1.1	2.1	-	-	-	-
	Bad smell	-	2	1.1	1	-	-	-	-
	Unscented grain	-	6.2	-	0.7	-	-	-	-
	Not suitable for cooking fatty rice	-	-	1.1	0.7	-	-	-	-
	Grey grain colour	-	-	0.3	0.2	-	-	-	-
	Susceptibility to diseases	-	-	0.3	0.2	33.3	93.3	-	9.5
	Not suitable for flooding	-	-	-	-	66.7	6.7	44.6	44.4
	High degree of gelatinization	-	-	-	-	-	-	2.1	1.7
	No taste compared to African rice	-	-	-	-	-	-	15.5	12.9
	Sensitivity to drought	-	-	-	-	-	-	1.1	0.9
	Low storage time of rice dough (less than 2 days)	-	-	-	-	-	-	6.2	5.2

N= Number of surveyed households.

Table 10: Varietal preference criteria of rice by farmers in the Republic of Benin

Preference traits	**North** (N=227)	**Centre** (N=53)	**South** (N=138)	**Percentage**
High productivity	28.6	39.6	33.5	31.3
Good culinary quality	24.4	27	24.1	24.6
Early variety	17.2	4.5	14.2	14.9
Resistant to pests and diseases	10.7	12.6	8.6	10.2
Good perfume	4.1	15.3	15.1	8.8
Grain size	3.6	-	3.9	3.3
Resistant to climatic hazards	4.8	1.0	0.6	3.0
Easy to sell	4.6	-	-	2.7
Shelling with less breakage	1.0	-	-	0.6
Adaptation to soils other than lowlands	1.0	-	-	0.6

Table 11: Farmers' perceptions of varietal performance for selected evaluated parameter in Benin

Evaluated parameter	Variables	Number of varieties	Name of performant varieties
Drought sensitivity	Sensitive Tolerant	96 1	Chinois
Flooding sensitivity	Sensitive Tolerant	91 6	Doga, Gambiaka1, Gambiaka2, Gambiaka3, Gambiaka4, IR841
Diseases sensitivity	Sensitive Tolerant	59 38	Aïsé, Bakini, BERIS21, BL19, Carder, Commonkounkounka, Degaule, Doga, Essai, Fondia Ibero, Fondia keno, Gambiaka1, Imon ipia, Imoniwon, Imonsoua, IR15, Takparakpassé, R8, IR841, Kanwaka, Kpantcho blanc, Lobelobe Koussèmou, Lèbèlèbè, Mli Lèbèlèbè, Moï lague, Moi koukourika , Mori Souan, Moï nihoun, Mori kpika, Moï poua, Pointinini, Suru Ftaré Kpika, Timonwonti, Timosoti, Toukouchèti, Tricos, Yamaboba, Yayi boni
Birds attack	Sensitive Tolerant	83 14	Aïsé, BL19, Degaule, Gambiaka2, IR841, Kpantcho blanc, Lèbèlèbè, Mli piri, Mli Lèbèlèbè, Djimbo gazéré, Mori kpika, Pointinini, Suru Ftaré Kpika, Timosoti
Insects attack in the fields	Sensitive Tolerant	55 42	Aïsé, Bakini, BERIS21, BL19, Carder, Chinois, Commonkounkounka, Degaule, Djimbo gazéré, Djimbo dogo, Essai, Fondia Ibero, Fondia keno, Gambiaka2, Imon Ipia, ImonIwon, Imonsoua, IR15, Takparakpassé, R8, IR841, Kanwaka, Kpantcho blanc, Lobelobe Koussèmou, Lèbèlèbè, Mli Lèbèlèbè, Moï lague, Moi koukourika, Mori Souan, Moï nihoun, Mori kpika, Moï poua, Pointinini, Suru Ftaré Kpika, Timonwonti, Timosoti, Toukouchèti, Tricos, Yamaboba, Yayi boni, NéricaL19, Toyéta
Sensitivity to weeds	Sensitive Tolerant	85 12	8à8, Bakikrouma, Bakini, Degaule, Gambiaka, Kpantcho, Lèbèlèbè doberome, Mori touanga, Pouinpoua, IR15, Yayi Boni1
Insects storage	Sensitive Tolerant	36 61	Aïsé, Bakini, BERIS21, BL19, Carder, Chinois, Commonkounkounka, Danroumorri, Degaule, Djimbo gazéré, Djimbo dogo, Essai, Fondia Ibero, Fondia keno, Gambiaka, Gbega, ITA3, Imon Ipia, ImonIwon, Imonsoua, IR15, Takparakpassé, IR841, Kanwaka, Kpantcho blanc, Kpantcho tèro, Lèbèlèbè doberome, Lobelobe Koussèmou, Mli Lèbèlèbè, Mli piri, Moï lague, Moi koukourika, Mori Souan, Moï nihoun, Mori kpika, Moï poua, Nérica 4, Nérica L14, Nérica L16, Nérica L19, Nérica L41, Nérica 5, Nérica L20, Pointinini, Pouinpoua, PROCAD, R8, Samoussagouni, Sinte fanrou, Sinvite Kpika, Suru Ftaré Kpika, Taka morri, Timonwonti, Timosoti, Toukouchèti, Tricos
Productivity	Low productivity High	50 47	Aïsé, Bakini, BERIS21, BL19, Carder, Degaule, Djimbo gazéré, Djimbo dogo, Essai, Fondia Ibero, Fondia keno, Gambiaka, Gbega, Imon Ipia, ImonIwon, Imonsoua, IR15, IR841, Kpantcho, Kpantchotèro, Lèbèlèbè Koussénou, Mli Lèbèlèbè, Mli piri, Moï lague, Moi koukourika , Moripoua ,Moï nihoun, Mori

	productivity		kpika, Moï touanga, Nérica L14, Nérica L19, Nérica L20, Sinte fanrou, Sinvite Kpika, Suru ftaré kpika,
Taste	Good	87	BL19, Degaule, Djimbo gazéré, Essai, Gambiaka, IR841, Moi nihoun, Moï touanga, Nérica L14, Yayi boni2
	Very good	10	
Cooking features	Good	86	BÉRIS21, Chinois, Djimbo gazéré, Djimbo dogo, Essai, Gambiaka2, IR841, Moi nihoun, Moï touanga, Wondia, Yayi boni1
	Very good	11	
Shelling	Difficult	88	Degaule, Djimbo gazéré, Essai, Imon ipia, IR841, Moï nihoun, Moï lague, Moï touanga, Yayi boni2
	Easy	9	

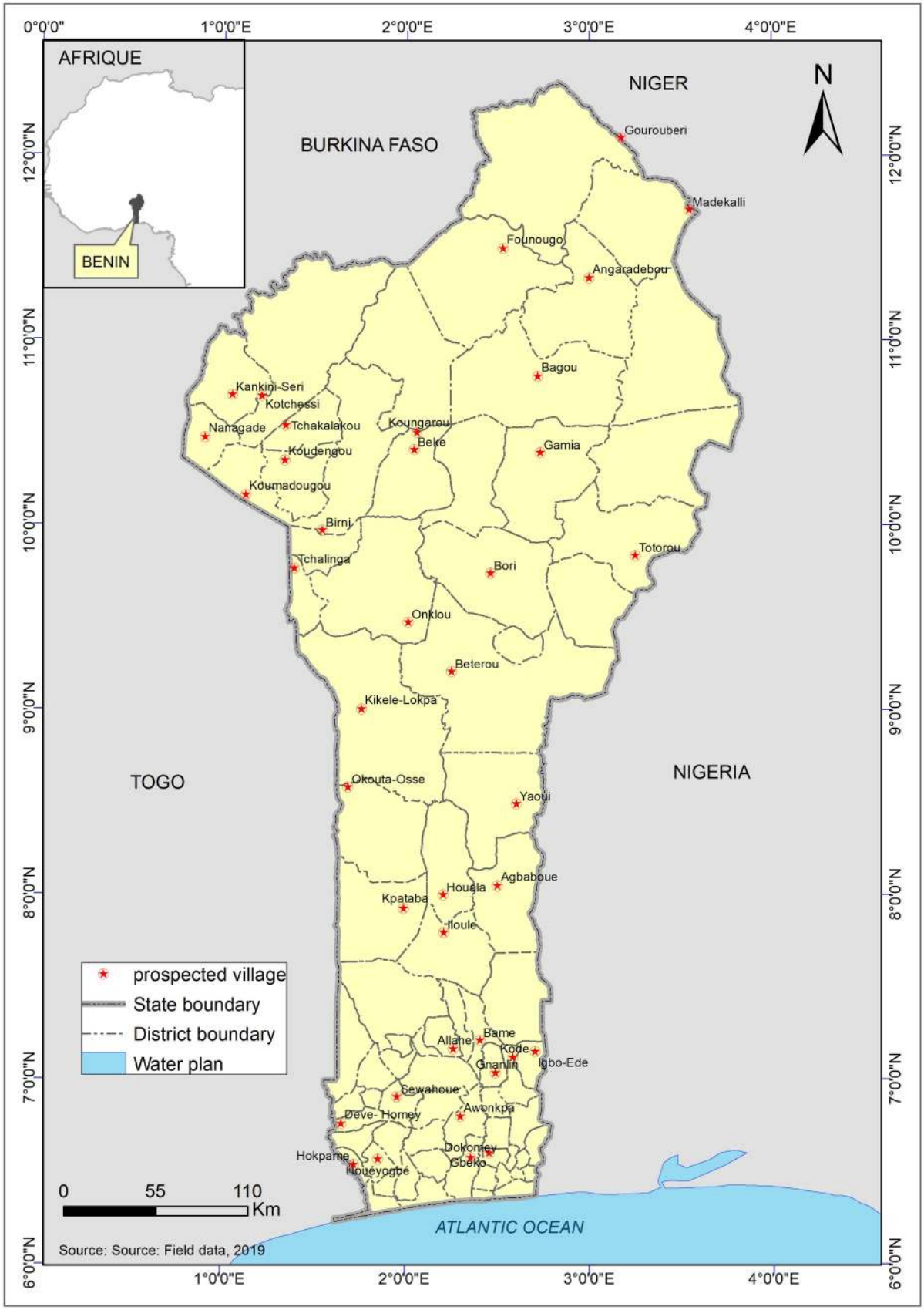

Figure 1: Map of Benin showing the surveyed villages

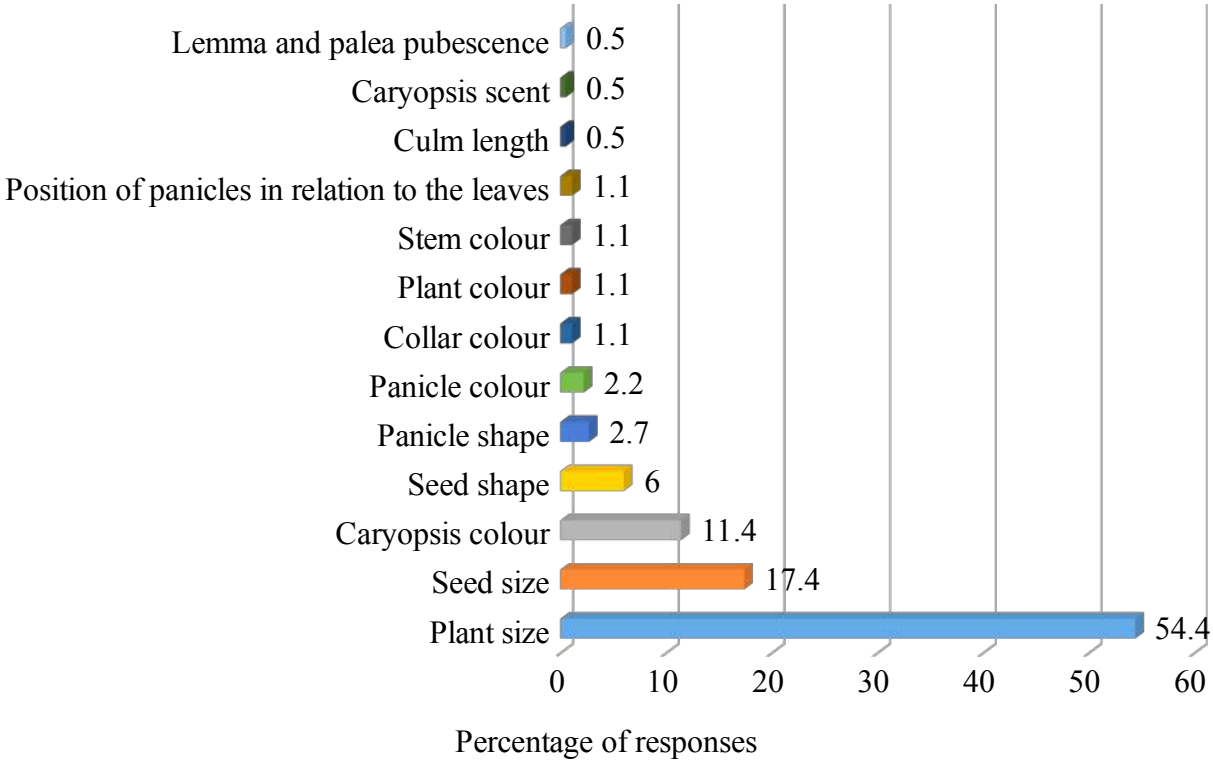

Figure 2: Criteria used by surveyed farmers to identify rice varieties in Benin

Figure 3: Morphotype of the inventoried rice ~~folk~~ varieties grown in the traditional Beninese agriculture

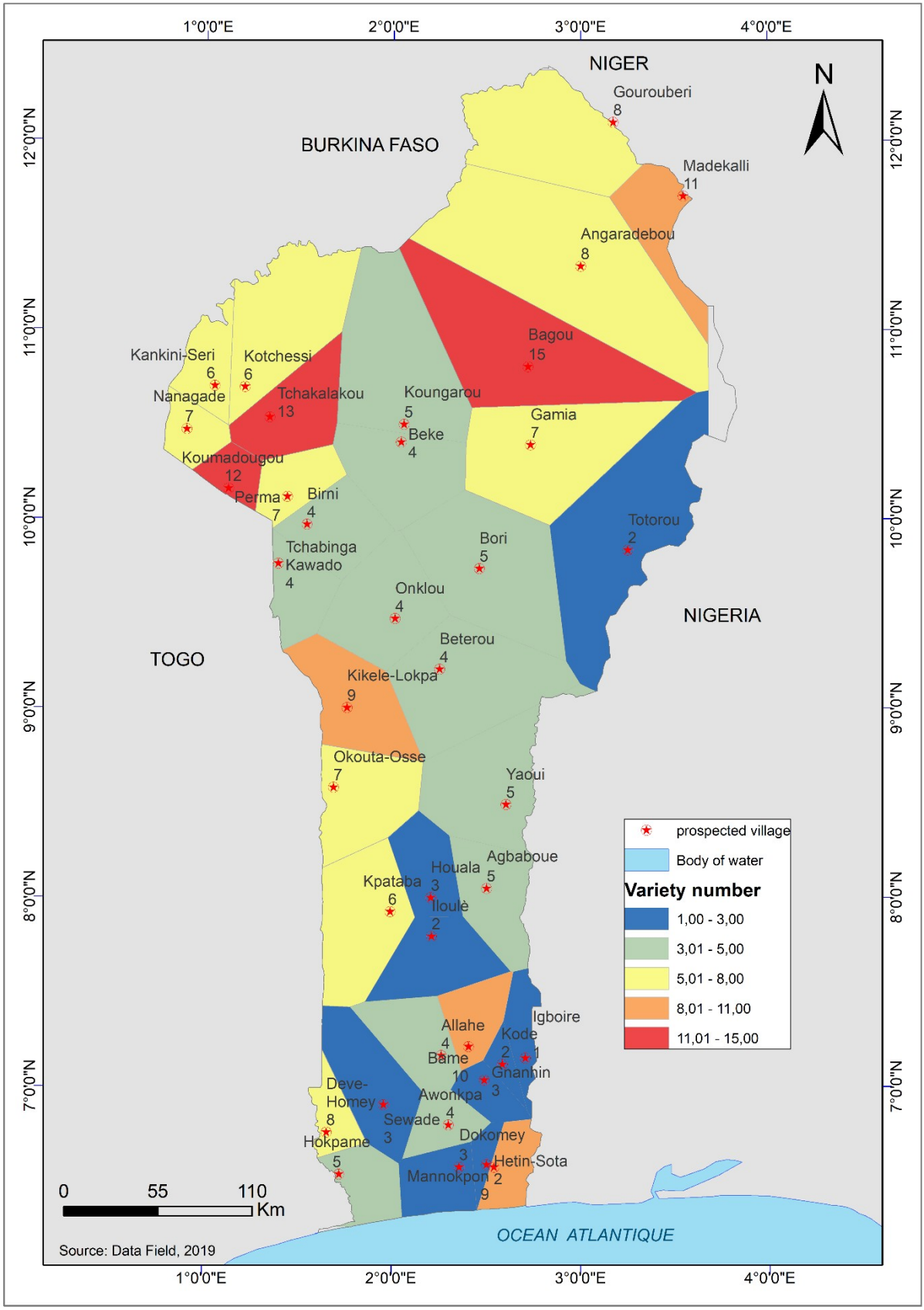

Figure 4: Map showing the repartition of rice diversity in the Republic of Benin

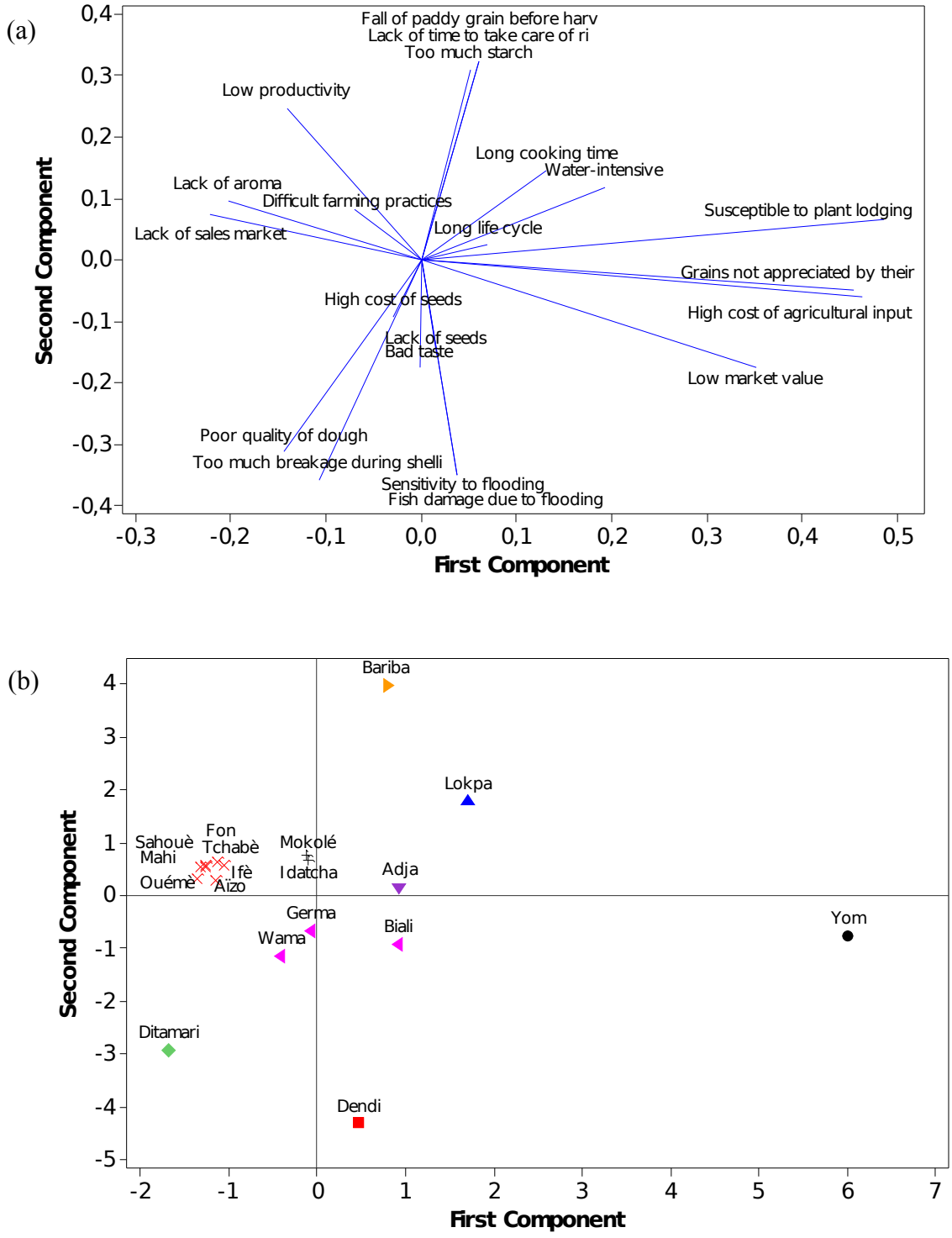

Figure 5: (a) Graphic representation of contribution of each variable to the contribution of the first and second component (axes 1 and 2). (b) Two-dimension plot of Principal Component Analysis (PCA) clustering based on the reason of rice varieties abandonment related to ethnic groups.

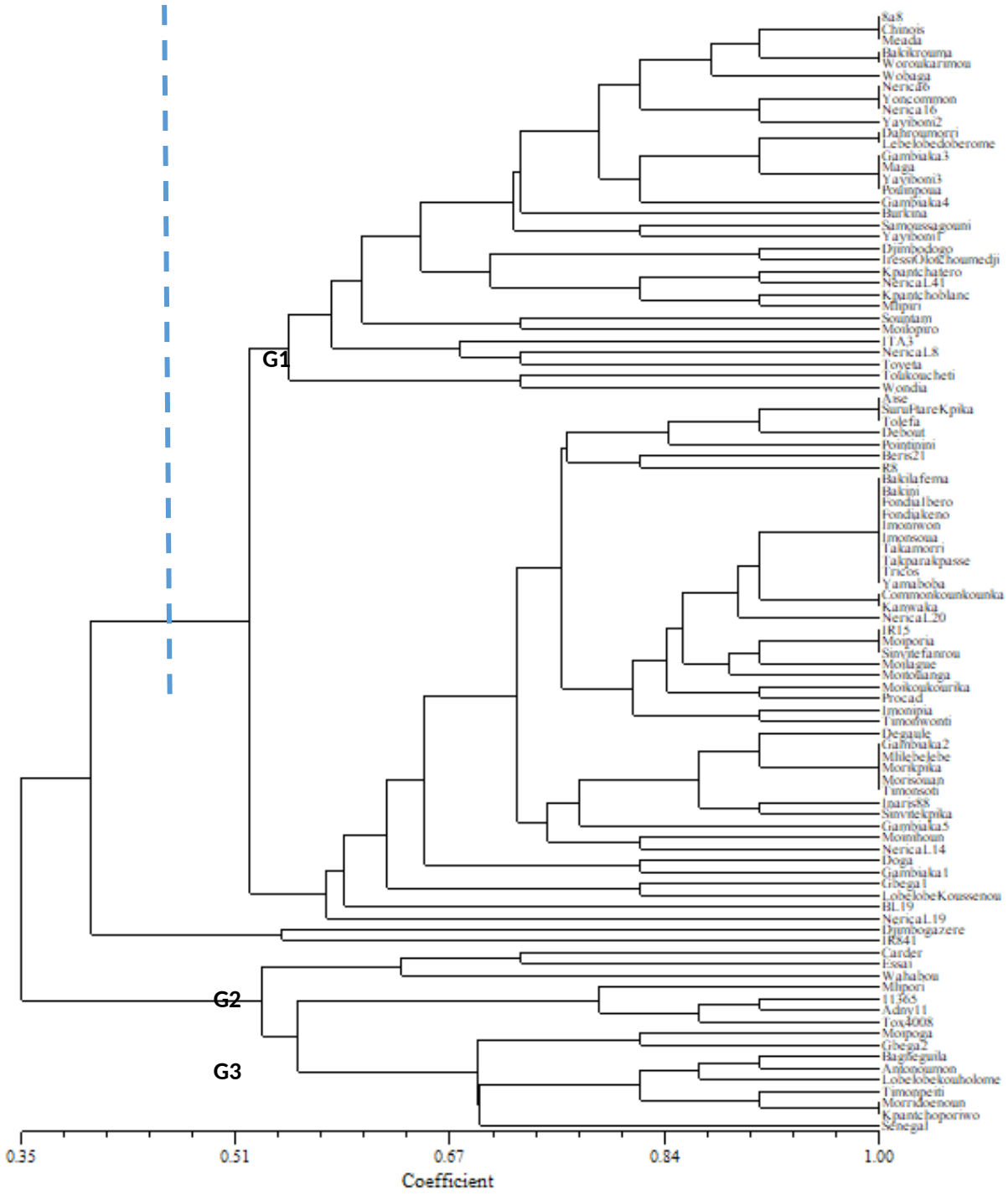

Figure 6: Dendrogram showing the relationship between the rice varieties grown in Republic of Benin based on participative evaluation