Genet Resour Crop Evol (2017) 64:419–436
DOI 10.1007/s10722-016-0370-7

RESEARCH ARTICLE

Horticultural practices and varietal diversity of chili pepper (*Capsicum annuum* L.) in Central and Northern Benin

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Received: 17 August 2015 / Accepted: 18 January 2016 / Published online: 5 February 2016

Abstract Chili peppers play a significant role in the world diet and can contribute to the improvement of horticultural producers' incomes. In Benin, chili pepper production is hampered by many challenges that need to be characterized, prioritized and addressed. Moreover, the existing diversity, as well as the agronomic potential, of the varieties being cultivated in Benin is still not well understood. In order to define the scientific basis for the improvement of chili pepper production and the preservation of its diversity, one hundred villages were randomly selected and surveyed in Northern and Central Benin by using participatory research appraisal tools and techniques. Twelve production constraints were identified, of which low productivity (19 %), soil infertility (18.5 %), drought (18.3 %), pests and disease susceptibility (17.9 %), early fall of plant organs (15 %) appear as the most important. In terms of diversity, 77 chili pepper varieties (40 from the frutescens group, 24 from the annuum group and 13 from the chinense group) including 72 local and five introduced varieties (*Tataché*, *Yèyèkouka*, *Yèyèkouokourè*, *Côte d'ivoire* and *MC*) were found. The number of varieties varies from three to seven (four on average) per village and from one to five by household. The proportion of loss of diversity per village varies from 0 to 75 % with an average of 26.61 %. Susceptibility to pests and diseases (37.1 % of responses), early fall of plant organs (11.6 % of responses) and susceptibility to drought (8.5 %), were the most important reasons given in attempts to explain the loss of diversity. Farmers' varietal preference criteria are essentially agronomic (90.4 % of responses). The participative agronomic evaluation revealed that the varieties of frutescens group are significantly higher with respect to the evaluated variables, but they are less appreciated by the consumers.

Keywords Agricultural practices · *Capsicum annuum* · Constraints · Folk nomenclature · Participative evaluation · Preference criteria

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Introduction

Chili pepper (*Capsicum annuum* L.) is a fruit vegetable belonging to the family of Solanaceae (Kumar et al. 2014). The genus *Capsicum* is native

of tropical America and includes 27 species, of which only five (*C. annuum* L, *C. chinense* Jacq., *C. frutescens* L., *C. baccatum* L. and *C. pubescens* Ruiz et Pavon.) are cultivated as spice and fruit vegetables throughout the world (Ibiza et al. 2011). Among these chili pepper species, only three (*C. annuum* L., *C. chinense* Jacq., *C. frutescens* L.) are cultivated in Benin (Akoègninou et al. 2006). Due to the existence of many difficult to identify intermediary forms resulting from natural interspecific crosses, these three species (*C. annuum* L., *C. chinense* Jacq., *C. frutescens* L.) are now treated as one species (*C. annuum* L.) with four cultivars groups (Onus and Pickersgill 2004) that are: chinense group (West Indies chili), frutescens group (bird chili), annuum group (hot chili) and sweet pepper group.

Chili pepper is a very significant condiment in African daily diets (Bosland and Votava 2001). It is rich in proteins, lipids, carbohydrates, fibers, mineral salts (Ca, P, Fe) and vitamins A, E, C, K and B2 (Orobiyi et al. 2013). Chili pepper is used in pharmaceutical industries for the production of oleoresins and capsaicinoids (Orobiyi et al. 2013). Capsaicinoids are alkaloids responsible for the fruits' pungency that also confer interesting medicinal properties (Athanasiou et al. 2007; Wahyuni et al. 2013). Chili pepper is also reported as having antioxidant, antimutagenic, and hypocholesterolemic properties (Morre and Morre 2003; Bhattacharya et al. 2010). Economically, chili pepper represents a significant source of income for both producers and traders in Africa (James et al. 2010).

Despite the nutritional, medicinal and economic importance of its fruits, chili pepper production in Northern and Central Benin is confronted by many biotic and abiotic constraints that have been poorly documented. To combat chili pepper's pests and diseases, producers use chemical products (pesticides) that have negative effects on both human health and the environment. The most efficient and economically profitable solution of producing chili pepper while preserving human health and the environment remains the use of resistant or tolerant varieties (Dansi et al. 2013). Such varieties can be developed through breeding or simply searched for within the existing diversity. Therefore, a good knowledge of the existing diversity is necessary.

This paper present the results of an ethnobotanical investigation carried out in Northern and Central Benin to:

- Identify and prioritize the local constraints related to chili pepper production.
- Assess existing chili pepper diversity and analyse its distribution and extent for conservation and breeding purposes.
- Identify and prioritize farmers' varietal preferences and selection criteria for breeding and extension.
- Evaluate the agronomic performance of cultivated varieties for use in a breeding program.

Materials and methods

Study area and site selection

The study was carried out in the Northern and Central regions of Benin (Fig. 1) located in West Africa. Northern Benin is semi-arid (one dry season and one rainy season), characterized by unpredictable and irregular rainfall oscillating between 800 and 950 mm/year (Yabi and Afouda 2012). The annual mean temperature is 27.5 °C while the annual relative humidity averages 58 % (Yabi and Afouda 2012). Central Benin is located in a humid (two rainy seasons; two dry seasons) agro-ecologic zone with 1100–1400 mm per year (Yabi and Afouda 2012). The study area is divided into 6 departments (Alibori, Atacora, Borgou, Collines, Donga, and Zou), inhabited by 21 principal ethnic groups including 14 (Ani, Biali, Naténi, Yom, Nagot, Mokolé, Bariba, Boko, Dendi, Ditamari, Kotokoli, Lokpa, Peulh, Wama) in the Northern region and 7 (Ifè, Itcha, Idatcha, Tchabè, Mahi, Fon and Holli) in the Central region. For the study area to be sufficiently covered in an exhaustive inventory of biodiversity, 100 villages (77 in North and 23 in the Center) were randomly selected and surveyed (Fig. 1).

Data collection

Data were collected in each selected village through the application of participative research appraisal tools (questionnaires) and methods (focus group surveys, individual surveys, fields) as described by Adjatin et al. (2012). Because of ethnic diversity, a translator or interpreter was locally recruited in each village to facilitate discussions and exchanges with producers, following Dansi et al. (2013). The group survey was

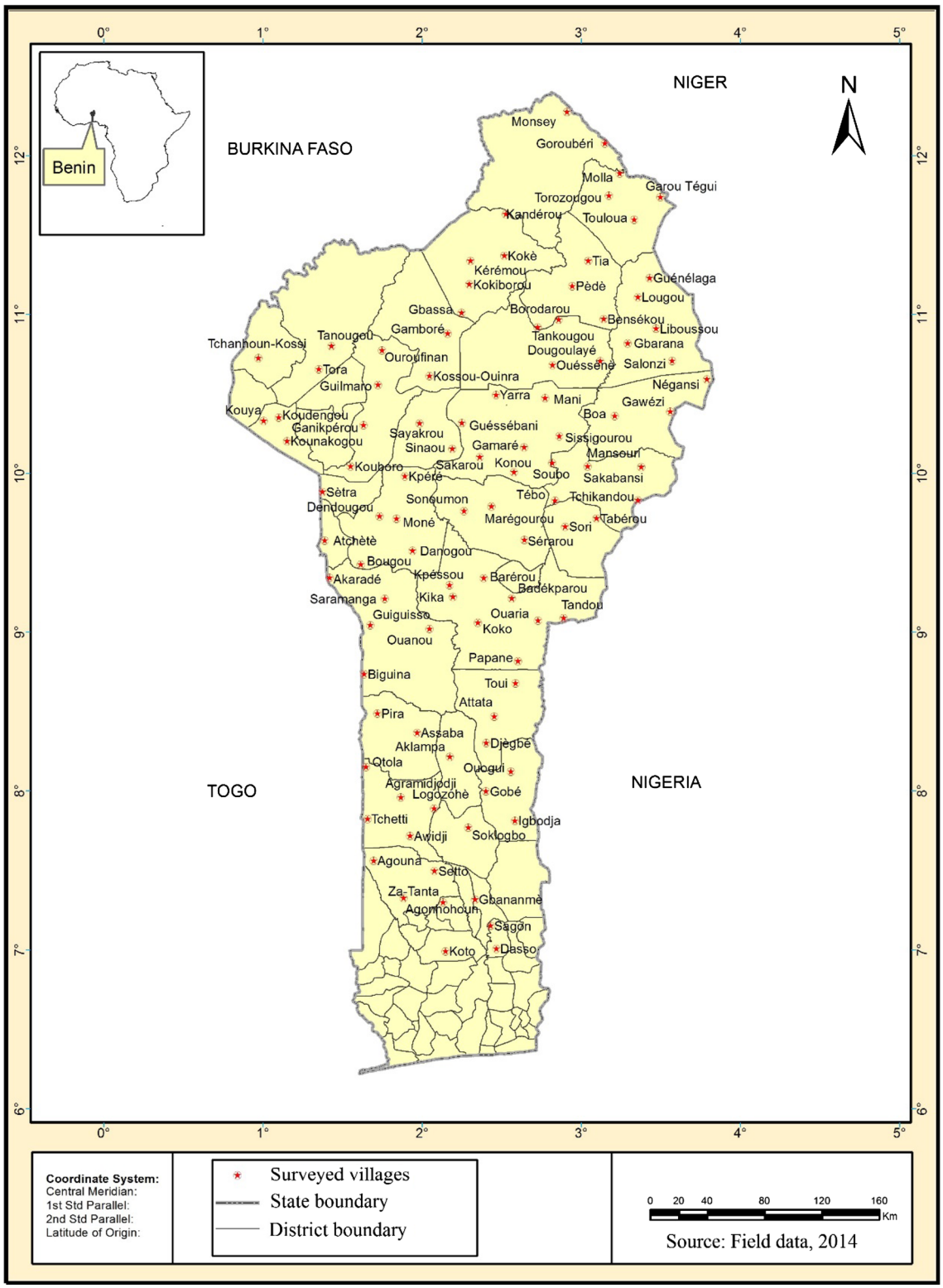

Fig. 1 Geographical distribution of the selected villages

carried out with 20 to 30 producers of both sexes and various age groups (Loko et al. 2013). To facilitate both discussions and to provide documentation, farmers were asked to bring samples of the chili peppers they cultivate or knew about. In each village, farmers were firstly asked to list in vernacular language all the constraints related to chili pepper production in their area. Enlisted constraints were prioritized in groups by identifying and gradually eliminating the most severe constraint, following Dansi et al. (2013). The same procedure was repeated until the last constraint was ranked, and the results were immediately given to producers for approval.

At the community level, a varietal inventory was done using vernacular names, following Dossou-Aminon et al. (2014). During the inventory process, varieties were classified by the farmers into three groups (popular varieties; threatened varieties; varieties of intermediary status) based on their perceived distribution and extent, following Dansi et al. (2010) and Kombo et al. (2012), in the sense that distribution and extent refer to the relative area (large or small) devoted to a variety and to the relative number of households (few or many) cultivating it. Popular varieties or "elite varieties" are cultivated by many households on large areas; varieties of intermediate status are those cultivated by many households on small areas (or by few households on large areas), while threatened varieties are cultivated by few households on small areas. This last group was used to assess the proportion of threatened or abandoned varieties, following Loko et al. (2013). Farmers' varietal preference criteria were identified at the community level in group settings and prioritized by using the progressive elimination approach described above.

The participatory evaluation of varieties was done by following the evaluation method described by Loko et al. (2015). In this approach, for each given trait, a variety is scored (by a group of farmers) 1 when it meets the criterion and 0 when it does not. Parameters considered were: productivity, resistance to early fall of plant organs (leaves, flowers and fruits), resistance to diseases, resistance to insects, earliness, adaptability to all types of soil, tolerance to high soil moisture, resistance to drought, facility of seed germination, fruit aroma, and easiness of fruit grinding.

Individual surveys were also conducted in three to four households, randomly selected from those producing chili peppers, in each of the selected villages. In each household, the interviewee was the head of household or his wife (Loko et al. 2013). In total, 234 women and 150 men producing chili peppers were surveyed in the 100 selected villages. The data collected included socio-demographic data (age, sex, household size, years of experience in chili pepper production, educational level, number of labourers), cultivated area, seed system (production, supplier, conservation methods, and duration of conservation); earliness of varieties, and cultural practices.

Statistical analysis

Data collected were analysed by the descriptive statistics (means, percentages, etc.) and results then presented in the form of figures and tables at different levels (village, study zone). For the study area, identified constraints were prioritized following Gbaguidi et al. (2013) based on the means of the following three parameters:

- The total number of villages (TNV) in which the constraint was noted
- The number of villages in which the constraint was classified among the principal constraints (PCO) among the first five
- The number of villages where the constraint is the major one or ranked first (MAC)

The importance of a constraint (IMC) was then determined by the formula $IMC = (TNV + PCO + MAC)/3$.

The proportion of threatened varieties or variety loss (RVL) at the village level was determined, according to Kombo et al. (2012) by the formula $RVL = (n - k)/N \times 100$, where n is the number of endangered varieties (cultivated by few households and small areas); k is the number of varieties newly introduced; and N is the total number of varieties identified in the village.

To evaluate the importance of diversity in each agro-ecological region, the Shannon–Weaver diversity index (H) was computed for the whole study zone following Shannon and Weaver (1948). Correlations between household socio-demographic parameters (age, sex, size of labour pool, and household size) and the varietal diversity maintained at the household level were calculated with Pearson's correlation analysis by using STATISTICA 7.1. software.

To study chili varietal diversity in terms of agronomic, technological and culinary performances, a dendrogram was constructed using UPGMA

(Unweighted Pair-Group Method with Arithmetic Average) clustering method with NTSYS-pc 2.2 (Numerical Taxonomy and Statistical Analysis) software (Rohlf 2005) by considering identified chili varieties as individuals and evaluation parameters as variables according to Kombo et al. (2012).

Results and discussion

Production constraints

Ten constraints affecting chili pepper production were identified and prioritized in the study area (Table 1). Among them, the most important were low productivity (18.9 % of responses), inadaptability to infertile soils (18.5 %), drought susceptibility (18.3 % of responses), pest and disease susceptibility (17.9 %), and early fall of plant organs, such as leaves, flowers and fruits (15 % of responses). These results are similar to those reported by Orobiyi et al. (2013) in Southern Benin.

High productivity is a characteristic sought after by nearly every producer. Therefore, it is not surprising that farmers devoted to such importance to it. Soil infertility, classified in second position by farmers, represents one of the biggest challenges to the production of chili pepper in Benin (Orobiyi et al. 2013). Because of high costs, many producers do not use fertilizers, and those who do are unfortunately rarely supervised by agricultural extension agents. Misapplication of fertilizer also causes, according to farmers, yellowing and early fall of flowers and fruits and a reduction in the duration of effective post-harvest storage of the fruits. Chili peppers of the chinense group, which are well appreciated by consumers because of their aroma, were mostly marked down for the poor post-harvest storage of their fruits.

The importance of individual constraints also varies from one agro-ecological zone to another (Table 1). In Northern Benin, varietal susceptibility to drought (21.6 %) was first followed by pest and disease susceptibility (19 %) and then to inadaptability to infertile soil (17.8 %). In Central Benin, low productivity (20.3 %) appeared first, and inadaptability to infertile soil (19.3 %) was second. This variability from one agro-ecological zone to another was not surprising, as it has already been reported from West Africa for *Digitaria exilis* Stapf and *Digitaria iburua* Stapf (Adoukonou-Sagbadja et al. 2006), *Dioscorea cayenensis–Dioscorea rotundata* complex (Loko et al. 2013), and *Manihot esculenta* Crantz (Agre et al. 2015). This should be an important consideration for both breeders and agricultural extension agents when setting their priorities for different agro-ecological zones.

Apart from low market value, all other constraints could theoretically be overcome through the development and use of resistant or tolerant varieties. It is therefore important to establish a chili pepper breeding program in Benin designed to address these constraints.

Seed system

Throughout the study area, the great majority (80.7 %) of the surveyed producers use seeds retained from the

Table 1 Chili pepper constraints in Central and Northern Benin

Constraints	TNV	PCO	MAC	Importance (%)	Ranking	Importance (%) per region	
						North	Centre
Low productivity	90	78	34	18.9	1	17.5	20.3
Inadaptability of many varieties to poor soil	94	86	17	18.5	2	17.8	19.3
Susceptibility to drought	88	80	26	18.3	3	21.6	14.9
Susceptibility to pets and diseases	97	86	6	17.9	4	19	16.8
Early fall of plant organs	84	72	3	15	5	15.1	14.9
Low post-harvest storage	29	7	0	3.4	6	2.2	4.6
Lack of quality seeds	21	6	1	2.6	7	2.6	2.7
Low market value	21	2	0	2.2	8	1.7	2.6
Susceptibility to high soil moisture	15	3	1	1.8	9	1.5	2.1
Difficult harvest	12	3	0	1.4	10	1	1.8

TNV total number of villages, *PCO* principal constraints, *MAC* major one or ranked first

previous harvest for the next planting. These seeds are typically collected from selected very productive and healthy chili pepper plants. Other producers either buy seeds from markets that are either ready for sowing (6.3 %) or not (7.3 %) as they still needs to be extracted from fruits. A small group of producers (5.7 %) buy seeds from extension services, such as national agricultural promotion centres or NGOs.

All the producers interviewed preserve chili pepper seeds without any chemical treatment in various types of containers. For instance, most producers (64.6 %) use glass or plastic bottles to preserve chili pepper seeds, while 19 % use nylon bags and 16.4 % wrap them in pieces of unused cloth.

Certain producers (14.7 %) store their seeds attached to their kitchen ceilings to take advantage of the smoke which could help protect seeds against insects. Other producers (85.3 %) store their seeds without employing this option. The duration of storage varies from one producer to another. The majority (84.6 %) of the producers only stored chili pepper seeds until the next growing season, which is between 4 and 5 months depending on the variety. The remaining producers stored their seeds in house for one (6.5 % of farmers), two (3.9 % of farmers) or three (5 % of farmers) years.

Agricultural practices and gender role

Seedling cultivation, transplanting, and harvesting are the three key periods of chili pepper production. All the surveyed producers reported that on average and whatever the variety, chili pepper seedling lasts 1 month and the cycle of production after transplanting varies from 2.5 to 4 months (Fig. 2). Among varieties notes as needing 4 months for instance (subject to synonymy), 16 belong to the frutescens group, 13 to the annuum group and 4 to the chinense group (Fig. 4). Six varieties equitably distributed across these three groups have a cycle of production of 2.5 months. According to producers, the cycle of production of chili pepper between transplant and harvest is influenced by soil moisture and fertility and by seed quality (Fig. 3).

In Central Benin, because of the existence of two rainy seasons there, chili pepper is cultivated only in a rainy season by the majority (80.5 %) of producers. In the northern region, 67.7 % of the 307 producers surveyed having fields located near rivers, streams or lakes or in lowlands cultivate chili pepper in both the rainy and dry seasons.

With regards to manure, most producers (65.9 %) use chemical fertilizers (NPK, urea) purchased from national centers of agriculture promotion, but 22.7 % reported using no chemical fertilizers or organic manures for chili pepper production. The remaining producers (11.4 %) cultivate chili pepper by using organic manures, such as chicken droppings (3.4 %), compost (2.1 %), sheep droppings (1.5 %) or cow dung (4.4 %).

In terms of crop protection, 63.1 % of producers take no specific actions against pests or diseases. Some producers (24.7 %) use chemical products for control. Other producers (12.2 %) use organic control methods, such neem (*Azadirachta indica* A. Juss.) extract or essential oil, wild lettuce [*Launaea taraxacifolia* (Willd.) Amin ex C. Jeffrey] extracts, or cassava (*M. esculenta* Crantz) peelings, or crop rotations to control associated pathogens. The use and efficacy of biopesticides in the production of horticultural crops is now well recognized (Chandler et al. 2011) and promoted worldwide due to their less hazardous effects on the environment.

Of the 384 producers surveyed, most (60.9 %) were women. They typically manage their chili pepper fields from seedling to harvest without male intervention. In the men's chili pepper production fields, harvesting, transportation, commercialization, seed selection and storage are generally carried out by women (their wives or female children). In the study area, chili production thus was determined to be predominantly a task for women, although men are

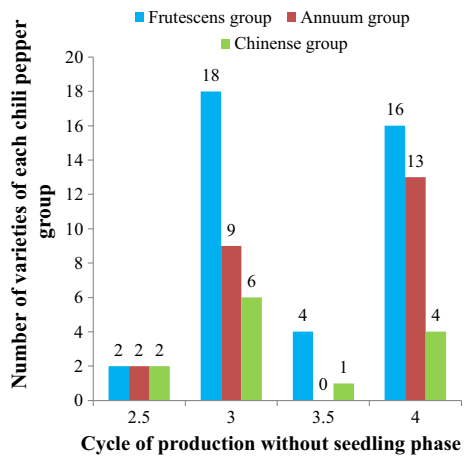

Fig. 2 Number of varieties of each chili pepper group according cycle of production of the plants after seedling until harvest

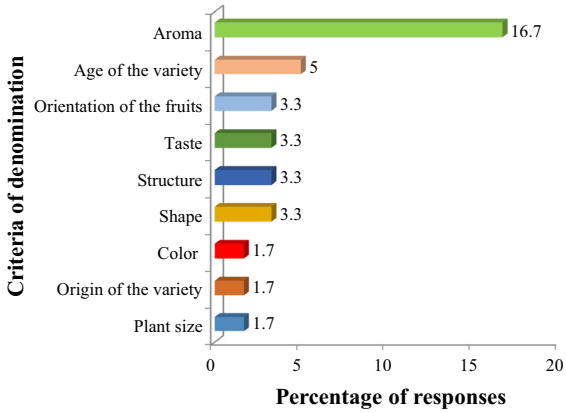

Fig. 3 Nature and importance of the criteria of denomination of chili pepper varieties

also involved. The custodial role of women in seed conservation in traditional farming and mainly in vegetable production has already been widely reported (Howard-Borjas and Cuijpers 2002; Upadhyay 2005; Zobolo and Mkabela 2006; Gruberg et al. 2013).

Folk nomenclature and taxonomy

In North and Central Benin, chili pepper is known by various vernacular names in local languages (following the names in parentheses) including: *Gninkou* (Bariba and Wama), *Boukounsina*, *Boukombamou* or *Yègoudè* (Ditamari), *Kolagui* (Naténi), *Kombouga* (Lokpa), *Tambo* (Nago, Idatcha, Tchabè) and *Takin* (Fon, Mahi). Among chili peppers, farmers recognize the existence of several local varieties that they name by referring mainly to the diverse characteristics (colour, aroma, shape, size, structure, taste, orientation) of their fruits, or the origin and the age of the variety (Fig. 4; Table 2). The vernacular names of the varieties that we recorded vary across ethnic groups and sometimes from one village to another within the same ethnic groups. These observations are common in folk nomenclature and were already reported on many crops, such as *M. esculenta* Crantz (Kombo et al. 2012), *Vigna unguiculata* Walp. (Gbaguidi et al. 2013), *Sorghum bicolor* (L.) Moench (Dossou-Aminon et al. 2015) and *Macrotyloma geocarpum* (Harms) Maréchal et Baudet (Assogba et al. 2015). For clarification of problems of synonymies both agro-morphological and molecular characterization are required as indicated by Gbaguidi et al. (2015).

Base on fruit shape and size, farmers traditionally classify local varieties into three groups:

- a group with large, elongated fruits called *Sorossoro* or *Guerri*;

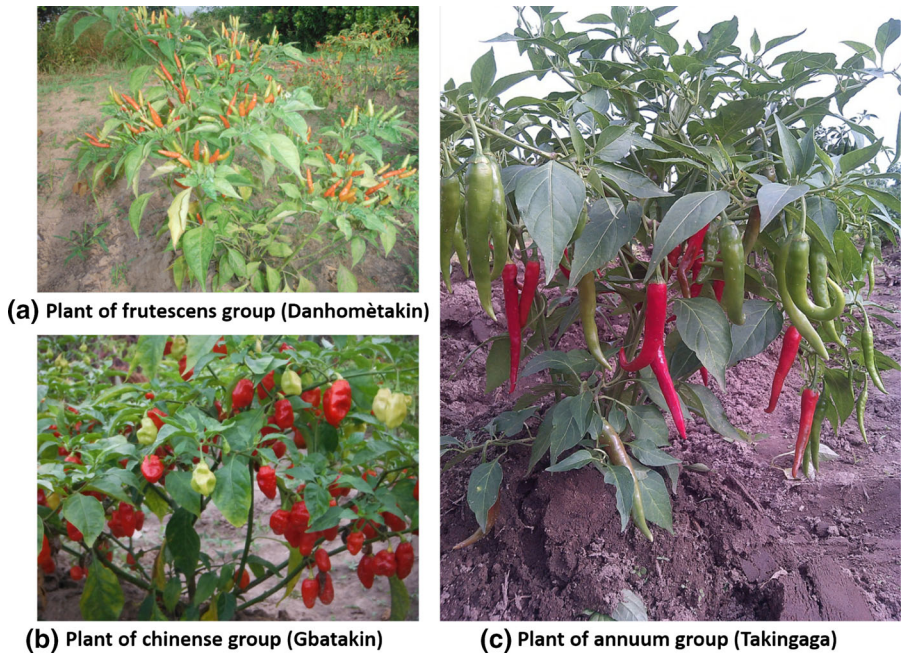

Fig. 4 Chili pepper plants of the different group with fruits

Table 2 Folk nomenclature of chili pepper varieties in Central and Northern Benin

Naming criteria	Names of the varieties	Significance of the names
Colour of the fruits	Berkpame	Red as red oil
Aroma of the fruits	Bo, Gbataki, Boukoussinabouata, Bouotèrèyèkourè, Kolabouahi, Lakamoubouata, Sabotéyèkou, Bokinon, Tchingboutouha, Dokounou	Chili pepper that has the odor of the goat
Fruits shape	Guerri	Chili pepper of banana shape
	Nkpankabouka	Chili pepper resembling to the Ear of rabbit
Fruits size	Bargoudjè ou Péto, Edjala, Fanafanaka, Gbonsigui ou Daméri, Gninka, Kolamainma, Koumka, Latogué, Koyolaha, Lakamoudala, Takinwiniwini, Outinon, Tambowèwè, Yèbargou, Gobi, Yèkohotoukou, Youyourse, Dèyèkouyonnan, Siyèkoukadoè, Youti, Missabome, Yèyèkouka	Small chili pepper
	Namouti	Middle chili pepper
	Bodanganda, Djouè, Gnonnanzon, Kibizou, Kolaguiotioki, Kotalaha, Lamaka, Sabalo, Tchombo, Tchingwoholou, Yèyèkouokourè, Yèfikou, Tchogolotchobé	Long chili pepper
Structure	Tampiyouha, Djodidjodi	Dehiscent chili pepper
Size of the plant	Pollipolli ou Sorossoro	Tall chili pepper
Origin of the variety	Baton	Chili pepper of the Batonou (Bariba)
Taste	Tchinglassi, Guiya	Too hot chili pepper
Orientation of the fruits	Tankpatcholè	Chili pepper with pendant fruits
	Tankpatcholèlè	Chili pepper with erect fruits
Age of the variety	Ibilè, Adiba, Abalayé	Ancient chili pepper

- a group with round fruits called *Gbatakin* (several ethnic groups), *Bo* in Peulh, *Bokinon* in Bariba, *Odougourou* in Ifè, and *Bouotèrèyèkourè* in Ditamari (Fig. 4); and
- a group with small, elongated fruits called *Gninka* or *Guiya* in Bariba (Fig. 4).

Within each group, producers often use several morphological characters, such as fruit shape, leaf width and length, floral and fruit orientation, and leaf pubescence, to recognize and differentiate various types of chili pepper. The frequency of utilization of these parameters is highly variable (Fig. 5).

Using the farmers' identification parameters as variables, the 77 inventoried varieties in our study (taken as individuals) clustered into three groups (Fig. 6) that exactly corresponded to those been described above by the farmers and also to the three groups of chili pepper (the annuum, chinense, and frutescens groups) noted by Akoègninou et al. (2006) (Fig. 7).

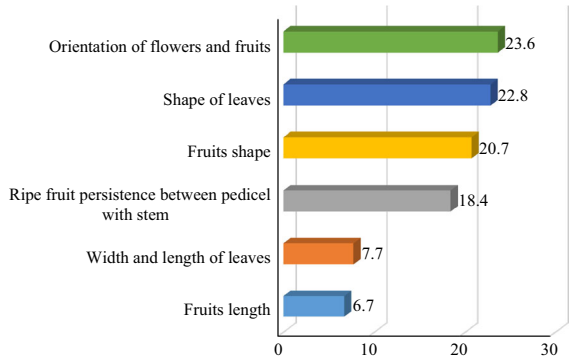

Fig. 5 Morphological characters used by farmers to recognised chilli peppers varieties

These results clearly show that producers have a good knowledge of their plant materials and that their knowledge is valuable for taxonomists and geneticists, as recommended by Dansi et al. (2010) for fonio (*Digitaria exilis* Stapf, *D. iburua* Stapf), Gbaguidi et al. (2013) for cowpea (*V. unguiculata* Walp.),

Kombo et al. (2012) for cassava (*M. esculenta* Crantz), and Assogba et al. (2015) for kersting groundnut (*M. geocarpum* (Harms) Maréchal et Baudet).

Varietal diversity in the study area

Without accounting for synonymy, 77 local varieties of chili peppers were listed in the 100 villages that we surveyed in Northern and Central Benin. Of these 77 varieties, 40 are from the frutescens group (small chili peppers), 24 from the annuum group (long chili peppers), and 13 from the chinense group (round chili peppers). Among these, 72 are known as local varieties, but the other five, *Tataché*, *Yèyèkouka*, *Yèyèkouokourè*, *Côte d'Ivoire* and *MC*, are all introduced from neighboring countries (Nigeria or Côte d'Ivoire). *Tataché* (from Nigeria) was found in 58 villages (Table 3), whereas *Yèyèkouka*, *Yèyèkouokourè*, and *Côte d'Ivoire* were only cultivated in one village each. The distribution of *Tataché* (Table 3)

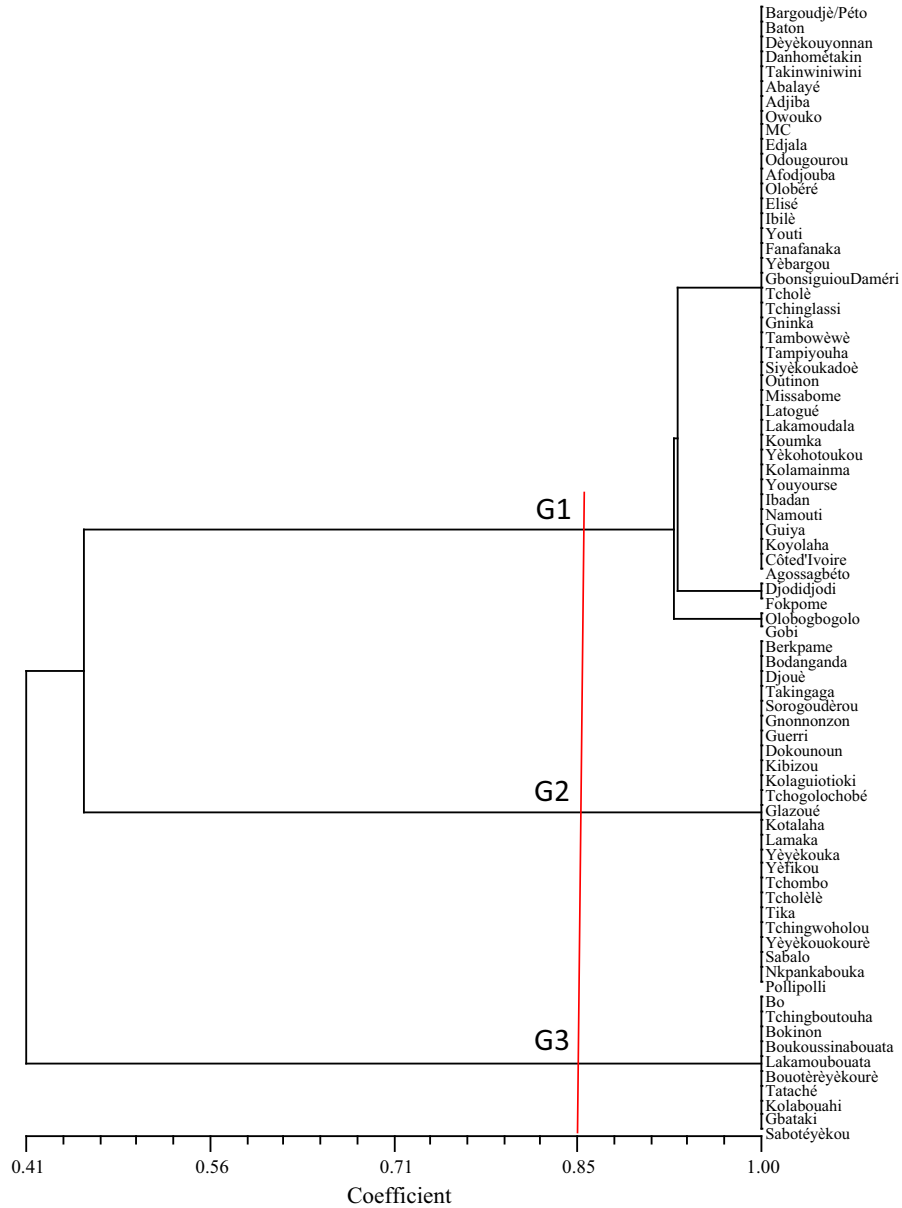

Fig. 6 Clusters obtained of the morphological characters of recognition of producers

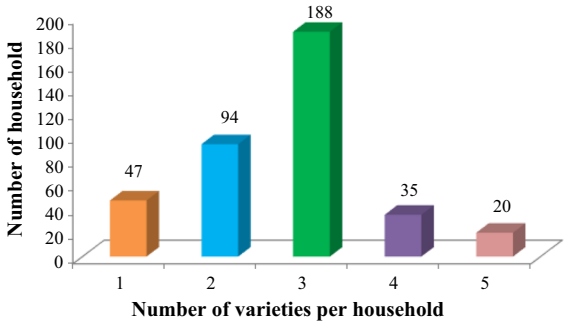

Fig. 7 Number of varieties maintained per household in the study area

could be explained by the fact that it has been for a long time introduced and produces very large and aromatic fruits. Its susceptibility to diseases, drought and saturated soils according to producers justify its limited use in some villages, where it was found cultivated by few farmers in small areas (Table 3).

The number of local varieties listed by village varied from three to seven (four on average). The greatest diversity (seven varieties) was recorded at Attata (district of Ouèssè). It is the most indicated village for eventual in situ conservation program The Shannon–Weaver diversity index showed that the

Table 3 Distribution and extent of some selected chili pepper varieties in Central and Northern Benin

Local varieties	Chili pepper group (according to the producers)	Number of villages	Distribution and extent
Berkpame	Long chili pepper	3	Dendougou(−−); Danogou(+−); Moné(+−)
Gbataki	Round chili pepper	54	Sétra(−−); Biguima(−−); Atchètè(++); Akaradè(++); Bougou(++); Dendougou(−−); Danogou(−−); Moné(−−); Ouanou(+−); Saramanga(+−); Guiguisso(+−); Papanè(++); Ouaria(++); Koko(++); Kpessou(++); Sori(+−); Taberou(+−); Tèbo(++); Sissigourou(++); Mani(++); Yara(++); Sakabansi(++); Mansouri(+−); Borodarou(++); Guenelaga(++); Gbarana(++); Salonzi(+−); Liboussou(+−); Pèdè(++); Tia(++); Touloua(++); Garoutégu(++); Torozougou(++); Molla(++); Goroubéri(++); Monsey(+−); Koké(++); Kérémou(+−); Kokiborou(++); Attata(+−); Koto(−−); Agramidodji(−−); Tchetti(++); Soklogbo(+−); Awidji(+−); Logozohè(+−); Otola(+−); Agouna(−−); Setto(−−); Agonhohoun(+−); Za-tanta(+−); Dasso(+−); Sagon(+−); Gbananmè(+−)
Gninka	Small chili pepper	13	Badékparou(+−); Tabérou(+−); Sonoumon(+−); Konou(−−); Guessébani(+−); sakarou(+−); Sakabansi(+−); Mansouri(+−); Boa(++); Gawezi(++); Negansi(+−); Ouèsséné(++); Gbassa(+−)
Tataché	Round chili pepper	60	Guilmaro(−−); Kouboro(−−); Gamborè(−−); Sayakrou(−−); Sinaou(−−); Kossou-ouinra(−−); Ouanou(−−); Papanè(+−); Kika(+−); Ouaria(+−); Tandou(+−); Badekparou(+−); Koko(+−); Kpessou(+−); Barerou(+−); Sirarou(+−); Sori(+−); Taberou(+−); Sonoumon(−−); Maregourou(+−); Tèbo(+−); Konou(+−); Soubo(−−); Gamare(+−); Sissigourou(+−); Mani(+−); Guessebani(−−); Yara(−−); sakarou(−−); Tchikandou(+−); Sakabansi(+−); Mansouri(−−); Boa(+−); Gawezi(−−); Negansi(−−); Lougou(−−); Ouèsséné(−−); Tankougou(−−); Borodarou(+−); Bensekou(+−); Dougoulayé(+−); Guenelaga(+−); Gbarana(+−); Salonzi(−−); Liboussou(−−); Pèdè(−−); Tia(+−); Touloua(+−); Garoutégu(+−); Torozougou(−−); Molla(−−); Goroubéri(+−); Monsey(+−); Kandérou(−−); Koké(+−); Kérémou(+−); Kokiborou(−−); Gbassa(−−);Assaba(−−); Pira(−−); Assaba(−−); Pira(−−)

NB: (++): varieties cultivated by many households on large areas; (+−): varieties cultivated by many households on small areas; (−+): varieties cultivated by few households on large areas; (−−): varieties cultivated by few households on small areas

Chinense group: round chili pepper; Frutescens group: small chili pepper; Annuum group: long chili pepper

Table 4 Status of chili pepper diversity per village

No.	Villages	NV	Local varieties status			AV	PVL (%)
			Popular	Intermediary	Endangered		
1	Akaradè	4	1	2	1	1	25
2	Atchètè	3	2	1	0	0	0
3	Badékparou	4	1	3	0	0	0
4	Barérou	4	2	2	0	0	0
5	Bensékou	4	0	4	0	0	0
6	Biguima	3	1	0	2	2	66.67
7	Boa	4	1	3	0	0	0
8	Borodarou	4	1	3	0	0	0
9	Bougou	4	1	2	1	1	25
10	Danogou	3	1	1	1	1	33.33
11	Dendougou	3	1	0	2	2	66.67
12	Dougoulayé	4	1	2	1	1	25
13	Gamaré	4	1	2	1	1	25
14	Gamborè	4	0	2	2	2	50
15	Ganikpérou	3	0	2	1	1	33.33
16	Garoutégu	4	3	1	0	0	0
17	Gawezi	4	2	1	0	0	0
18	Gbarana	4	2	2	0	0	0
19	Gbassa	4	1	2	1	1	25
20	Goroubéri	4	1	3	0	0	0
21	Guénélaga	4	1	3	0	0	0
22	Guessébani	4	1	2	1	1	25
23	Guiguisso	4	0	4	0	0	0
24	Guilmaro	4	0	1	3	3	75
25	Kandérou	4	2	2	0	0	0
26	Kérémou	4	0	3	1	1	25
27	Kika	4	3	1	0	0	0
28	Koké	4	2	2	0	0	0
29	Kokiborou	4	1	1	2	2	50
30	Koko	4	2	2	0	0	0
31	Konou	4	1	2	1	1	25
32	Kossou-ouinra	4	0	2	2	2	50
33	Kouboro	4	2	0	2	2	50
34	Koudengou	5	1	0	4	2	40
35	Koumakogou	4	1	1	2	2	50
36	Kouya	4	2	1	1	1	25
37	Kpèrè	3	0	1	2	2	66.67
38	Kpessou	4	3	1	0	0	0
39	Liboussou	4	2	1	1	1	25
40	Lougou	4	1	2	1	1	25
41	Mani	4	1	2	1	1	25
42	Mansouri	4	0	3	1	1	25
43	Marégourou	4	1	2	1	1	25

Table 4 continued

No.	Villages	NV	Local varieties status			AV	PVL (%)
			Popular	Intermediary	Endangered		
44	Molla	4	1	2	1	1	25
45	Moné	3	1	1	1	1	33.33
46	Monsey	4	2	2	0	0	0
47	Négansi	4	0	3	1	1	25
48	Ouanou	4	2	1	1	1	25
49	Ouaria	4	2	2	0	0	0
50	Ouèsséné	4	3	0	1	1	25
51	Ouroufihan	3	0	1	2	2	66.67
52	Papanè	4	3	1	0	0	0
53	Pèdè	4	3	0	1	1	25
54	Sakabansi	4	1	3	0	0	0
55	sakarou	4	2	1	1	1	25
56	Salonzi	4	2	1	1	1	25
57	Sammongou	3	2	0	1	1	33.33
58	Saramanga	4	1	1	2	2	50
59	Sayakrou	4	0	1	3	3	75
60	Sétra	3	1	0	2	2	66.67
61	Sinaou	4	0	1	3	3	75
62	Sirarou	4	2	2	0	0	0
63	Sissigourou	4	1	2	1	1	25
64	Sonoumon	4	1	2	1	1	25
65	Sori	4	2	1	1	1	25
66	Soubo	4	2	1	1	1	25
67	Tabérou	4	3	1	1	1	25
68	Tandou	4	1	3	0	0	0
69	Tankougou	4	2	1	1	1	25
70	Tchanhoum-Kossi	4	1	2	1	1	25
71	Tchikandou	4	2	2	0	0	0
72	Tèbo	4	2	2	0	0	0
73	Tia	4	3	1	0	0	0
74	Tora	4	1	1	2	2	50
75	Torozougou	4	3	0	1	1	25
76	Touloua	4	1	3	0	0	0
77	Yara	4	1	2	1	1	25
78	Toui	5	4	0	1	1	20
79	Attata	7	1	0	4	3	42.86
80	Djègbé	6	4	1	1	1	16.67
81	Ouogui	5	3	1	1	1	20
82	Igbodja	6	3	1	2	2	33.33
83	Gobé	6	4	1	1	1	16.67
84	Soklogbo	6	3	2	1	1	16.67
85	Awidji	4	1	1	2	2	50
86	Tchetti	6	2	1	3	3	50

Table 4 continued

No.	Villages	NV	Local varieties status			AV	PVL (%)
			Popular	Intermediary	Endangered		
87	Agramidodji	4	1	0	3	3	75
88	Logozohè	4	1	1	2	2	50
89	Otola	5	1	3	1	1	20
90	Aklampa	6	3	1	2	2	33.33
91	Assaba	6	1	0	5	3	50
92	Pira	5	2	0	3	3	60
93	Agouna	4	0	2	2	2	50
94	Setto	4	0	2	2	2	50
95	Agonhohoun	4	0	3	1	1	25
96	Za-tanta	4	2	1	1	1	25
97	Koto	4	2	0	2	2	50
98	Dasso	4	2	1	1	1	25
99	Sagon	4	2	1	1	1	25
100	Gbananmè	4	2	1	1	1	25
Average		4.12	1.48	1.48	1.14	1.09	26.61

NV number of total varieties collected per village, *AV* abandoned varieties, *RVL* proportion of varieties loosed

Northern region (H = 4.3) has more varietal diversity than does the Central region (H = 3.1). Our distribution and extent analysis (Table 4) revealed that, out of the average four varieties cultivated per village in the study area, only one was popular and cultivated by many households on large areas, two had intermediate status, and one was endangered (cultivated by few households on small areas).

In the villages where some varieties are threatened, their proportion varied from 0 to 75 % with an average of 26.61 % (Table 4). This proportion is not negligible, providing justification for the conservation (both ex situ and in situ) of these varieties, as the disappearance of varieties is unavoidably followed by the loss of useful genes which could have been used for varietal improvement (Caballero et al. 2010). As reported by Loko et al. (2013), the absence of threatened varieties in a given village is not a reflection of a high capacity of conservation, but most often of a total abandonment of minor varieties to concentrate on the small set best adapted to their agro-ecological conditions.

The reasons for varietal abandonment listed by producers are variable (Table 5). The most important are susceptibility to pests and diseases (37 % of responses), early senescence of plant organs (11.6 % of responses), susceptibility to drought (8.5 % of responses), low productivity (8 % of responses), difficulty of harvesting (6.7 % of responses) and susceptibility to high soil moisture (6.4 % of responses). Apart from susceptibility to poor soils, these factors align well with general production constraints.

We completed a correlation analysis between the diversity maintained by households and their socio-demographic characteristics (age, sex, covered area, labour, and size of household and years of experience). This analysis showed that there was no significant correlation ($P > 0.05$) between the diversity maintained by households and any socio-demographic characteristics. Similar results were reported by Orobiyi et al. (2013) for chili peppers in southern Benin and by Gbaguidi et al. (2013) for cowpea (*V. unguiculata* Walp.) in Benin.

Farmers' varietal preference criteria

Within the existing diversity, farmers select or adopt varieties based on thirteen preference criteria of an agronomic, technological, culinary, or economic nature (Table 6). The agronomic criteria, including high productivity (18.3 % of responses), drought tolerance (16.9 % of responses), adaptability to infertile soils (13.9 % of responses), pest and disease tolerance (13.5 % of responses) and resistance to early

Table 5 Reasons of abandonment of varieties

Reasons	% of responses (study area)	Ranking	Importance (% of responses) per zone	
			North	Center
Susceptibility to pests and diseases	37	1	34.3	39.8
Early fall of plant organs	11.6	2	14.6	8.6
Susceptibility to drought	8.5	4	8.9	8.1
Low productivity	8.0	5	8.1	7.9
Difficult harvest	6.7	6	6.6	6.9
Susceptibility to high soil moisture	6.4	7	6.1	6.4
High pungent taste	4.3	8	4.9	3.8
Susceptibility to soil poverty	3.7	9	4.4	3
Birds attack (attract birds)	2.9	10	3	2.5
Low post-harvest storage	2.8	11	2.5	3.1
Low marketable value	2.8	13	1.9	3.7
Lack of quality seeds	2.7	12	2.5	2.9
Dehiscence of the fruits	0.8	15	1.1	0.6
Fruits too small	0.7	16	0.3	1.2
Low pungent taste	0.7	16	0.7	0.8
Absence of aroma	0.4	18	0.1	0.7

Table 6 Farmers' varietal preference criteria

Categories	Preferences	TNV	PCO	MAC	Importance (%)	Importance (%) per region	
						North	Centre
Agronomic (89.1 %)	High productivity	98	88	40	18.3	18.4	18.2
	Tolerance to drought	91	87	30	16.9	18.4	15.4
	Adaptability to infertile soils	85	73	13	13.9	16.5	11.3
	Tolerance to pests and diseases	86	68	12	13.5	14.2	12.8
	Resistance to early fall of plant organs	67	56	1	10.1	9.0	11.2
	Good post-harvest storage capacity	43	23	4	5.7	4.6	6.8
	Availability of good quality seeds	34	18	0	4.2	3.0	5.5
	Fruits size	31	9	1	3.3	3.4	3.2
	Tolerance to high soil moisture	19	3	0	1.8	1.4	2.2
	Adaptability to zones of mountain	12	4	1	1.4	0.6	2.1
Technological and culinary (6.9 %)	Presence of aroma in the fruits	41	16	1	4.7	3.7	5.7
	Easiness of grinding	23	4	0	2.2	2.5	1.9
Economic (4 %)	High market value	41	8	0	4	4.3	3.7

senescence of plant organs (10.1 % of responses), are most important and represent 72.7 % of the total responses. Two technological and culinary aspects which are presence of aroma in the fruits and ease of grinding were highlighted by producers. Importance attached to fruit aroma is related to the preference granted to round chili pepper varieties (chinense group), which are naturally aromatic. The economic aspect (4 %) seemingly represents the least important criterion taken into account by the producers in the study area, but overall productivity and market differentiation based on aroma or other traits preferred by consumers also enter into the overall economic picture.

Table 7 Variation of farmers' varietal preference criteria according to the ethnic groups

Preference criteria	Ani	Biali	Dendi	Bariba	Peulh	Ditamari	Naténi	Wama	Lokpa	Kotokoli	Yom	Mokolé	Nagot	Fon
High productivity	20.8	23	19.2	19	19	19.4	23	27.3	19.4	16.6	17.7	14.9	22.5	17.6
Tolerance to drought	8.3	15.4	16.7	19.9	21.4	16.7	15.4	18.2	11.1	16.6	23.5	22.2	8.3	15.3
Adaptability to infertile soils	–	15.4	15.4	16	17.9	19.4	15.4	9	19.4	20.8	17.7	11.1	4.7	6.3
Resistance to pests and diseases	12.5	15.4	12.8	12	11.9	11	15.4	18.2	19.4	20.8	14.7	14.8	9.6	11.7
Resistance to early fall of plant organs	8.3	7.7	12.8	11	8.3	–	7.7	18.2	11.1	–	–	14.8	11.9	15.7
Long post-harvest storage	8.3	7.7	–	3.2	1.2	13.9	15.4	–	8.3	16.6	11.8	–	7.7	10
High marketable value	–	–	5.1	3.2	7.1	2.8	7.7	9.1	2.8	–	–	3.7	1.8	3.8
Presence of aroma in the fruits	12.5	–	2.6	4	3.6	2.8	–	–	5.7	4.3	–	3.7	12.0	6
Size of the fruits	8.3	7.7	6.4	2.4	3.6	5.6	–	–	2.8	–	8.8	3.7	1.5	4.7
High rate of germination	8.3	–	1.3	6.2	3.6	5.6	–	–	–	4.3	2.9	–	11.1	5.8
Easiness of grinding	12.5	–	2.6	2.2	1.2	2.8	–	–	–	–	2.9	7.4	4.2	1
Tolerance to excessive moisture	0.2	7.7	5.1	0.9	1.2	–	–	–	–	–	–	3.7	4.7	2.1

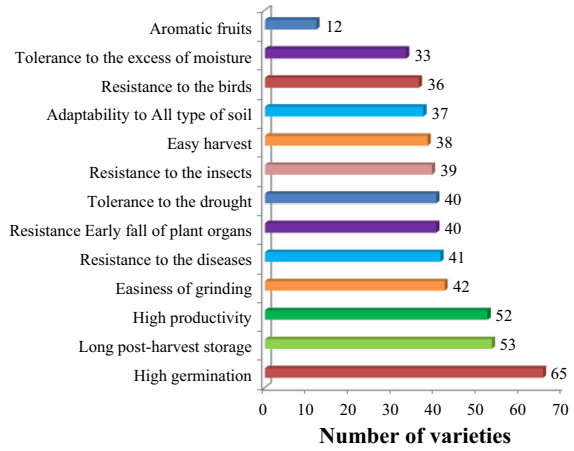

Fig. 8 Number of varieties (subject to synonymy) by agronomic performances as revealed by the participatory evaluation

As recommended by Frank et al. (2001) and Mohammed et al. (2007) for crop plants in general, these prioritized preference criteria should always be taken into account by breeders as a key component of their varietal improvement programs.

In addition, the nature and importance of varietal preference criteria may vary between agro-ecological zone and/or ethnic groups (Table 7). For example, with the Ani, Yom and Nago ethnic groups, respectively, nine, eight and eleven varietal selection criteria were listed. The importance of the "high productivity" criterion exceeded 20 % with the Ani, Biali, Naténi, Wama, Nagot, Idatcha, Ifè, Itcha and Holli ethnic groups, but only comprised 14.8 % of responses with the Mokolé group. We recommend that the improvement programs take into account the preferences of various ethnic groups through a participatory approach (Dossou-Aminon et al. 2015; Gbaguidi et al. 2015).

Participatory evaluation

Our participatory evaluation showed, per parameter considered, that the number of varieties having good performance varied from 12 to 65 (Fig. 8). Excepting the criterion "presence of aroma in the fruits" which contained only 12 varieties, each of the other parameters included at least 33 varieties. Parameters, such as post-harvest storage of fruits (53 varieties), disease resistance (41 varieties), high productivity (52 varieties), resistance to early senescence (40 varieties), and resistance to insect attack (39 varieties), are, subject to synonymy, well recognized among existing

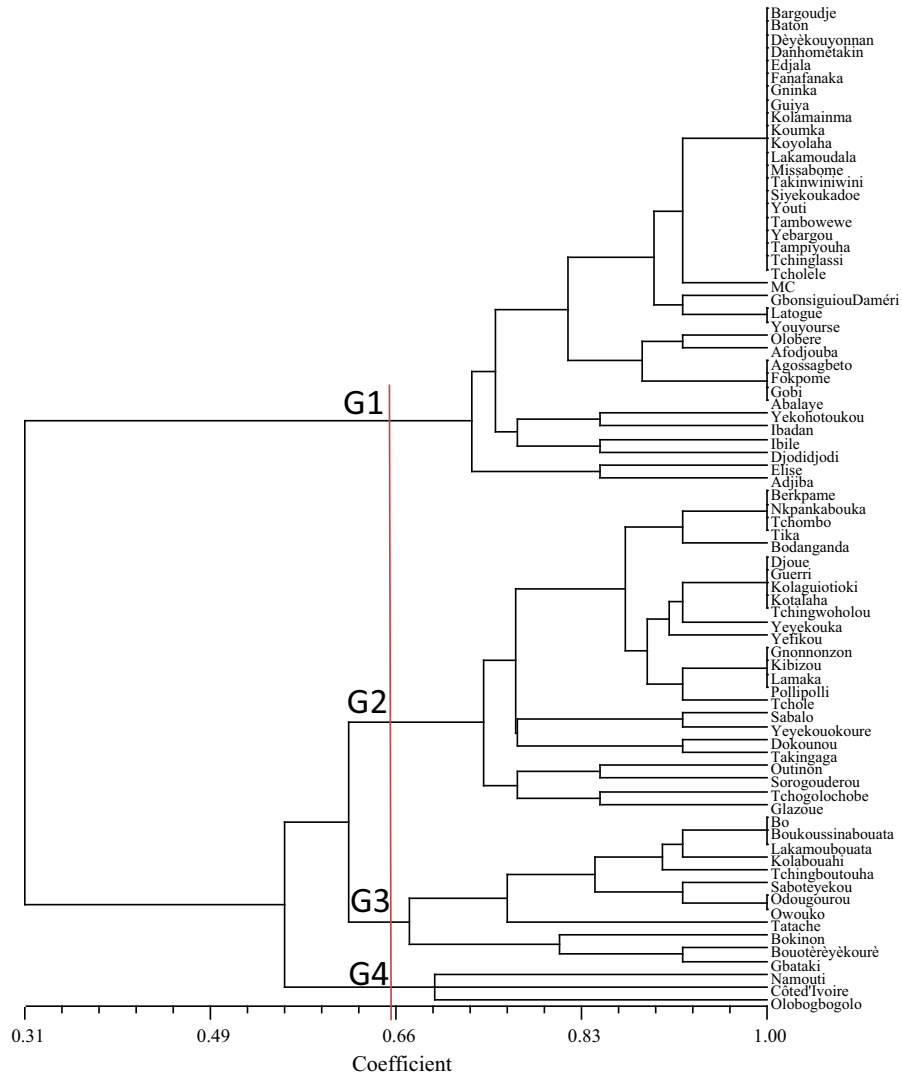

Fig. 9 UPGMA dendrogram showing a partitioning of the varieties into four groups

varieties. These results seem to conflict with our extensive list of constraints, but they can be explained by the fact that a majority of good performing varieties obtained for these criteria belongs to chili peppers of the frutescens group. Varieties of this group are not well appreciated by consumers or producers because of their absence of fruit aroma and difficulty in harvesting (very small, tart and persistent fruits). Still, when considered by criterion, the identified varieties do constitute a pool of candidate varieties that could be exploited by breeding programs as parents or by development projects through varietal exchanges, as is currently the case with yam (Gbaguidi et al. 2013; Dansi et al. 2013).

The UPGMA dendrogram constructed (Fig. 9) using the evaluation parameters as variables, clustered varieties into four groups G1, G2, G3, G4. Subject to synonymy:

- G1 included 37 varieties belonging to the frutescens group; it contains very productive, disease and pest resistant chili peppers, with long post-harvest storage, but they are not aromatic and are difficult to harvest because of their relatively small size and high level of pungency.
- G2 included 25 varieties, of which 24 belong to the annuum group and only one (*Outinon*) to the frutescens group. Varieties of this group have long

post-harvest storage, are infrequently attacked by birds, and are very easy to harvest, but are very susceptible to pests and diseases.

- G3 included 12 varieties belonging to the chinense group. This class contains varieties with aromatic fruits that are easy to grind and not attacked by birds.
- G4 grouped three varieties, among which two are local varieties of the frutescens group and the other is introduced from Côte d'Ivoire of the chinense group. Varieties of this group are susceptible to pests and diseases, tolerant to drought and have long post-harvest storage.

The UPGMA dendrogram constructed was also permitted to cluster (subject to synonymy) varieties into inventoried into 40 agronomic types.

Conclusion

This study helps document chili pepper production constraints, patterns of diversity, and preference criteria in Northern and Central Benin. Attata village, which had the highest overall varietal diversity, is the most indicated for eventual in situ conservation program. In addition, our participative agronomic evaluation carried out with the farmers' preference criteria revealed the existence of good candidate varieties for various agronomic characters, which can be used in varietal improvement or directly exploited through varietal exchange. The names of these listed varieties vary among villages and ethnic zones. Agro-morphologic and molecular characterizations are necessary to identify duplicates and clarify synonymy. Agronomic trials should also be carried out to verify reported performance information for use in breeding and development programs.

Acknowledgments This study was sponsored by Benin government through the Ministry of Higher Education and Scientific Research of Benin. We thank Dr Korie Nnaemeka (IITA, Ibadan) for language assistance and all producers and agricultural technicians met during the surveys.

Compliance with ethical standards

Conflict of interest None.

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