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Fonio [*Digitaria exilis* (Kippist.) Stapf.] Diversity Revealed by Farmers and its Importance in Cropping Systems in Niger

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A B S T R A C T

Fonio [*Digitaria exilis* (Kippist.) Stapf.] is a cereal which is experiencing a renewed interest worldwide due to its organoleptic, nutritional and dietary qualities. Investigations on farm and sample collections were conducted in order to study the different types of fonio by famers' perception and its position relative to other crops in agricultural systems to its production area in Niger. The results were used to classify the accessions according to the length of their cycle into four types of varieties: extra -early, early, intermediate and late. Classification on the basis of the color of unshelled beans has three distinct varieties: varieties of color brown or black (10.4% of accessions collected), varieties of color gray or pale yellow (87.2 % accessions) and varieties with black hairs on the spikelets (2.4% of accessions). The classification on the basis of the position given by the farmers during the interview and, cultivated fonio indicates that occupies the third place among the cultivated species for 19 % of the farmers surveyed and 4th place 43% of peasants. However, it is not cultivated by 19 % of farmers surveyed, these harvest wild fonio (*Panicum laetum*. Kunth) that grows near swamps. Sowing fonio is done on the fly and the different varieties are alone or sometimes mixed in peasant farms surveyed. The evolution of the production of fonio in recent years is also variable depending on the villages surveyed. She saw an increase of 49 % of villages, stability to 2% and a 30% decline. A loss of culture fonio was even recorded in 19% of the surveyed villages.

Introduction

One of the major challenges facing the Sahelian countries like Niger is to sustainably ensure food security of their populations. This requires knowledge and rational use of their local biodiversities able to adapt to climate changes observed in recent years (Sadok, 2013). Many cultivated and neglected species can contribute effectively to solving the problems of food insecurity during lean periods (Vall *et al.,* 2011).Indeed, in West Africa, many people resort to secondary crops such as fonio (*Digitaria exilis* (Kippist.) Stapf), sesame (*Sesamum indicum* L.), (*Cyperus esculentus* L.) onion (*Allium cepa* L.), cassava *(Manihot esculenta* Crantz), sweet potato (*Ipomoea batatas* L.), bambara groundnut (*Voandzeia subterranea* (L.) DC.), sugar cane (*Saccharum officinarum* L.), Guinea sorrel (*Hibiscus sabdariffa* L.), and okra (*Abelmoschus esculentus* L.) etc. to ensure food self-sufficiency and family expenses (Aïssatou *et al.,* 2006).Although these species occupy small areas in agro-ecosystems in parts of Niger (DS / MDA, 2012), their socio-economic role is considerable. Indeed, these species are not only a source of protein and energy but some such as fonio also offer resilience in environmentally degraded areas (Vall *et al.,* 2008). A better understanding of these secondary species thus proves necessary to ensure their sustainable use by producers.

Fonio is one of the oldest domesticated cereals with a high cultural value in certain ceremonies in West Africa (Adoukonou-Sagbadja *et al.,* 2006; Dansi *et al.,* 2010). It seems less sensitive to parasitic damage during storage than other cereals (Adoukonou-Sagbadja *et al.,* 2006; Adoukonou-Sagbadja *et al.,* 2007b;. Dansi *et al.,* 2010).Well suited to local soil and climatic conditions, drought resistant thanks to its C4 metabolism and helps to maintain the environment by ensuring green cover on environmentally sensitive soils and undervalued (Vietnameyer *et al.,* 1996; Aslafy 2003; Cruz, 2004; Cruz *et al.,* 2011). Its grains, particularly rich in methionine and cysteine two amino acids deficient in other cereals (Fliedel *et al.,* 2003), are consumed in various forms: couscous, porridge, soup or donuts. The grains are also used for making selection of dishes for different parties or traditional ceremonies.The fonio straw is often used as fodder to feed cattle but also goats, sheep, especially in the driest areas, where the sources of animal feed are rare (Cruz, 2004; Jideani *et al.,* 2010; Cruz *et al.,* 2011; Ezechil *et al* 2012; Jideani, 2012).Poor gluten, fonio is recommended for diabetics and overweight people (De Lumen *et al.,* 1993; Bama, 1999 Kuta *et al.,* 2003). In Niger the average annual area under cultivation of fonio during the period 2000 to 2011 is 6742 ha with an average annual production of 2,460 tons. (DS / MDA, 2012).

Despite the importance of this secondary crops for food security and in other fields of everyday life of many populations of West Africa, very little scientific work has been devoted to a better understanding of it. This study aims to inventory the diversity of fonio called Niger, to list all the terms associated with the nomenclature of fonio, know the importance of this crop in the agricultural systems of villages surveyed, namely the evolution of the production of that crop during recent years in Niger.

Materials and Methods

Study area

A survey of fonio cultivars was held in Niger in May 2011 in the regions of Dosso and Tillabery between latitudes 12-13 ° N and longitudes 2 to 4 ° E (Figure 1). Located in the Sudanien region of south-west Niger, Dosso region is characterized by an annual rainfall of

between 600 and 800 mm over 3 to 4 months. This area is best suited for agriculture in Niger. The Tillabery region lies to the west of the country in the Sahel sedentary with an annual rainfall of between 400 and 500 mm in 3 months. In addition to the agricultural vocation of the area, farming is also practiced especially in the northern border (Saadou 1990; Bakasso 2010). Regions and villages where the collection was made were chosen on the basis of a first survey conducted in 2010 by researchers at Abdou Moumouni University and the Research Institute for Development, but also statistics fonio production obtained at the Department of Statistics of the Ministry of Agricultural Development of Niger indicating areas of culture fonio (DS / MDA, 2010; DS / MDA, 2011; DS / MDA, 2012).

Collection method of fonio accessions

Surveys with fonio sample collections were conducted to gather the maximum of diversity present in Niger. The collection was performed in 10 to 15 farmers per village in the form of individual interview. A sample was taken per farmer. The meeting allowed to collect information on the identity of the farmer, he cultivates different species, different varieties of fonio and the cultural technique and the area devoted to it. Finally, information on the evolution of the production of fonio in recent years and the cycle length of the plant were also obtained at the farmers surveyed in each village.

Data analysis

Geographic coordinates of the villages where the collection was made were collected using a GPS Garmin eTrex and were later incorporated into the ArcGIS software v 9.1 in order to be on the Niger map production areas fonio. The evolution of crop in the different villages surveyed was also shown in the Niger card. An analysis of variance was performed on the survey parameters [cycle, state of culture (EDC) per hectare cultivated area (Sc / ha) Quote Rank (RC)], using Fisher's test R.3.5.1 the software to see if there is a significant difference at the 5% level, these parameters in the surveyed villages.

Results and Discussion

Number of farmers surveyed and collected accessions

A total of 469 farmers distributed in different agro-ecological zones of cultivation of fonio in Niger were interviewed based on their ethnicity. In addition, 250 accessions were collected in 38 villages in the regions of Dosso and Tillabery which are the main production areas of fonio (Table 1).

In the region of Tillabery, population especially crop *Panicum laetum* in marshy places as wild fonio used as solder food.

The results of the analysis of variance show that at the village level, the difference is highly significant for all the studied parameters as indicated by the values of F (Table 2). When this analysis is done at the farm level the difference is not significant for all parameters except for the status of culture (EDC) where it is very highly significant (Table 2). This difference translates in fact the size of the family of the farmer in terms of labor, the cultivable area available to it, and its economic situation to acquire the fields of labor and manure. Thus the farmer has more labor more it will grow fonio and more if the culture surface is more important he can devote much to the culture of fonio.

The priority of farmers in these areas are mainly millet as a food crop and cowpea and / or groundnuts as a cash crop.

Diversity of fonio as perceived by farmers

Local nomenclature of fonio accessions

Four terminologies are commonly used to designate fonio grown by 469 farmers surveyed in both areas of study**:**

« Intaya baka » in Hausa or "furabi" in Zarma language to designate the varieties of fonio whose color of paddy grain is black, brown or purple. This represents 10.4% of the collected accessions (Figure 2a);

« Intaya fara » in Hausa or "fura Kirey" in Zarma to designate fonio varieties whose color of paddy grain is gray, light brown or pale yellow, or 87.2% of the collected accessions (Figure 2b);

« Koura » in Hausa language to designate the varieties of fonio whose color of paddy grain is black with hair on the spikelets. This group represents 2.4% of the collected accessions;

« Semerey / furori » in Goumantché language or « Mobi » in Falmangné to designateall forms of fonio accessions.

Diversity of the accessions according to the growth cycle

The varietal diversity perceived by farmers as the cycle length of fonio accessions helped to identify four types of varieties: extra-early [60-90 Days After Seeding (DAS)], early (90 to 110 JAS), intermediate (110 to 130 JAS) and late (over 130 JAS).However, survey results show that Niger, extra-early varieties (50% of villages surveyed) and intermediate (26.31% of the surveyed villages) are the most cultivated. In fact, 13.15% of the villages grow late varieties and only 10.52% of the villages cultivate early varieties and early sowing (Table 3). Early extra varieties were harvested mainly in the Dosso region in the villages of Karey Goussou, Touloua, Gueza, Farey, Djagoga, Lokoko, Lido, Kara Kara and Zabori and the Tillabery region in the village of Diney Bankarey. Early was obtained in the village of Tombo Dogo located in the Dosso region.The intermediate cycle varieties were encountered in the villages of Tessa, Youmbou, Doumega, Mournahadi, Kobokitanda, Tombo Dogo located in the region of Dosso and Djabarma in the Tillabery region. Finally late varieties are grown only in four villages in the Dosso region (Sandiday, Adigalélé, Farey and Lido).

Fonio place in the crop system in Niger

To determine the importance of fonio in crop systems, a ranking of different species cultivated by the farmers surveyed was conducted on the basis of the area cultivated and rank accorded to crop (Table 4). The results show that fonio occupies the 4th place among the species cultivated for 43% of farmers with an average area of 1.3 ha and 3rd place for 19% of respondents with an average area of 1.4 ha. For 19% of the peasants, it occupies the 6th place with only an average of 0.7 ha area down.

Finally 19% of those surveyed do not practice at all this crop but some are reaping the Djerji or gansi called *Panicum laetum* Kunth near swampy areas, like wild fonio.However, it is important to note that the estimated acreage awarded to culture by farmers is always subjective because it is made visually. It is generally based on the endogenous knowledge of farmers in the demarcation of their fields based on the importance accorded to the species they grow. This brings us to relativize this area estimation given by the farmers surveyed in this study.

Status of fonio crop in Niger

The evolution of the production of fonio in recent years is also variable depending on the

villages surveyed (Figure 3). Thus it saw an increase in 49% villages, stability at 2% and a decline at 30%. A disappearance of fonio crop was even recorded in 19% of villages surveyed. This change both at the village level variable farm level (Table 2) is essentially linked to post-harvest operations that restricts expanding fonio in this production area. The respondents mentioned the lack of peasants land and labor available as reasons to abandon the fonio.

Figure.1 Location of surveyed for the cultivation of fonio in Niger villages

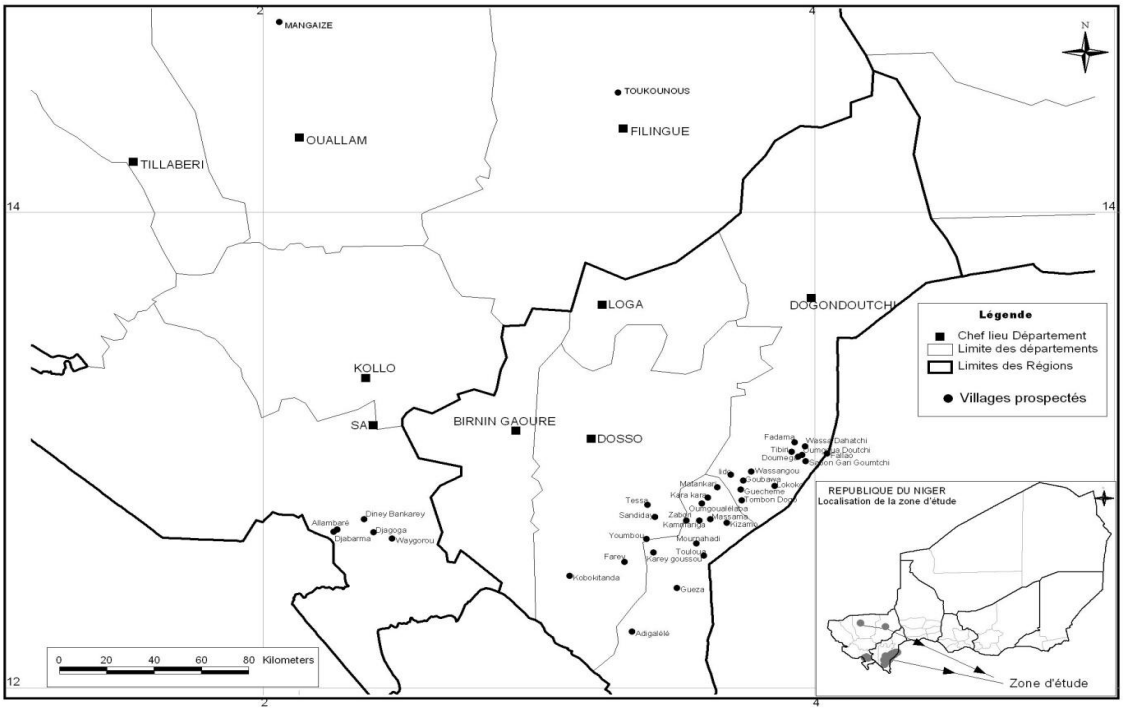

Figure.2 Morphotype of fonio. a. "Intaya baka" or "Furabi" b "Intaya fara" or "Fura Kirey"

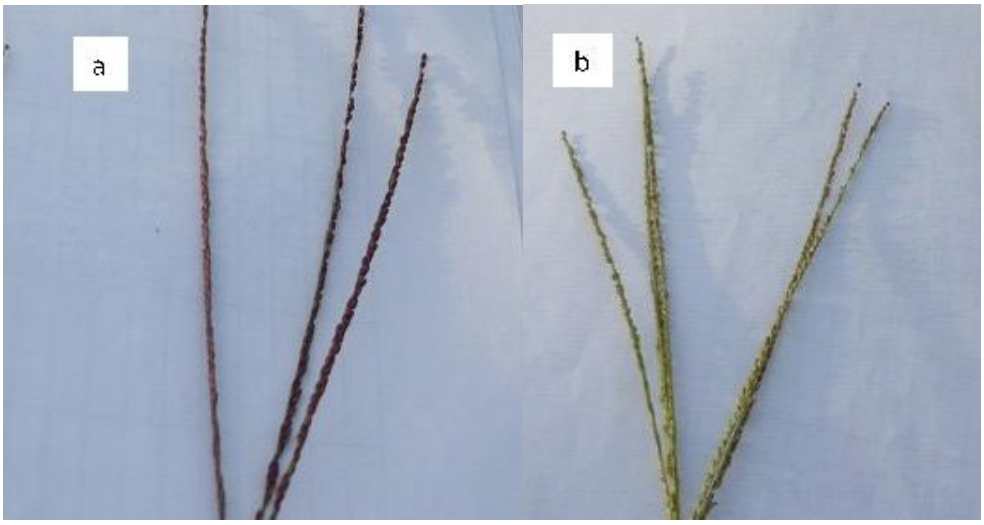

Figure.3 Evolution of the fonio crops in the villages surveyed

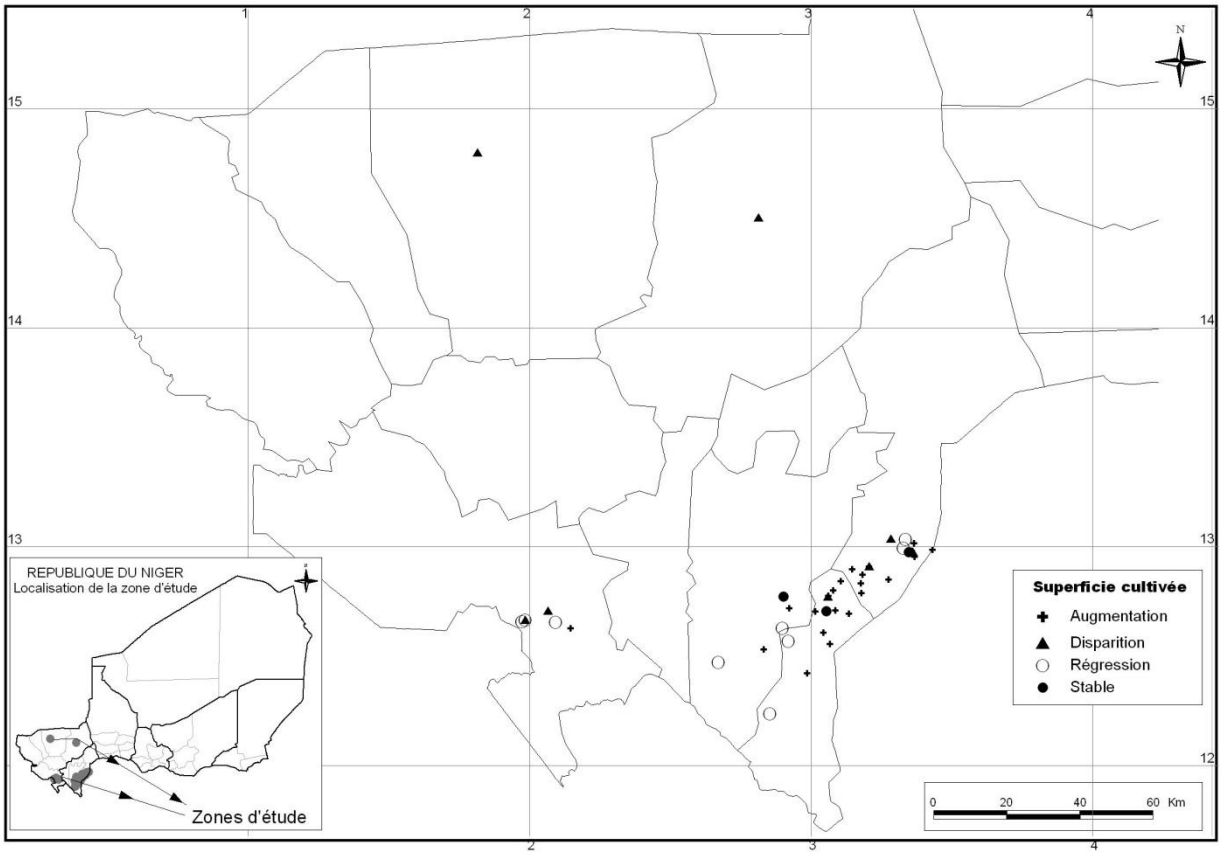

Table.1 Summary of surveyed villages and numbers of farmers surveyed in the growing regions of fonio in Niger

Régions	Villages prospectés	Nombres des paysans enquêtés
Dosso	Tessa, Sandiday, Youmbou, Karey goussou, Touloua, Mournahadi, Gueza, Adigalélé, Farey, Kobokitanda, Tibiri, Doumega, Fadama, Wassa Dahatchi, Sabon Gari Goumtchi, Oumgoua Doutchi, Fallao, Birni Fallao, Lokoko, Wassangou, Goubawa, Guecheme, Tombon Dogo, lido, karakara, Zobori, Matankari, Kizamo, Oumgoualélaba, Massama, Kammariga.	405
Tillabéry	DineyBankarey, Djagoga, Waygorou, Djabarma, Toukounous, Mangaizé,	64
Total	38	469

Table.2 Summary results of the analysis of variance on some parameters investigated

Source de variation	Valeur de F			
	RC	Cycle	Sc/ha	EDC
Village	4.628***	3.556***	2.489***	20.058***
Paysans	0,303^{ns}	0.952^{ns}	1.214^{ns}	2.996***
Pr(>F) (Village)	6,55.10-^{09}	2,52.10^{-06}	0.0008123	2,20.$^{10-16}$
Pr(>F) (Paysans)	1	0.6085	0.1581	3,96.$^{10-15}$

RC: Rang de citation, **Cycle**: cycle des accessions données par les agriculteurs dans les villages prospectés, **Sc/ha**: Superficie cultivée accorée à la culture du fonio par hectare dans les villages prospectés, **EDC**: Etat de la culture dans les villages prospectés**, ns:** non significatif. ***: Tres hautement significatif.

Table.3 Cycle length of fonio accessions according to the farmers in the villages surveyed

Paramètres				
Cycle végétatif des accessions (jours)	60-90 (extra-précoce)	90-110 (précoce)	110-130 (intermédiaire)	> 130 (tardive)
Proportion des paysans qui cultivent les accessions (%)	42	3	40	15
Proportion de villages où sont cultivées les accessions (%)	50	13,15	26,31	10,52

Table.4 Rank and area given to the cultivation of fonio among farmers surveyed in Niger

Proportion des paysans (%)	superficie	Rang
43	1,3	4^{e}
19	1,4	3^{e}
19	0,7	6^{e}
19	0	0

High ecological plasticity plant fonio is grown in areas with an average annual rainfall of 150-3000 mm. But its cultivation is concentrated in areas where the annual average is 900-1000 mm and a height of 600-1500 mm in West Africa (Burkill, 1994). This great adaptability implies the existence of genetic diversity within the species. It has a different resistance to drought as millet, but local varieties suitable for rapid maturity areas where rainy seasons are short (Vall *et al.*, 2008). In regions of very low rainfall, it is grown in valleys benefiting runoff. Fonio can adapt to poor soils, shallow, sandy or rocky unsuitable to other cereals (Cruz, 2004; Cruz *et al.*, 2011). But he did not succeed in saline or heavy soils. On the Fouta Djallon Plateau of Guinea, it grows on acidic soils with aluminum content is very high (Burkill, 1994; Diallo, 2003; Vodouhe *et al.*, 2006; Cruz *et al.*, 2011). In Niger the cultivation of fonio grows on sandy soils low, but also on soils have lost their fertility after cultivation of other cereals such as sorghum and millet (Oumarou, 2012).

In Niger, the criteria used by farmers to classify fonio accessions are the color of

unshelled beans (color glumes) and the cycle length of the plant that distributes in four varieties as previously reported by other researchers (Portères, 1976; Cruz, 2004; Adoukounou *et al.,* 2007; Cruz *et al.,* 2011).. The work of Diallo *et al* (2008) noted the existence of many local varieties in Guinea that differ color and plant habit, color or grain size and more frequently by the vegetative cycle length of fonio. But these authors as the farmers of Niger used color glumes and plant cycle length as the first criterion to categorize accessions. Based on these criteria, four varieties of fonio could be counted in Niger. So that there are varieties unshelled beans black, brown, gray or pale yellow, with black hair on the grain. These characters colorings are found irregularly distributed in the different villages surveyed in the collected accessions. Inside these four types of varieties, there are extra-early varieties [60-90 Days After Seeding (DAS)] early (90 to 110 JAS), intermediate (110 to 130 JAS) and late (over 130 JAS).

Moreover, the existence of diversity, according to the growth cycle length, indicating the presence of several varieties in fonio, has been demonstrated by Adoukounou *et al.,* (2007a) during surveys carried out in growing areas fonio in West Africa, where 50% of the surveyed farmers were cultivating early varieties [Precocious (90-110 JAS)] as opposed to only 3% in Niger. This percentage is a strategic choice of the farmers who grow primarily millet, cowpea and / or peanuts. They wish to have less early varieties to minimize seed losses. This diversity of vegetative cycle at varieties fonio was previously shown by Portères (1955) based on the morphological characteristics of the plant. Thus early gracilis accessions known as described by Portères variety name are located in Guinea, Mali and Senegal under the Bèrèle names (or Bèrèlen); stricta early varieties also are located in Guinea, Mali and Senegal under the Momo names, Kouroukeleni, peazo or early white fonio; accessions early seedling varieties known under the name mixta are located in Guinea under Saara names, Moussogbé, Keleaningbé; Late varieties known as accessions name densa are located in Togo under the name or Semre Sebre, and also the varieties rustica located in Guinea, Mali and Senegal under the Foniba names, Konso, Rane, Siragué, Kassambara and Tama (Cruz *et al.,* 2011). This shows the existence of a large diversity it will confirm for accessions of Niger by morphological and genetic evaluation, to ensure long-term conservation and prevent genetic erosion of the species. This assessment will help to better evaluate the cycle. For many farmers, there is confusion between maturity (physiological phenomenon) and harvest depends on the availability of labor.

According to our survey results, some accessions are exclusively found in some villages in relation to their biotic and abiotic characteristics. As early varieties extra cycle almost exclusively found in villages Karey Goussou, Touloua, Gueza, Djagoga, Diney bankarey, Lokoko, kara kara and Zabori. Early accessions are located in the village of Tombo Dogo. Accessions intermediate cycles were collected in the villages of Tessa, Youmbou, Doumega, Mournahadi, Kobokitanda, Djabarma, Tombo Dogo and finally late accessions are grown only in the village of Sandiday, Adigalélé, Farey and Lido. The villages where early accessions are identified occur in areas where the rainy season lasts on average three months. It is therefore vulnerable villages as structurally deficient in terms of cereal production. Conversely, late fonio accessions are confined to the Sudanien zone or the rainy season lasts 3-4 months with an average annual rainfall between 600 and 800 mm (Saadou 1990; Bakasso 2010). The cycle time, that extends

when you go up in altitude, that early accessions currently available are not well adapted to Niger for areas whose altitude is between 190-230 meters. But for some farmers the choice of variety depending on the ring is linked to the agricultural calendar because the fact of having varieties with longer cycle will allow them to take care of fonio in last place with less grain loss.

Place and area given to the fonio crop in Niger therefore reflect its importance in the diet of the farmers surveyed especially during lean periods. In Niger, the average area given to the fonio crop in the last twelve years (2000 to 2011) was 3939.95 ha (MDA, 2010; MDA, 2011); The reduction of this area is linked to population growth causing a shortage of arable land (MDA, 2012 Oumarou, 2012), but also the introduction of rice crop in certain production areas of fonio (Oumarou, 2012). According to our investigations in these fonio production zones in Niger, 81% of surveyed villages currently grow fonio while in 19% of cases a total disappearance of the culture was observed. This fact is linked to the difficulty of post harvest operations that requires a significant amount of labor (Cruz *et al.*, 2011) on one hand, but also by the introduction of new crops in some villages of somewhere else. In the region of Tillabery, fonio considered lean food is much more wild harvested mostly by Tuareg herders. This is the *Panicum laetum* that the population of this region called fonio. This practice is unknown in the Dosso region. As the harvest period fonio most often coincides with that of major grain crop grown by farmers, there arises a problem of availability of labor. This lack of local works hand during harvest has led to the decline or disappearance of the cultivation of fonio in some villages at the expense of major crops such as millet, sorghum. However, 4.69% of surveyed farmers stated that the decline of culture was due to the attack caused by grasshoppers which lowers crop yields. The quality of post-harvest product (presence of sand) is a cause for fonio remains a growing family use or at most locally. Although it is a very popular food especially by the older generation, it has not invaded large urban centers to thereby generate demand for increasing its production.

In conclusion, in Niger fonio is mainly grown in two areas between isohyets 400 to 500 mm (Tillabery Region) and 600 to 800 mm (Dosso Region). Despite a recent new customer production interest witnessed in years, the cultivation of fonio has experienced significant regression, see the map of disappearing cultures of some villages. Culture undemanding, it can play an important role in the fight against food insecurity strategy. This culture should hence further investigations not only to improve its potential and its crop expansion, so to be a future culture in Niger but also to better confirm and position varieties of Niger, which were previously unknown, for compared to the five varieties described by Portères in West Africa.

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