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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

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1 **On-farm management of rice diversity, varietal preference criteria, and farmers'**
2 **perceptions of the African (*Oryza glaberrima* Steud.) versus Asian rice (*Oryza sativa* L.) in**
3 **the Republic of Benin (West Africa): implications for breeding and conservation**

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13 **Short title:** “Loko et al: On farm management of rice diversity in Benin”

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15 **Abstract**

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

24 68 local varieties were registered and their folk nomenclature and taxonomy were documented.
25 The north of Benin had the highest diversity of rice with the greatest number of traditional
26 varieties, making this region the best place for an *in situ* conservation program. The number of
27 rice varieties maintained per village varied from 1 to 15 (six on average). The foursquare analysis
28 revealed that the improved variety IR 841 was by far the most popular variety. Most of NERICA
29 varieties were abandoned in the south, while the north still host a wide range of local varieties.
30 Twenty-one reasons explained varietal abandonment by farmers, varying according to geographic
31 areas and ethnic groups. The seed system was both formal and informal in the study area. The
32 participatory evaluation revealed the necessity to create and introduce tolerant/resistant rice
33 varieties to drought and flooding stresses in Beninese agriculture that meet farmers' preferences.
34 Our results showed that the north Benin would be the most suitable place for in situ conservation
35 of local rice diversity.

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

37

38 **Introduction**

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

47 The rice sector has become one of the most dynamic agricultural sectors in the Republic of
48 Benin with production increasing steadily over the years (FAO 2018). This increase in rice
49 production could be due to an increase in cultivable areas and also by the massive introduction
50 into Beninese agriculture of improved rice varieties such as the hybrid NERICA (New Rice for
51 Africa) varieties, resulting from the cross between African (*Oryza glaberrima* Steud.) and Asian
52 (*Oryza sativa* L.) rice (Yokouchia and Saito 2017). However, little information exists on the
53 impact of the introduction of improved rice varieties on the maintenance of local varieties in
54 Beninese agriculture. Indeed, it is well known that a large number of traditional varieties are
55 often supplanted by a small number of improved varieties, which contribute to their
56 disappearance (Joshi and Bauer 2007). The loss of traditional varieties could be accompanied by
57 a loss of unique genes of interest for the breeding of improved rice varieties (Ficiciyan et al.
58 2018). Therefore, it is important to document rice diversity maintained in the traditional Beninese
59 agriculture and how farmers manage this diversity. This information is a fundamental prerequisite

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

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

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

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

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

88 **Material and methods**

89 **Study area**

90 The present study was carried out in the Republic of Benin located in West Africa (between the
91 parallels 6° 30' and 12° 30' north latitude, and the meridians 1° and 30° 40' east longitude). With
92 a population estimated at 11 340 504 inhabitants, the Republic of Benin is subdivided into three
93 geographic zones (South, Centre, and North) and three climatic zones (Guineo Congolese zone
94 (6 °25'–7 °30'N) in the south, Sudano-Guinean transition zone (7 °30'–9 °45'N) in the centre and
95 Sudanic zone (9 °45'–12 °25'N) in the north). In the Guineo Congolese zone, the rainfall regime
96 is bimodal with alternating dry seasons (November to March and mid-July to mid-September)
97 and rainy seasons (April to mid-July and mid-September to October). While, the two other
98 climatic zones have a unimodal rainfall distribution pattern characterized by a dry season from
99 November to April and a rainy season from June to September. Three types of vegetation
100 characterize Benin: the savannah with trees in the Sudanese regions of the North; the savannah in
101 the Centre with species like Mahogany and Iroko; and the forest in South Benin. The temperature
102 varies from 24° C to 31°C throughout the study area. The soils are deep ferrallitic or rich in clay
103 in the south Benin, ferruginous in the centre, and hydromorphic in the north.

104 **Ethnobotanical surveys**

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

110 Classical participatory research appraisal tools (individual interviews, focus groups, and
111 direct observations) were used for collected data. In each village, the interviews and discussions
112 were conducted in the local language or dialect with the help of local translators. The focus group
113 discussions (FGDs) in each village comprised 15 to 20 rice farmers, of both genders and different
114 ages. These rice farmers were identified and assembled with the assistance of the local farmers'
115 associations and village chiefs, in order to facilitate the organization of the meetings and the data
116 collection (Kombo et al. 2012). When coming for FGDs, after obtaining the farmers' oral consent
117 to participate, farmers were requested to bring samples of the rice varieties they currently or
118 recently cultivate. During the FGDs, farmers were asked to list (using vernacular names) and
119 display the different rice varieties grown in their villages. The distribution and extent of
120 cultivated rice varieties were assessed using the Four Squares Analysis approach (Loko et al.
121 2013; Orobiyi et al. 2017). This approach helps to classify the varieties at community level,
122 taking into account the area (large or small) devoted to the variety and the number of households
123 (few or many) cultivating it. The varieties can thus be classified into four groups (varieties
124 cultivated by many households on large areas; varieties cultivated by many households on small
125 areas; varieties cultivated by few households on large areas, and varieties cultivated by few
126 households on small areas). To do this, criteria were established together with the farmers
127 following Kinhoégbè et al. (2020): (i) a variety was considered cultivated by many households
128 when over 50 % of the households of the village grew it; and (ii) a variety was considered

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

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

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

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

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

158 **Data analysis**

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

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

$$166 \quad PRL = 100 \times NVLP/NVLL \times (N_{H+} + N_{A+})/2NVLP \quad (1)$$

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

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

$$173 \quad RTLTD = NLTD /TNL \times 100 \quad (2)$$

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

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

$$180 \quad H = - \sum P_i \text{Log } P_i \quad (3)$$

181 $P_i = n_i / N$, with n_i = number of varieties in each village and N = sum of n_i .

182 For rice diversity map, Thiessen polygon method was applied to determine the different
183 zones of influence by geometric cutting. The method is based on the Delaunay triangulation using
184 the mediator method between the different rice production fields, using ArcGIS software version
185 10.2.

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

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

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

204 **Results**

205 **Socio-demographic characteristics of the households surveyed**

206 Men (74.6%) headed most of the households interviewed in the three surveyed regions
207 (Table 1). Very few, non-significant, differences were observed between the three regions in
208 terms of educational level, with most of the farmers being illiterate (64.4%), and only 1.2%
209 having a university level (Table1). The surveyed farmers were relatively young with an age
210 ranging from 17 to 85 years with an average of 44 years. The surveyed households had large
211 families ranging from 1 to 34 people, and differences in household size were observed from
212 region to another: average size of surveyed households in northern Benin (9.5 ± 0.4 people) was
213 significantly higher than that of southern households (7.5 ± 0.3 people) and central Benin ($7.7 \pm$
214 0.4 people). In terms of years of experience in rice production, the interviewed producers in the
215 northern (15.1 ± 0.8) and central (15.1 ± 1.9) regions were found to be more experienced than
216 those from the southern region (11.5 ± 0.3). In general, the surveyed producers had good
217 experience in the production of rice with an average of 14 years of practice. The heads of
218 households interviewed were smallholders, with farms averaging 0.9 ha, but average farm size
219 varied considerably between regions, with the south having the largest plots planted by farmers
220 (Table 1). Twenty-one ethnic groups were interviewed across the study area.

221 **Local nomenclature**

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

231 **Folk taxonomy**

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

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

249 **Diversity structuration based on seed characteristics**

250 The FGDs carried out in each village helped identify, subject to synonymy, 30 improved and
251 68 local rice varieties across the study area (Table 4). A classification of these varieties, based on
252 the seed morphological traits, enabled to group them into 21 morphological groups (Figure 3).
253 There were significant differences between the 21 seed morphotypes, in terms of grain length
254 ($ddl = 106, F = 3.106, P < 0.000$), and grain width ($ddl = 106, F = 2.938, P < 0.000$). The seeds had
255 different lemma and palea pubescence (glabrous, hair on upper portion, hair on lemma keel and
256 short hairs), lemma and palea colour (straw, brown, gold, purple spots straw, purple, reddish to
257 light purple, and gold and gold furrows), caryopsis shape (long spindle-shaped, half-spindle-
258 shaped, and semi round) and pericarp colour (white, red, and brown) (Table 4). The Poinpoua
259 variety collected in Kenkini-Séri village had the longest grain size and Takamorri, Moi
260 koukourika, Timonpéti varieties, presented the smallest grains (Table 4). On the other hand, the
261 rice varieties Yamaboba, and Gambiaka 5 had the widest grains. Further, 10 and eight rice
262 morphotypes were found in the south (N° 1, 2, 3, 4, 8, 11, 12, 18, 19, 21) and centre (N° 1, 2, 3,
263 8, 11, 12, 18, 19) of Benin, respectively (Figure 3), while 12 (N° 5, 6, 7, 9, 10, 13, 14, 15, 16, 17,
264 20, 21) were specific from the northern region. Some morphotypes included both African and
265 Asian rice varieties (Table 4).

266 **Distribution of rice varieties**

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

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

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

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

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

300 **Abandoned rice varieties**

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

313 **Reasons for varietal abandonment**

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

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

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

342 **Farmers' perceptions of Asian versus African rice**

343 For most of the surveyed farmers (59.6%), there was no difference between African and
344 Asian rice. The remaining surveyed farmers (40.4%) used eight criteria to differentiate African
345 from Asian rice: plant size (78.7% of responses), long life cycle (6.3%), productivity (5.7%),
346 seed length (4.1%), and lodging of rice plants (3.4%) were generally cited, although few
347 surveyed farmers used the taste (0.6%), leaf width (0.6%), and seed colour (0.6%). Farmers
348 revealed 14 and 10 undesirable traits of African and Asian rice, respectively (Table 9) and 13 and
349 10 desirable traits (Table 9). For the farmers in southern and central Benin, the flooding
350 adaptation and the resistance to diseases were the main desirable traits of the African rice while
351 good taste dominated among the northern farmers (Table 9). Throughout the study area, the most
352 undesirable trait of African rice mentioned by farmers was its long life cycle (5-6 months), and
353 susceptibility to flooding of fields and diseases for the Asian rice (Table 9).

354 **Seed system**

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

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

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

368 Almost all the surveyed farmers (96%) revealed that the seed they used was of good quality,
369 while few (2.9%) considered that the seed was of an acceptable quality. Most of the surveyed
370 farmers (80.1%) reported that they did not make any selection of seeds for the following season,
371 whereas the remaining (19.9%) selected seed to obtain good quality seeds. To select seed, the
372 farmers used four criteria: seed uniformity (45.5% of responses), seed size (42.2%), seed colour
373 (11.7%) and seed purity (0.6%).

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

378 **Farmers' varietal preference criteria**

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

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

385 **Evaluation of agronomic, technological and culinary performances of rice varieties**

386 Subject to synonymy, the participatory evaluation of rice varieties led to the identification of
387 1 to 65 performant varieties per evaluated parameters (Table 11). Tolerance to insect storage
388 attacks (61 varieties), high productivity (47 varieties), tolerance to insect attack in the fields (42
389 varieties), and tolerance to diseases (38 varieties) were the parameters for which more performant
390 varieties were found. Very few performant varieties were identified for drought tolerance (1),
391 flooding tolerance (6 varieties), and easy shelling (9 varieties). Several rice varieties were found
392 to be well performing for more than one parameter (Table 11).

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

399 **Discussion**

400 Through the surveyed ethnic groups, 91 names of rice varieties were recorded, indicating the
401 long history of rice production in Benin, but also a quite considerable rice diversity. Similar to the
402 Malagasy (Radanielina et al. 2013), Nepalese (Bajracharya et al. 2010), and Lao (Appa Rao et al.
403 2002) rice producers, most of the names given to rice varieties had significant meanings, and
404 reflected, for the majority, the rice morphological characteristics. Thus, the knowledge of the
405 meanings of the rice names did not only facilitate communication and knowledge exchange

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

417 Our results regrouped the rice accessions in 21 morphological groups based on seed
418 characteristics. This diversity is very low compared to those found in Guinea (387 rice varieties;
419 Barry et al. 2008), in Bangladesh (670 unique rice varieties; Tiongco and Hossain 2015), and in
420 Madagascar (346 rice varieties; Radanielina et al. 2013). However, as in Lao (Appa Rao et al.
421 2002), we noted that the same rice variety could be called by different names and different
422 varieties could have the same name. Both agro-morphological and molecular characterization are
423 required for clarification of problems of synonymy and homonymy.

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

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

436 The average number of varieties cultivated per village in the study area is low compared to
437 that found in the villages of the island of Madagascar (10.9; Radanielina et al. 2013), Guinea
438 (24.6; Barry et al. 2008), and in the Kumaun region of Indian Central Himalaya (11; Agnihotri
439 and Palni 2007). However, the diversity maintained at the household level (2.2) is almost similar
440 to that held by Malagasy (Radanielina et al. 2013), and Indian farmers (Laishram et al. 2020), but
441 lower than those held by Nepalese farmers (Bajracharya et al. 2010). The low diversity observed
442 at Igbo-Idé village could be explained by the fact that farmers of this village began to grow rice
443 after recent sensitization campaigns carried out by government extension services and NGOs to
444 promote the crop in the area considering that it is suitable for rice production: therefore, farmers
445 grow only the recent rice varieties with high market value. In the case of the villages with a high
446 diversity such as Bagou (15 varieties), Madécali (14 varieties), or Kounadogou (14 varieties),
447 farmers have been growing rice for centuries, and the high diversity observed in these areas could
448 be explained by the fact that farmers cultivate both local and improved rice varieties. Indeed, this
449 allows them to maintain their socio-cultural habits, while meeting standardized market needs
450 (Orozco–Ramírez et al., 2014). However, in these villages, only a few of the surveyed farmers
451 maintain high rice diversity on their farm. Unfortunately, most of these villages with high rice
452 diversity also show a high rate of threat of diversity disappearance. Nevertheless, Tchakalakou,
453 Angaradébou and Founougo villages from northern Benin can be considered as conservative

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

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

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

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

480 Most of the surveyed farmers who do not distinguish any difference between African and
481 Asian rice were those surveyed mainly in South Benin. This could be explained by the fact that
482 rice production in southern Benin is very recent, and is mainly based on the cultivation of
483 improved varieties. The concordance of the farmers' perceptions of desirable and undesirable
484 traits of both rice species with scientific data reveals the good knowledge they have of their rice
485 materials. For instance, the surveyed farmers mentioned as undesirable traits of African rice its
486 long cycle, low productivity, big seed, and unscented grain, which are corroborated by the
487 observations made Bezançon and Diallo (2006). The adaptation to flooding (Kawano et al.,
488 2008), frequent lodging (Sarla and Swamy 2005), high swelling (Gayin et al. 2017), and easy
489 shelling/dehusking without breaking of the grain (Nayar, 2010) of the African rice have been
490 widely reported in scientific literature. The diversity of desirable traits of the African rice listed
491 by the surveyed farmers in northern Benin reflects the preference of this population for this
492 particular rice species.

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

501 According to the surveyed farmers, the aroma and swelling are also important selection criteria,

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

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

516 The preference of farmers for using seed from the previous harvests signifies the current
517 state of the rice sector in Benin, which is still essentially traditional. The same trend was
518 observed in Tanzania (Kangile et al. 2018; Gebeyehu et al. 2019), Guinea (Okry et al. 2011),
519 Indonesia (Lakitan et al. 2018), Nepal (Sapkota et al. 2013), and Indian Himalayas (Pandey et al.
520 2011). It is, therefore, important to enhance farmers' skills in seed selection and maintenance for
521 boosting rice production (Gebeyehu et al. 2019). Nevertheless, more and more farmers obtain
522 rice seed from public institutions and NGOs; unfortunately, they are faced by numerous seed
523 supply constraints. Similarly to Nepalese farmers (Sapkota et al. 2013), the unaffordable price,
524 and inadequate seed were the most common registered constraints among the surveyed farmers in
525 Benin. In agreement with Dossouhoui et al. (2017), it is imperative to establish a partnership

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

530 **Conclusion**

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

545

546

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554 **Compliance with ethical standards**

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

557 **Disclosure of potential conflicts of interest**

558 The authors declare that they have no conflict of interest.

559 **Data availability**

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

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713

714 **Figure captions**

715 **Figure 1:** Map of Benin showing the surveyed villages

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

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

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

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

724 **Figure 6:** Dendrogram showing the relationship between the rice varieties grown in Republic of
725 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)	Beautiful like young lady	
		Fondia keno (Dendi)	Beautiful like tall lady	
		Fondia Ibero (Dendi)		
Cooking strategy	1.8	Samoussagouni (Dendi)	The woman that don't have the experience cannot cook it	
Cycle duration	6.9	Moï lague (Biali)	Early variety	
		Moï touanga (Biali)		
		Moï nihoun ou Moi Manga (Biali)	long-cycle variety	
		Toyéta (Yom)	Variety of three months	
Seed colour	29.3	Lobelobe Koussénou (Lokpa)	Rice with purple seeds	
		Imon Iwon (Ditamari)		
		Su itara kpikpa (Wama)		
		Mli piri (Yom)		
		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 ftofe 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)	Rice with long seeds	
		Gbéga (Bariba)		
		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	HU P	S	HS S	W	7.3 ± 0.4abcd	2.2 ± 0.1abcd	Djimbo dogo, Kanwaka, Iressi Olotchoumédjé, Gambiaka1, Samoussagouni, Bakilafema, Yoncommon, Mli pori	Tricos
2	SH	S	HS S	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	LS S	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	HU P	B	HS S	W	8.1 ± 0.2d	2.1 ± 0.0cd	Pouinpoua	-
5	HU P	Go	HS S	W	7.7 ± 0.3cd	2.1 ± 0.4cd	Moï lague, Kpantcho blanc, Imon ipia, Bagnéguila	-
6	HL K	PSS	SR	R	6.9 ± 0.1abcd	2.5 ± 0.0cd	Imonsoua, Mori souan, Gambiaka2	-
7	HU P	Go	LS S	W	6.6 ± 1.2abcd	2.4 ± 0.0cd	Comonkounkouna, Bakikrouma, Wahabou	-
8	G	Pu	SR	R	7.7 ± 0.2cd	2.1 ± 0.0cd	Timonwonti	-
9	HU P	S	LS S	W	5.9 ± 0.8a	2.2 ± 0.2a	Takamorri, Moï koukourika, Timonpéti	-
10	HU P	RLP	HS S	Br	5.9 ± 0.3abcd	2.3 ± 0.1abcd	Sinvite fanrou, Antonoumon	-
11	HU P	S	LS S	W	6.7 ± 0.6abcd	2.1 ± 0.1abcd	Gambiaka3	Gbéga1
12	SH	GG F	HS S	W	6.3 ± 0.6abc	2.0 ± 0.0abc	Moï nihoun, Lobelobe koussémou, Gambiaka4	-
13	HU P	S	LS S	W	6.0 ± 0.5ab	2.2 ± 0.0abcd	Méada, Morri doenoun, Takparakpassé	Debout
14	SH	GG F	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, Moï poria,	Senegal

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

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	RTLTD
		(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; RTLTD: 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 poriwò	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-Koukougouga	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, moïkourika
	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
	Centre	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, Manyianza, kouatérizé, sobsob
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 (<i>O. glaberrima</i>)				Asian rice (<i>O. sativa</i>)			
		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)
Desirable									
	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

	-	-	-	-	-	-	0.3	0.3
Undesirable	(N=34)	(N=23)	(N=187)	(N=244)	(N=24)	(N=15)	(N=187)	(N=226)
Less water demanding	-	-	-	-	-	-	0.3	0.3
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	96	Chinois
	Tolerant	1	
Flooding sensitivity	Sensitive	91	Doga, Gambiaka1, Gambiaka2, Gambiaka3, Gambiaka4, IR841
	Tolerant	6	
Diseases sensitivity	Sensitive	59	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 Koussémou, Lèbèlèbè, Mli Lèbèlèbè, Moï lague, Moï koukourika, Mori Souan, Moï nihoun, Mori kpika, Moï poua, Pointinini, Suru Ftaré Kpika, Timonwonti, Timosoti, Toukouchèti, Tricos, Yamaboba, Yayi boni
	Tolerant	38	
Birds attack	Sensitive	83	Aïsé, BL19, Degaule, Gambiaka2, IR841, Kpantcho blanc, Lèbèlèbè, Mli piri, Mli Lèbèlèbè, Djimbo gazéré, Mori kpika, Pointinini, Suru Ftaré Kpika, Timosoti
	Tolerant	14	
Insects attack in the fields	Sensitive	55	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 Koussémou, Lèbèlèbè, Mli Lèbèlèbè, Moï lague, Moï koukourika, Mori Souan, Moï nihoun, Mori kpika, Moï poua, Pointinini, Suru Ftaré Kpika, Timonwonti, Timosoti, Toukouchèti, Tricos, Yamaboba, Yayi boni, NéricaL19, Toyéta
	Tolerant	42	
Sensitivity to weeds	Sensitive	85	8à8, Bakikrouma, Bakini, Degaule, Gambiaka, Kpantcho, Lèbèlèbè doberome, Mori touanga, Pouinpoua, IR15, Yayi Boni l
	Tolerant	12	
Insects storage	Sensitive	36	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 Koussémou, Mli Lèbèlèbè, Mli piri, Moï lague, Moï 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
	Tolerant	61	
Productivity	Low productivité	50	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, Moï koukourika, Moripoua, Moï nihoun, Mori
	High	47	

	productivité		
			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,
	Very good	10	IR841, Moï nihoun, Moï touanga, Nérica L14, Yayi boni2
Cooking features	Good	86	BÉRIS21, Chinois, Djimbo gazéré, Djimbo dogo,
	Very good	11	Essai, Gambiaka2, IR841, Moï nihoun, Moï touanga, Wondia, Yayi boni1
Shelling	Difficult	88	Degaule, Djimbo gazéré, Essai, Imon ipia, IR841, Moï
	Easy	9	nihoun, Moï lague, Moï touanga, Yayi boni2

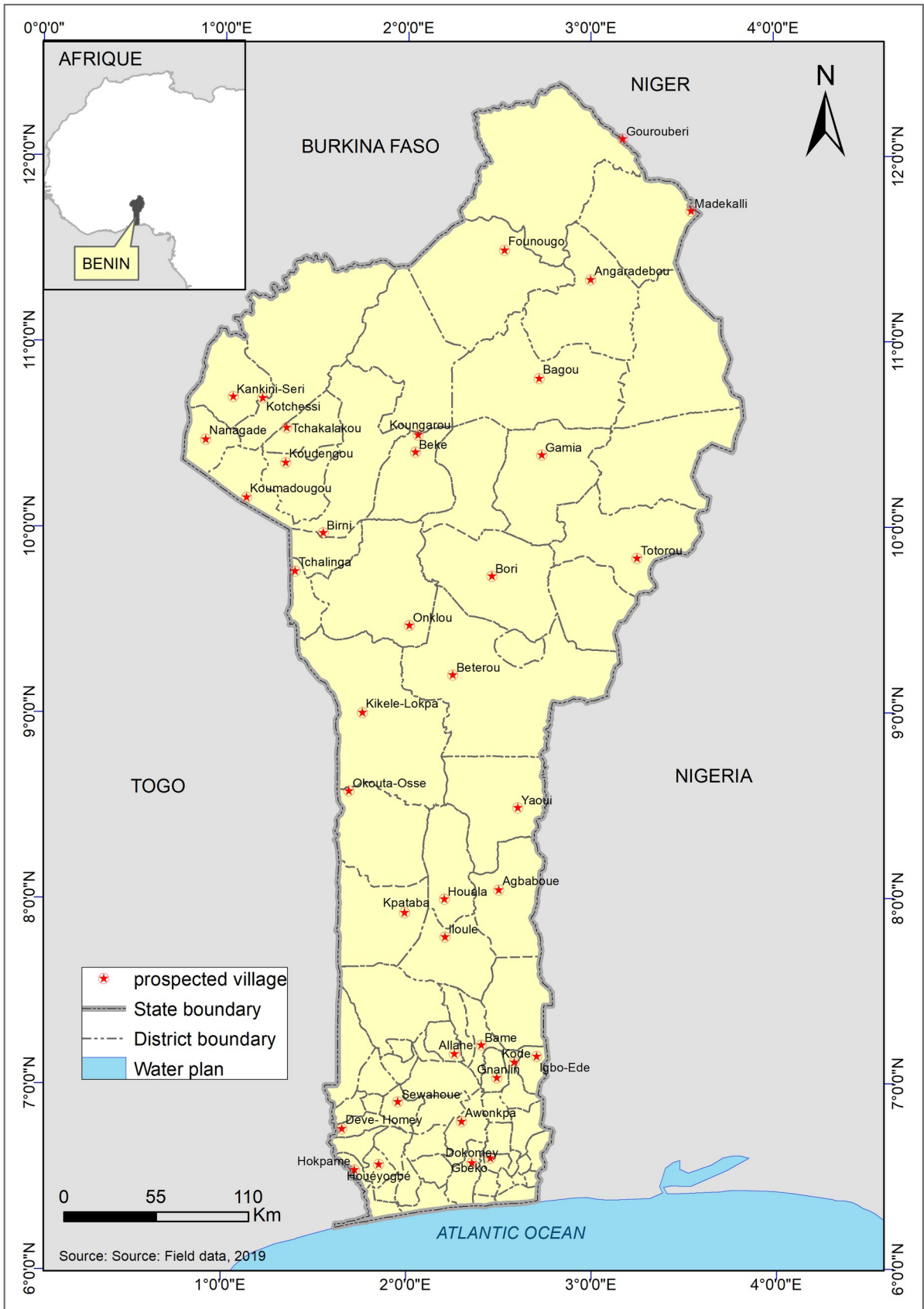


Figure 1: Map of Benin showing the surveyed villages

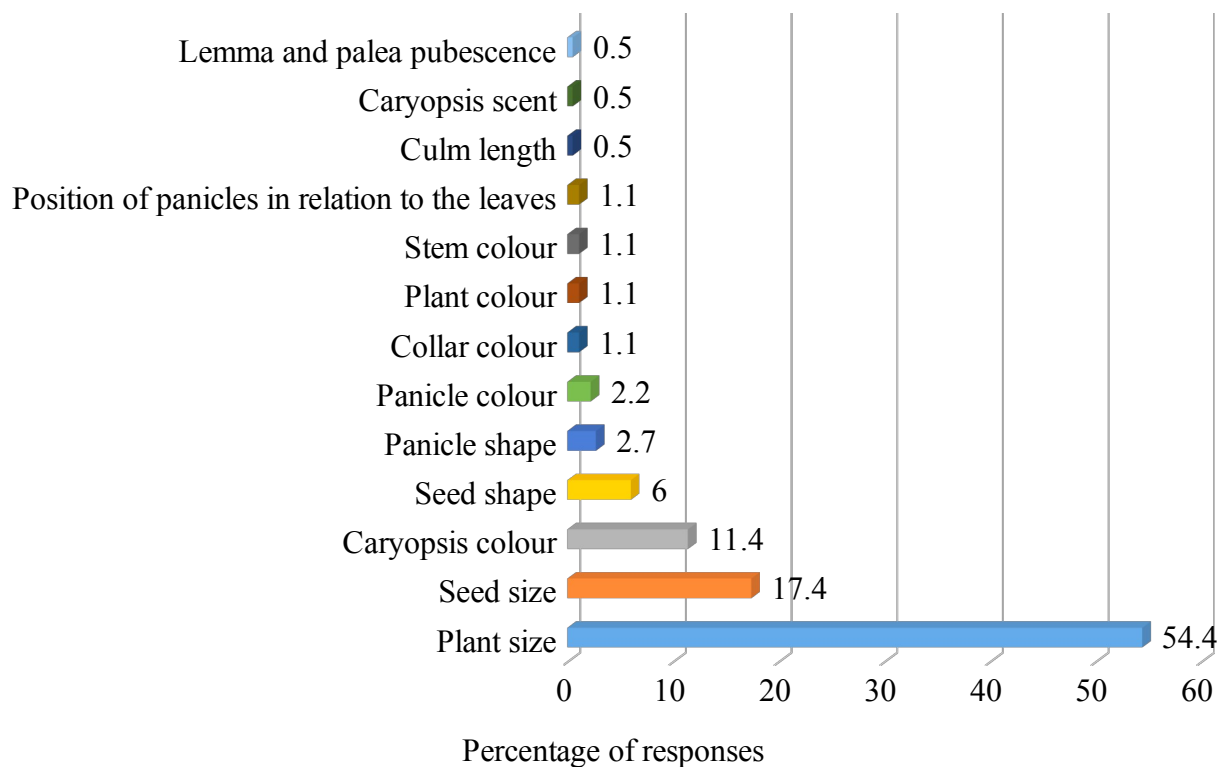


Figure 2: Criteria used by surveyed farmers to identify rice varieties [in Benin](#)



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

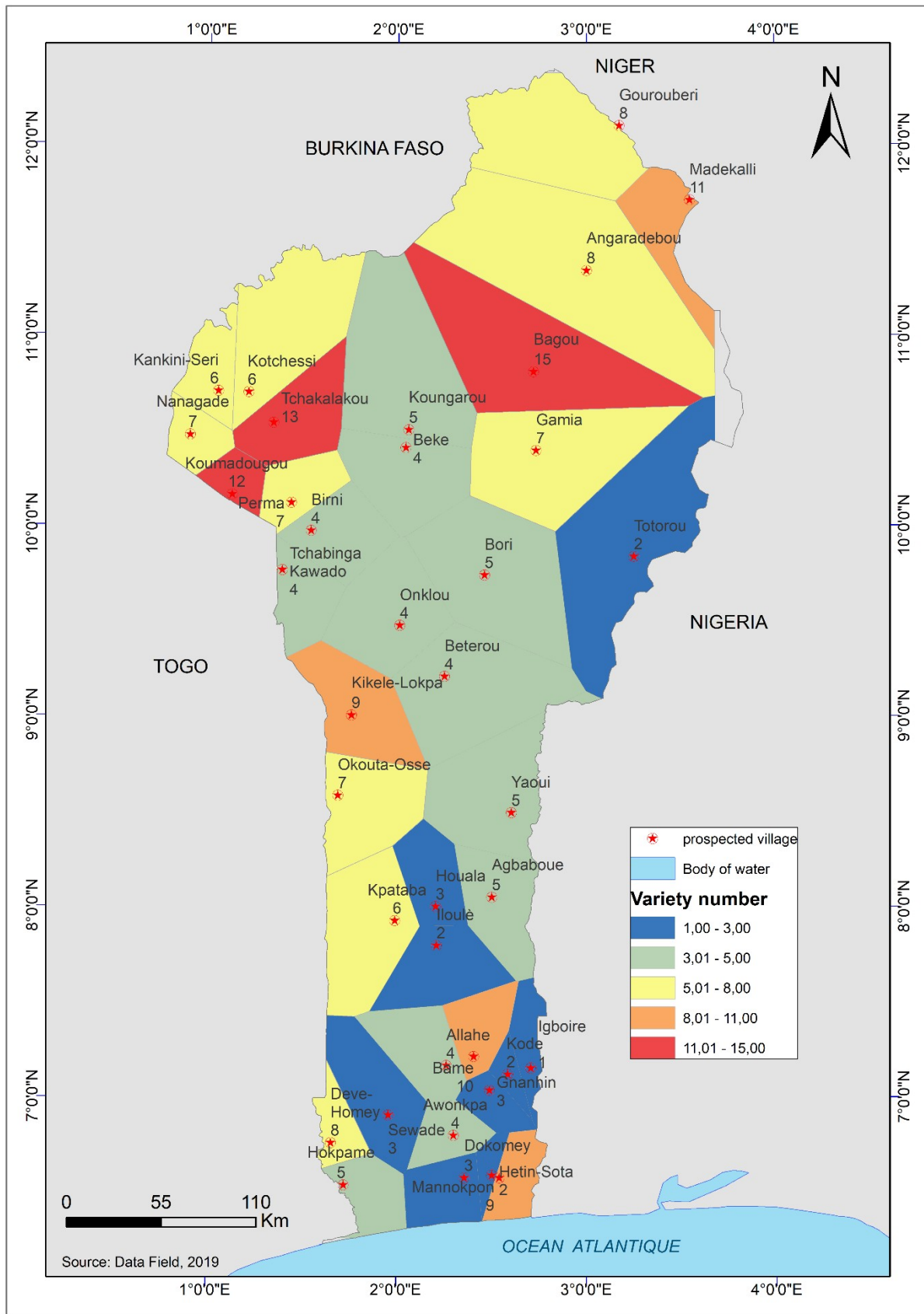


Figure 4: Map showing the repartition of rice diversity in the Republic of Benin

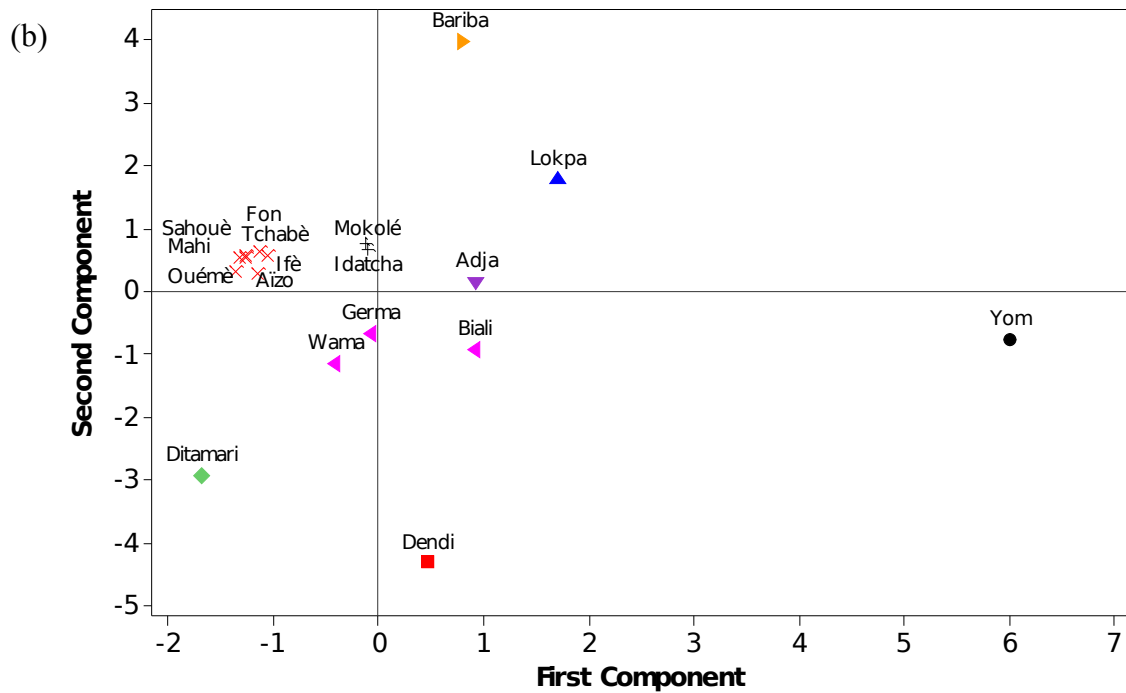
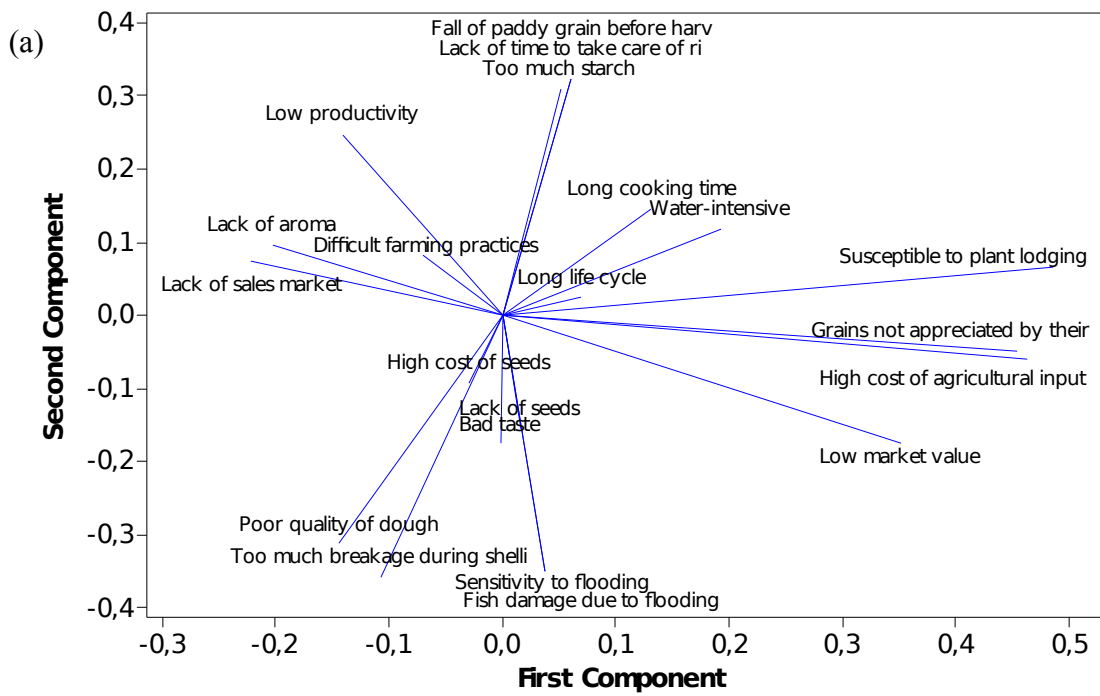


Figure 5: (a) Graphic representation of contribution of each variable to the contribution of the first and second component (axes 1 and 2). (b) Two-dimension plot of Principal Component Analysis (PCA) clustering based on the reason of rice varieties abandonment related to ethnic groups.

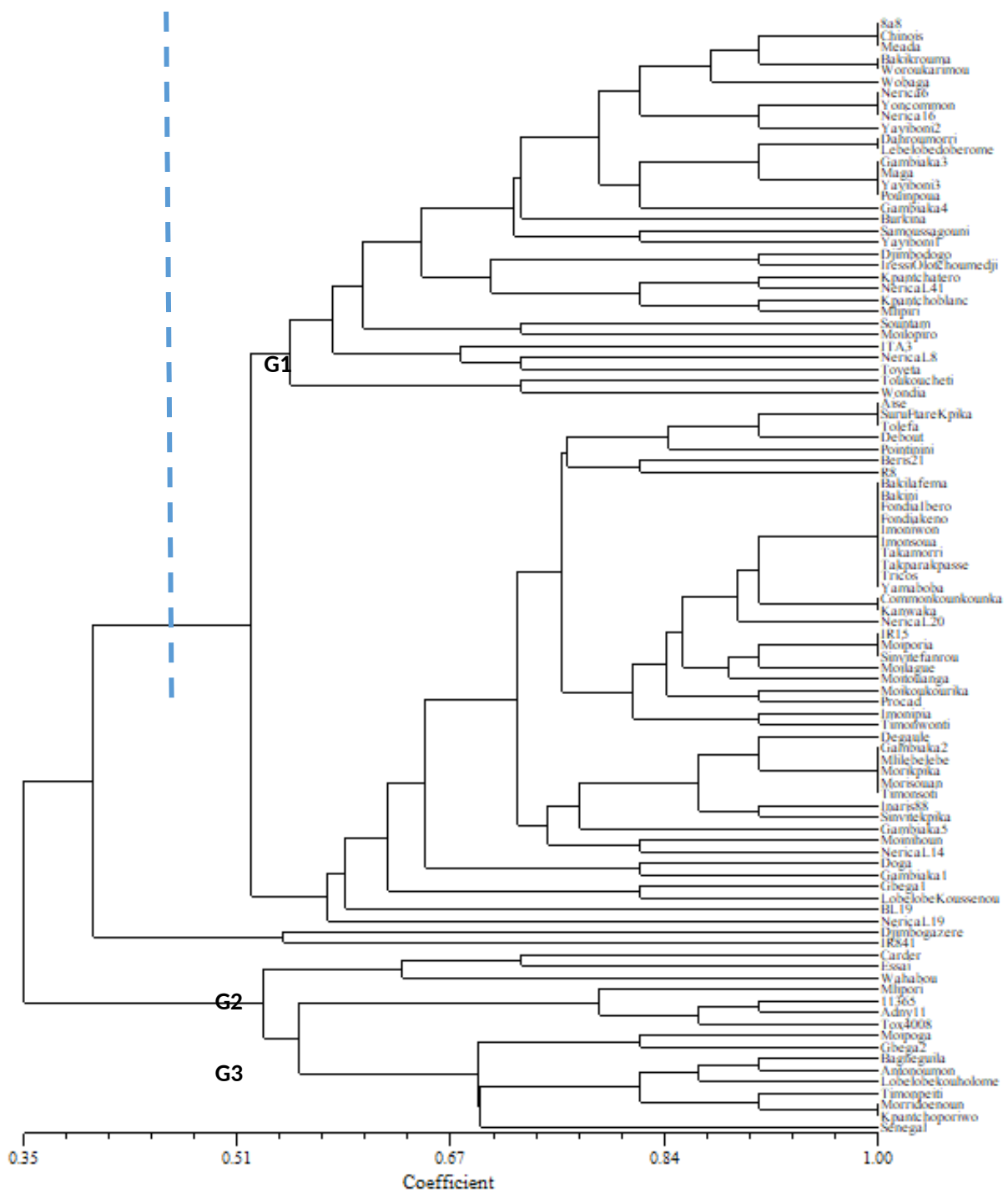


Figure 6: Dendrogram showing the relationship between the rice varieties grown in Republic of Benin based on participative evaluation