

Diversity, conservation and related wild species of Fonio millet (*Digitaria* spp.) in the northwest of Benin

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Abstract Fonio (*Digitaria exilis* (Kipp.) Stapf, white fonio; *Digitaria iburua* Stapf, black fonio), is one of the oldest native, but neglected, cereal crops of cultural, nutritional and economic importance of West Africa. To gather key information that will help to preserve its diversity in Benin and develop modern and well-adapted varieties that could meet both farmers' and consumers' needs, a participatory research appraisal survey was conducted in 15 villages randomly selected in the fonio production zone of Benin. Altogether 15 farmer-named landraces were recorded and further grouped into five morphotypes of which four belong to *D. exilis* and one to *D. iburua*. The number of landraces inventoried varied from one to five per village (three on average) and from one to three per household. Their distribution and extent are presented and their importance in terms of genetic resources conservation is discussed. Farmers' preferences for fonio varieties

were assessed and eight preference criteria (earliness, culinary characteristics, ease of processing, productivity, facility of harvesting, grains size, storability, and drought tolerance) were identified and prioritised according to the gender. The traditional seed supply system and on-farm seed maintenance were investigated. Two plant species (*Digitaria horizontalis* Willd. and *Digitaria longiflora* (Retz.) Pers.) were reported by farmers as putative parents of cultivated fonio. Of these, only *Digitaria longiflora* has interesting agronomic traits (erect habit; stem long, big, strong and resistant to lodging; panicle long and rich in grains; large sized seeds) that are useful for the improvement of cultivated fonio. In the entire study area, the crop is under threat. Therefore, concerted efforts should be deployed to preserve its diversity and increase its use to combat food insecurity and malnutrition in Benin.

Keywords Benin · Conservation ·
Digitaria · Diversity · Fonio · Selection criteria ·
Wild relatives

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Introduction

Fonio (*Digitaria exilis* (Kipp.) Stapf, white fonio and *Digitaria iburua* Stapf, black fonio), is one of the oldest native cereal crops of West Africa (Portères 1955; Pursglove 1975; Adoukonou-Sagbadja et al. 2006). Regarded as grains of life, the crop takes an

important place in household food security and currently nourishes several millions of people in the sub-region (Haq and Ogbe 1995; Vietmeyer et al. 1996; Adoukonou-Sagbadja et al. 2006). Its numerous traditional and technological uses are now well documented (Portères 1976; Jideani 1999; Vodouhè et al. 2003; Adoukonou-Sagbadja et al. 2004, 2006). In both rural and urban markets of West Africa, fonio remains one of the most expensive cereal crops (Kwon-Ndung et al. 1998; Kuta et al. 2003) and is therefore considered by many scientists as an important treasure for the region (Vodouhè et al. 2003).

In spite of its cultural, nutritional and economic importance, fonio, in Benin, has been for a long time neglected by scientific research and development programmes (Adoukonou-Sagbadja et al. 2007a, b). Consequently, cultivated varieties are still landraces and their cultivation is in serious decline due to pest and disease pressures, poor yield, tedious harvesting and processing, small grain size, and seed shattering (Dossou-Yovo 1998).

Today, the development of modern and well-adapted varieties of fonio that could meet the needs of both farmers and consumers becomes an imperious challenge (Ibrahim 2001; Morales-Payan et al. 2002). The knowledge of existing landraces and farmers' selection criteria are a prerequisite to designing a concrete breeding programme and to hope that the improved varieties will be adopted (Galt 1989; Sperling et al. 1993, Kamara et al. 1996, Defoer et al. 1997; Kwon-Ndung et al. 1998; Adoukonou-Sagbadja et al. 2006).

To preserve the existing landraces against genetic erosion, germplasm collection and conservation *ex situ* is a necessity (Plucknett et al. 1983; Brown and Marshall 1995; Dansi et al. 2008a, b). However, for the landraces to evolve and be continuously adapted to their environment, complementary on-farm conservation strategies should be also developed (Maxted et al. 1997; Brush 2000; Adoukonou-Sagbadja et al. 2004). To do this, the status of the diversity of the crop and the traditional seed system as well as the on farm seed maintenance should be well understood.

We report in this paper the results of a study conducted in the fonio production zone in Benin (Department of Atakora) in order to:

- (1) Assess the diversity of fonio at both community and household levels
- (2) Identify farmers' variety preference and selection criteria
- (3) Understand the traditional seed system and on farm seed maintenance
- (4) Document the farmers' knowledge on the wild relatives of fonio
- (5) Collect germplasm for *ex situ* conservation

Methodology

The study area and its potential in fonio production

The study was conducted in the Department of Atakora in the northwest of Benin. This Department is located in a semi-arid agroecological zone characterized by unpredictable and irregular rainfall (800–950 mm/year) with only one rainy season and a dry season lasting more than 5 months (Adam and Boko 1993). The region is partitioned into seven districts: Boukoubé, Cobli, Kouandé, Materi, Natitingou, Tanguieta and Toukountouna. The area is mountainous with poor sandy, rocky and encrusted soils and some shallows.

Fonio production in this area is intensive at Boukoubé, average at Cobli and Natitingou districts, marginal at Tanguiéta and Toukountouna and absent at Materi and Kouandé. The annual production is about 2,400 t (Dossou-Yovo 1998). The yields (300–600 kg/ha) are very variable from one season to another because of climatic hazards.

The Department is inhabited by seven ethnic groups (Bariba, Berba, Ditamari, Lamba, Natimba, Wama, Bialli) that have, apart from the Bariba and Berba, a very long tradition in fonio cultivation (Dossou-Yovo 1998).

Site selection and survey

Fifteen villages were randomly selected for the survey (Table 1; Fig. 1). Data were collected from the different sites during expeditions through the application of Participatory Research Appraisal tools and techniques, such as direct observation, group discussions, individual interviews, and field visits using a questionnaire following Adoukonou-Sagbadja et al. (2006), and Dansi et al. (2008a, b). Interviews were conducted with

Table 1 List of the villages surveyed, their localisation and number of landraces inventoried

No	Village	District	Ethnic group	Number of landraces inventoried
1	Agbonté	Boucoumbé	Lamba	05
2	Dikokoré	Toucountouna	Ditamari	02
3	Dipoli	Boucoumbé	Lamba	05
4	Kouba	Toukountouna	Natimba	02
5	Koumadôgou	Boucoumbé	Ditamari	04
6	Kounadorgou	Natitingou	Ditamari	03
7	Koutagou	Boucoumbé	Ditamari	04
8	Koutayagou	Boucoumbé	Ditamari	04
9	Kouya	Boucoumbé	Ditamari	04
10	Nafayaoti	Tanguiéta	Natimba	01
11	Namontiaga	Cobli	M'bermè	02
12	Perpoyakou	Natitingou	Wama	01
13	Tabota	Boucoumbé	Ditamari	04
14	Tikouati	Natitingou	Wama	02
15	Touga	Cobli	M'bermè	03

the help of translators from each area. In each site, local farmers' associations were involved in the study to facilitate the organisation of the meetings and the collection of data. Prior to the meeting, farmers were requested in advance to bring samples of the fonio landrace varieties they produce or knew about. Information on the location (name of district, name of village, ethnic group) was first collected after a detailed presentation of the research objectives to the farmers. Then, farmers were asked to list (vernacular names) and display the different varieties of fonio produced in their village. Through discussions, detailed traditional morphological descriptions as well as the agronomic and culinary characteristics of the listed varieties were documented.

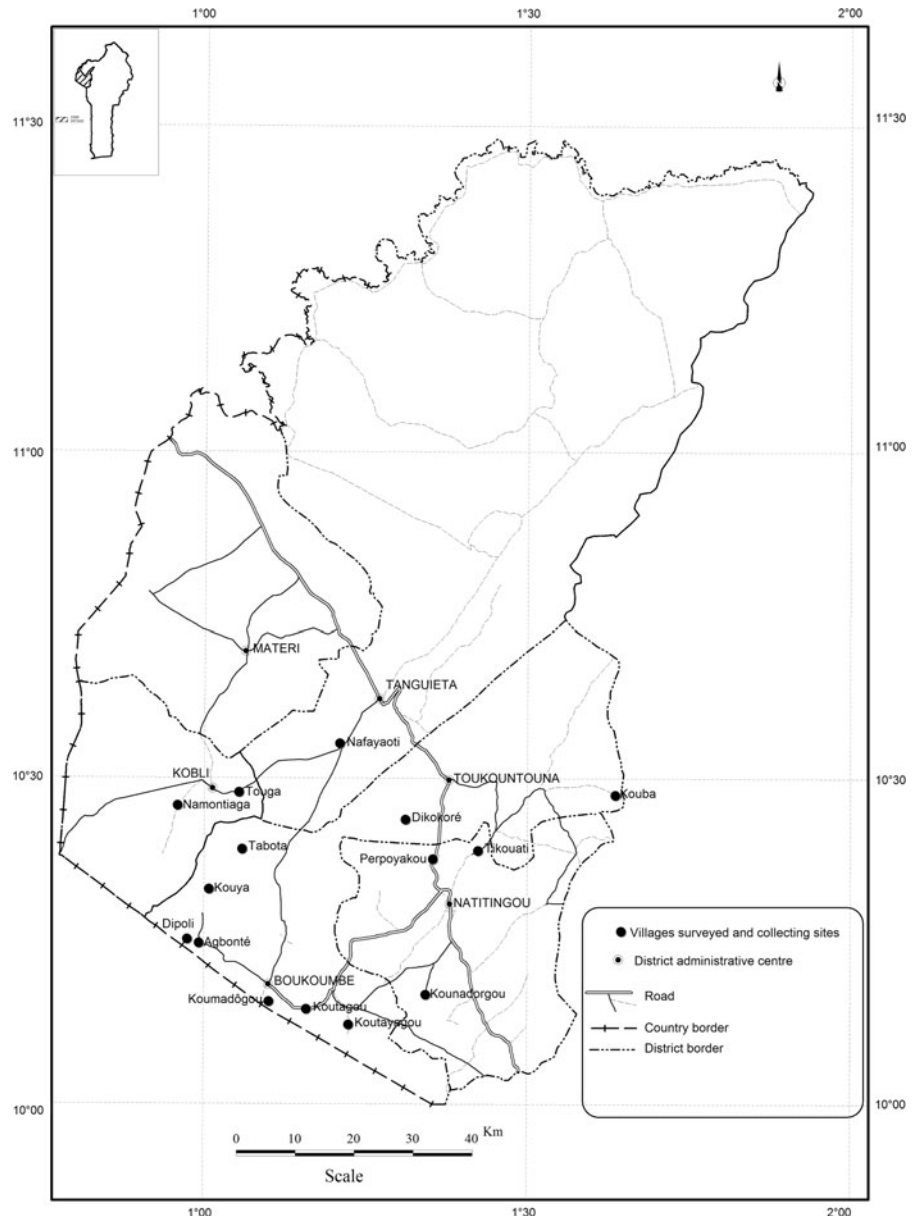
The distribution and extent of the varieties were assessed using the Four Squares Analysis approach described by Brush (2000), Tuan et al. (2003), and Dansi et al. (2008a, b). At the community level and based on two parameters ("number of households" and "cultivated area"), this participatory analysis method helps to classify existing varieties 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, varieties were individually taken and evaluated by farmers using the first parameter (number of households). For this parameter, farmers were asked to indicate for each

variety whether it is produced by many or few households. The same evaluation process was repeated for all the varieties for the second parameter (cultivated area). By combining the results of the two parameters, varieties were classified in the different quadrants and the results were immediately presented to the farmers for eventual comments. After this, the discussion moved to details of each variety with the objective of understanding the reasons for their status. Hence, reasons that justify the cultivation of each variety by many or few households and on large or small areas were documented. The traditional seed system and its maintenance on farm were also discussed.

In each of the survey sites where more than one variety was recorded, 20 farmers (both men and women) were randomly selected, after the group discussion, for individual interviews. Using the matrix scoring technique (Gueye and Freudenberger 1991; Kamara et al. 1996; Defoer et al. 1997; Chweya and Eyzaguirre 1999; Adoukonou-Sagbadja et al. 2006; Dansi et al. 2008a, b) and on an individual basis, varieties were ranked and the preference criteria were identified and prioritized. At both individual and group level, the discussions were free, open-ended, and without a time limit being set, following Christinck et al. (2000).

Within a village, seed samples of each landrace variety were independently collected, when possible, from two to three randomly selected farmers and this,

Fig. 1 Map of the northwest of Benin showing survey and collection sites



directly from their granaries or fields. In the field, accessions were collected from panicles of at least 50 individual plants and at many sites (separated by 15–20 steps) following Brown and Marshall (1995). Each accession collected was packaged in a paper bag and documented, following Moss and Guarino (1995). The descriptors used for data collection included: accession number, collection institution, date of collection, name of collector, type of material, scientific name, vernacular name and language, status

of sample, sampling information and the location of the collection site.

Statistical analysis

Data were analysed through descriptive statistics (frequencies, percentages, means, etc.) to generate summaries and tables at different (villages, individuals) levels using SAS software (SAS Institute 1996). In addition, the key morpho-physiological descriptors

(colour of the grain, colour of the leaves, colour of the panicle, colour of the shoot, presence of tiny hairs on the seeds, ease of husking, growth cycle, shattering tendency) used by farmers to describe fonio landraces throughout the study zone were selected and scored as a Bernoulli variable (0, 1). Using this methodology, 29 variables were created and a binary matrix was compiled. Pairwise distances between landraces were computed by the NTSYS-pc 2.2 software package (Rohlf 2000) using the simple matching coefficient of similarity (Gower 1985) and a dendrogram was created by Unweighted Pair-Group Method with Arithmetic Average (UPGMA) cluster analysis (Sneath and Sokal 1973; Swofford and Olsen 1990).

Results and discussion

Diversity of fonio landraces at community and household level

In the north west of Benin fonio is known under some generic names that vary according to the ethnic groups. The crop is called Ipoaka in Ditamari, Péi in Wama, Poaji in Natimba, Ipoé in Bialli and Afiôhoun in Lamba. Diverse farmer-named landrace varieties exist and are identified according to their earliness, the colour of their grains, their panicle types, and/or

the colour of their leaves. The number of landraces inventoried varied from one to five per village (Table 1) with three, on average. Villages cultivating higher number of landrace varieties belong to the Ditamari (4 varieties) and Lamba (5 varieties) tribes (Table 1).

The variety names vary within and between ethnic areas (Table 2). For example, with the Ditamari farmers, the variety Ipordapia is also called Tontonga, Ikentoni, or Kpatinafa. The distortion of an original name by differing pronunciation across villages led sometimes to a diversity of vernacular names for a given landrace. Hence, Ida, Iporda and Iporlada (Table 2) designate the same landrace; Inouri is the contracted appellation of Iponouri while Sèmrè and Sèlèmbè are distortions of the original name Sèmbè. In the entire study zone, 36 different local names (15 principal names and 21 synonyms) of landraces were recorded (Table 2). Each village seems to have its own series of vernacular names. These findings which are common in folk nomenclature have already been reported on many crops, including yam (Dansi et al. 1999), cassava (Sambatti et al. 2001), fonio (Adoukonou-Sagbadja et al. 2006), sorghum (Mekbib 2007) and traditional leafy vegetables (Dansi et al. 2009).

Based on the correspondences between varieties' names across ethnic groups and areas indicated by

Table 2 Vernacular names of the fonio landraces cultivated in the study zone and corresponding number of accessions collected

No	Vernacular name	Other names	Ethnic group	Number of accessions collected
1	Fôlôm	Fouloum	Lamba	04
2	Ipognirmè	–	M'bermè	02
3	Ipoaga	Inouri, Iponouri	Ditamari	06
4	Iporni	Ini	M'bermè	04
5	Ipordawan	Ikounga, Iporhouan, Ipordagou, Koupordagou	Ditamari	10
6	Ipordapia	Ida, Iporda, Iporlada, Ikantoni, Kpatinafa, Tètohountotihounta, Tontonga	Ditamari	16
7	Ipoyè	Kpatinafè	M'bermè	04
8	Pédaaï	–	Wama	02
9	Péniï	–	Wama	02
10	Polaji	Polata	Natimba	04
11	Poniji	Puôniiji	Natimba	04
12	Sèmbè	Sèlèmbè, Sèmrè	Lamba	06
13	Tamaou	–	Lamba	02
14	Tintinga	Kantenga	Lamba	04
15	Yôrô	–	Lamba	02

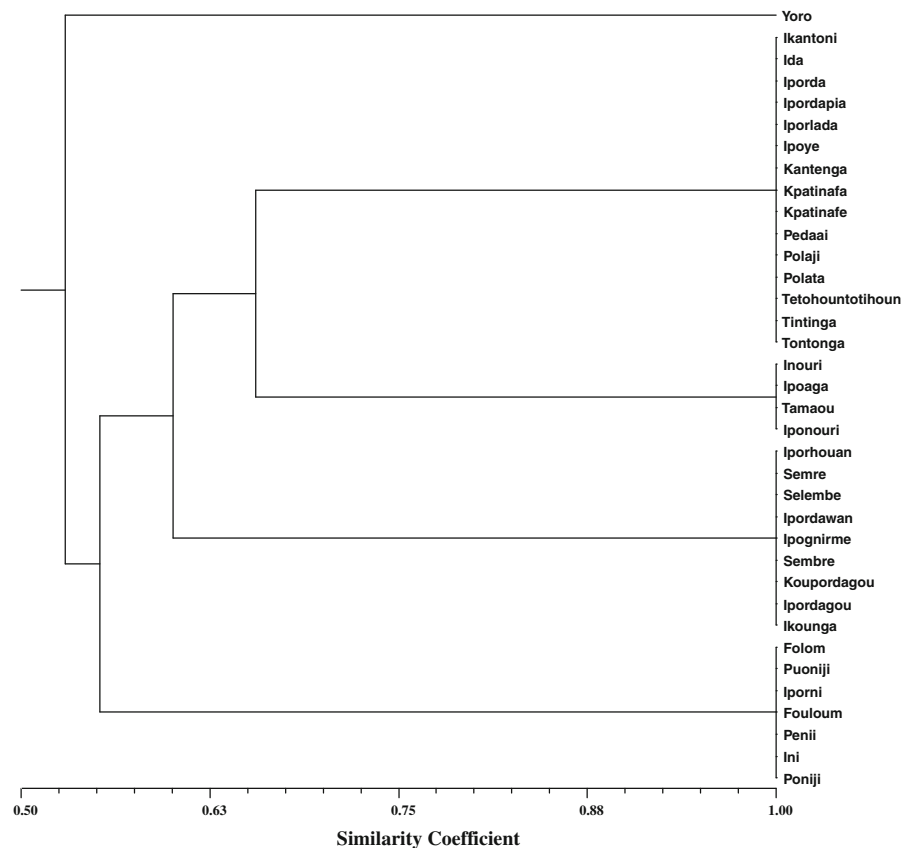
experienced farmers interviewed, the 15 principal names recorded correspond only to five different morphotypes named after their most popular appellation (Table 3). Among these five morphotypes, four (Yôro, Ipordapia, Ipordawan, Iporni) belong to *Digitaria exilis* and one (Ipoaga) to *Digitaria iburua*. Yôro is linked to the ethnic group Lamba and is found only in their traditional areas. Ipoaga exists only with the Ditamari and the Lamba, while Ipordapia and Iporni are known everywhere.

Ipordawan is unknown in Wama and Natimba cultural areas. At 75% of similarity, the dendrogram constructed considering landraces as individuals and farmers' descriptors as variables (Fig. 2) revealed five distinct clusters corresponding to the five morphotypes indicated above. Moreover, the recent molecular characterisation of West African fonio landraces including some materials from Benin (Adoukonou-Sagbadja et al. 2007) partially confirmed farmers' classification and shows, as reported

Table 3 Farmers' grouping of the fonio landraces cultivated in the northwest of Benin

Morphotypes (given name)	Species	Corresponding landrace in the ethnic area				
		Ditamari	M'bermè	Wama	Natimba	Lamba
Yôro	<i>D. exilis</i>	–	–	–	–	Yôro
Ipordapia	<i>D. exilis</i>	Ipordapiah	Ipoyè	Pédaaï	Polaji	Tintinga
Ipordawan	<i>D. exilis</i>	Ipordawan	Ipognirmè	–	–	Sèmbre
Ipoaga	<i>D. iburua</i>	Ipoaga	–	–	–	Tamaou
Iporni	<i>D. exilis</i>	Iporni	Iporni	Péniï	Poniji	Fôlôm

Fig. 2 Dendrogram showing at 75% of similarity the grouping of landraces into five clusters corresponding to the five morphotypes Yôro, Ipordapia, Ipoaga, Ipordawouan and Iporni



on yam (Dansi et al. 2000), that farmers have a good knowledge of their varieties and that, in terms of classification, identification and use, their knowledge would be extremely useful to geneticists and breeders. The morphological traits (farmers' description) of the morphotypes and their agronomic and culinary characteristics are presented in Table 4 and in Figs. 3, 4 and 5.

The distribution and extent of the diverse landraces in their production areas as revealed by the Four Square analysis are variable (Fig. 6). The landraces Iporgnirmè, Ipordawan and Sembrè, which belong to the same morphotype Ipordawan, were all produced by many households on large areas. Yô rô on the one hand, Ipoaga and Tamaou on the other were found grown by few households and on small areas; Folom, Iporni, Penii and Porniji, grouped into the morphotype Iporni, were cultivated by a few households on large areas. The five landraces constituting the morphotype Ipordapia were found with many households but on small areas. The positions of the landraces in the quadrants Q1, Q3 and Q4 are quite comprehensible when their preferred and non-preferred traits, as reported by farmers and summarised

in Table 4, are considered. Hence, landraces in Q2, for example, are late maturing and drought sensitive. In a semi-arid agro-ecological zone, characterized by unpredictable, irregular and shorter rains added to climate change, only farmers who have their fields in a relatively humid areas (i.e., along water courses, or around shallows) can produce these landraces with a long duration growth as their yield in the ordinary fields is uncertain. In terms of genetic resources conservation, landraces in Q4 which were reported to be disappearing need to be preserved *ex situ*. For landraces in Q2 and Q3, complementary conservation strategies (*ex situ* and on farm) should be developed; while for landraces in Q1, no urgent action is required. However, considering the general situation in the study zone, very urgent action is needed to preserve the crop and the diversity of its landraces. In fact, according to the farmers interviewed, a fonio production is being generally abandoned because of diverse constraints in the production and processing of the crop, the introduction of maize (higher yield; easier production and harvesting, processing and commercialization) during this last decade and the promotion of cotton (an industrial crop) production.

Table 4 Key characteristics of the fonio morphotypes identified in the northwest of Benin

Varieties name	Morphological traits	Agronomic and culinary characteristics
Yô rô	Dark-green leaves; whitish panicles mostly with 2 to 3 racemes; white grains	Extra-early maturing (2.5 months); Harvesting, drying and conservation very difficult as it matures during the rainy season; low yield and high loss of seeds due to shattering; grains must be roasted before pounding; paste not soft and difficult to prepare
Ipordapia	Light-green leaves; white-dirty panicles with 3 to 4 racemes; white grains	Early maturing (3 months); Harvesting, drying, and conservation difficult as it matures during the rainy season; High yield; easy to husk; not susceptible to soils fertility; slight and soft paste; easy to digest
Ipordawouan	Light-green leaves, reddish shoots and panicles; panicles with mostly 4 to 5 racemes; reddish grains	Intermediate landrace (3.5 months); Easy cultivation, drying, and storage; high yield; grains big and easy to husk; paste soft and tasty. Susceptible to drought and poor soils (reduced yield)
Ipoaga	Light-green leaves and panicles; panicles with mostly 4 to 5 racemes; black grains	Semi-late landrace (4 months); Easy cultivation, drying and storage; drought tolerant; high yield; Large and very hard chaff; husking difficult and time-consuming; paste normally soft and tasty but its quality and colour are generally affected by non removed chaff
Iporni	Whitish panicles with mostly 5 to 6 racemes; vigorous plants; white grains with tiny hairs	Late maturing (5 months); Easy cultivation, drying and storage; performs well in humid zones (around shallows); low seed loss (low shattering); Drought susceptible; hard bran; husking difficult and time-consuming; paste normally soft and tasty but its quality and colour can be affected by non removed bran

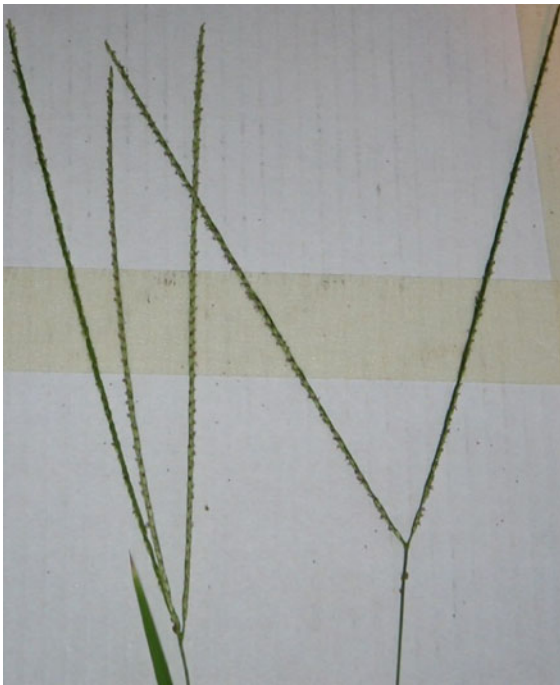


Fig. 3 Raceme of Yôro (*D. exilis*)



Fig. 4 Raceme of Ipoaga (*D. iburua*)

This tendency observed is not specific to Benin. It has already been reported in Nigeria (Kwon-Ndung et al. 1998), Togo (Adoukonou-Sagbadja et al. 2004, 2006) and in many other West African countries (Vodouhè et al. 2003).

Within villages cultivating many landraces and among the households surveyed, 86% grew only one variety, 11% cultivated two varieties, and only 3% grew three varieties. The average number of varieties maintained by an individual household is much lower



Fig. 5 Reddish shoots of Iporawouan (*D. exilis*)

than the total number of existing varieties. This result suggests that there is a low overlap in the sets of varieties that each farmer grows. Therefore, there will be a need to sample several farmers, if the diversity of landraces is to be captured at a village level.

The diversity of fonio varieties found in Benin is lower than the one reported in Togo (Adoukonou-Sagbadja et al. 2004, 2006). This is not surprising when considering the multiple origins of the Togo landraces in contrast to the almost unique origin of Benin germplasm: a very ancient introduction from Burkina Faso (Portères 1976; Adoukonou-Sagbadja et al. 2006) complemented by the relatively recent introduction from Togo of the extra-early maturing landrace *Yôrô*.

A total of 72 accessions of fonio landraces were collected and conserved at the Plant Genetic Resources Research Unit of the Faculty of Science and Technology (University of Abomey-Calavi, Benin) with duplication to the genebank held by the National Agricultural Research Institute (INRAB), based at Niaouli.

Farmers' preferences for fonio varieties

In the two major fonio production zones (Lamba and Ditamari ethnic areas), pair-wise comparisons of the different landrace varieties conducted on an individual basis with farmers growing more than one landrace, resulted in a preference ranking of fonio landraces (Table 5). For both men and women Lamba farmers, the early maturing variety Tintingwa was the most preferred followed by the intermediate Sémbéré while the late maturing Tamaou and Fôlôm were the

Fig. 6 Distribution and extent of the fonio landraces cultivated in the northwest of Benin

Q1 Many households, large areas	Q2 Few households, large areas
Iporgnirmè	Fôlôm
Ipordawan	Iporni
Sèmbre	Pénii
	Porniji
Q3 Many households, small areas	Q4 Few households, small areas
Ipordapia	Ipoaga
Ipoÿè	Tamaou
Pédaaï	Yôro
Polaji	
Tintinga	

less preferred. Preferences for varieties clearly differed between the sexes. No women, for instance, liked Tamaou. These results, which are similar to those obtained with Ditamari farmers (Table 5) when considering the equivalence between landraces (Table 3) and the absence of Yôro can be explained as follows: the early maturing landrace Tintinga is more preferred as it helps farmers to bridge the food

Table 5 Farmers' preferences for fonio landraces in Lamba and Ditamari ethnic area

Ethnic area	Variety name	No. of times the variety was preferred by		Total	Ranking
		Men	Women		
Lamba ^a	Fôlôm	26	7	33	4
	Sémbre	83	26	109	2
	Tamaou	12	0	12	5
	Tintinga	91	32	123	1
	Yôro	43	30	73	3
Ditamari ^b	Ipordapia	62	36	98	1
	Ipordawan	51	29	80	2
	Ipoaga	16	0	16	4
	Iporni	22	6	28	3

^a Each of the landraces was involved in a total of 160 comparisons (112 with the men and 48 with the women)

^b Each of the landraces was involved in a total of 120 comparisons (75 with the men and 45 with the women)

shortage period when no other crops are ready for harvest and consumption. It also completes its growth cycle quickly to avoid a drastic yield loss due to drought (the impact of climate change). Farmers' preference for Sémbre was based mainly on the exceptional processing facilities of its grains. The late or semi-late maturing landraces Tamaou and Fôlôm were disliked mostly because of their long growth cycle and the difficulties in husking their grains. This last reason explained why no women preferred Tamaou. The grains of this landrace are particularly hard and very difficult to husk with the traditional pestles. In the households where it still exists, women tried to convince or force their husbands to abandon its cultivation. According to farmers, it is for the same reason and by the same way that the farmer-named landrace Waarô (*D. iburua*) has completely disappeared from the entire study area. This information confirms the influence of women in decision making for the conservation of agricultural biodiversity on-farm, as reported by many authors (Howard-Borjas and Cuijpers 2002; Howard 2003; Vazquez-Garcia 2007).

Preference criteria and ranking

Eight preference criteria (Table 6) were identified through the comparison matrix exercise across the

ethnic areas surveyed. Their relative importance varied according to gender. Hence, women mostly considered the culinary characteristics, ease of processing, and storability when making a choice whereas men mainly considered early maturity, productivity (yield, grain size) and ease of harvesting as their key criteria. Such variation by gender in the importance of variety preference criteria is frequent and has been already reported in many crops such as cowpea (Kitch et al. 1998), musa (Gold et al. 2002), maize (Abebe et al. 2005), telf (Belay et al. 2006), sorghum (Teshome et al. 2007), and even fonio (Adoukonou-Sagbadja et al. 2006). Leaving aside the gender consideration, earliness is the most important criteria in the selection of fonio landraces in Benin followed by culinary characteristics which, as expressed by the farmers, include the texture, the colour and the taste of the fonio paste generally wanted soft, white and delicious. The ease of processing, although ranked third, is a determining criterion in preferring landraces. Before cooking, fonio seeds are first processed into flour using pestles and mortars. In this traditional processing system, husking seeds with thick and hard bran like those of Tamaou appears difficult and time-consuming. Moreover, it is quite impossible to remove all the chaff from their flour and the part remaining seriously affects the colour and quality on the paste. Productivity (13.3% of responses) ranks fourth, followed by facility of processing, the size of the grains, storability and tolerance to drought (Table 6). The small size of fonio grains hampers their husking (Vodouhè et al. 2003). Therefore breeding varieties with larger grain

sizes is an urgent necessity. The facility of harvesting indicated above is not linked to any morphological features of the plant as could be expected but it is related to the availability of labour and the intensity of the heat at the crop's time of maturity. For example, the late maturing landrace Iporni, disliked by many farmers, matures mostly during the very hot period when harvesting is most difficult and labour is also scarce. The other criteria (storability and drought tolerance) are also important and represent, in total, 10.2% of the responses (Table 6). No criterion regarding marketing was reported by the farmers. This result was expected, as in the study area, fonio is mostly considered a household food crop rather than a commercial crop. The criteria identified and prioritized in this study should be taken into consideration by scientists aiming at developing varieties with novel characteristics to meet farmers and consumers' requirements. They are also important for research and development organizations that would like to introduce varieties from other countries to strengthen the existing diversity in the study area.

Seeds supply system and on-farm seed maintenance

According to farmers, the sources of seeds are diverse and included in order of priority: own farm (88.2% of responses), neighbours and relatives (10.6%), market (1.2%). Acquisition of planting materials from neighbours, friends, or relatives is free of charge and happens when the farmers have failed to save enough seeds from their previous harvest, or when their neighbours, relatives, or friends have different or new varieties that they would also like to try. The practices of borrowing and friendly exchange of planting materials serve to strengthen social cohesion in local communities.

Buying fonio seeds from open markets is rarely practised by the farmers (seeds bought in the market being mostly a mixture of landraces) and occurs when germination failed in the fields and no more seeds are available from personal stock or relatives/friends' seed stores for replanting.

Generally, fonio seeds to be sown the next season are taken directly from the newly harvested stock and stored separately from the remaining part, destined for household needs. However, a very few farmers harvest the seeds destined for sowing before the

Table 6 Farmers' criteria in fonio landraces selection (% of responses)

Criteria	No. (%) by		Total	Ranking
	Men	Women		
Precocity	29.8	18.3	25.2	1
Culinary characteristics	10.6	34.4	20.1	2
Ease of processing	6.4	26.9	14.5	3
Productivity	19.9	3.2	13.3	4
Facility of harvesting	14.2	6.5	11.1	5
Grain size	7.8	8.6	5.6	6
Storability	4.9	2.2	6.8	7
Drought tolerance	5.7	0	3.4	8

general harvest. According to these farmers, such pre-harvest of seeds allows them to avoid contamination with alien seeds mainly from *Digitaria horizontalis* Willd.

The methods used by farmers to handle seeds were similar across villages and households. Seeds harvested and sun-dried were packaged in various materials and stored in homesteads in granaries. No chemical treatment was reported. Materials used for seeds storage were of three types: gourds (63.5% of responses), pots (29.2%) and bottles (7.3%). In the study zone, the gourd or African calabash (in its high diversity) is widely produced and constitutes the most important traditional container. According to farmers, the traditional conservation systems described above would maintain seed viability for 1–3 years.

At the household level, when many landraces are cultivated, seeds are always stored separately to avoid a mixture of landraces. As indicated by Baco et al. (2008) in cowpea, this is a good practice for germplasm management on farm.

Farmers' indigenous knowledge on the related wild species of fonio

Two plant species were considered by the farmers as the wild relatives of fonio. These were *Digitaria horizontalis* Willd. and *Digitaria longiflora* (Retz.) Pers.

For the Bialli, Ditamari, Lamba, and Wama farmers, *Digitaria horizontalis* would be the related wild species of cultivated fonio. These people do not consider *Digitaria longiflora* to be a parent of cultivated fonio because of its erect characteristic and low tillering ability. In the fields, *Digitaria horizontalis* which is seen as a weed, always grows together with fonio and is never completely eliminated through weeding because of its high resemblance to the crop. Forgotten plants of *Digitaria horizontalis* mature at the same time as the cultivated fonio and are harvested together with it.

Taking into account the similarity of the panicles, Natimba farmers considered *Digitaria longiflora* to be the putative parent of cultivated fonio. This opinion is shared by the scientific community (Dalziel 1937; Portères 1976; Harlan 1992; Hilu 1994, 1995; Hilu et al. 1997). These farmers reported that *Digitaria longiflora* has many interesting agronomic traits that are useful for the improvement of fonio.

These are: the erect aspect of the plant, the size of the stem and its resistance to the wind, the length of the panicle and its richness in grains and the large size of its seeds.

In Benin, *Digitaria longiflora* exists and grows in natural populations (Akoègninou et al. 2006). Ethnobotanical and ecogeographical surveys coupled with analyses of genetic diversity and technological studies will help to better document the species for its sustainable conservation and rationale use in Benin.

Conclusion

The study revealed that despite the threats that are posed to fonio production in Benin, a substantial amount of diversity is still maintained. Landraces to be cultivated are chosen based on criteria that vary primarily by gender. Genetic erosion, however, appears to be on the increase, indicating the necessity to develop integrated strategies for the sustainable conservation and use of fonio genetic resources in Benin. These will include intensive research, raising farmers' awareness, and key development actions.

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