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DIVERSITY AND PRODUCTION CONSTRAINTS OF BAMBARA GROUNDNUT (*VIGNASUBTERRANEA* L.) IN DRY SAVANNAH OF TOGO

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ABSTRACT

Bambara groundnut [*Vigna subterranea* (L.) Verdc.], a grain-legume is a neglected and under used crop in Africa and Togo in particular. The objectives of the present study were to evaluate the diversity of Bambara groundnut in the dry savannah zones of Togo, crop management practices and challenges faced by farmers in sustainable production of the crop. A survey followed by collection of Bambara groundnut accessions was therefore undertaken in the seven districts of Kara Region. A total of 107 producers were randomly interviewed and 133 landraces were collected. The results showed that twelve morphotypes of different colours were grown by both men (59%) and women (41%) on small area (0.12 - 1ha) without fertilizer and pesticides. Cream (62%) and red (14.04%) landraces were the most grown. Corresponding factor analysis revealed specificity of each district according to the morphotypes found. The major constraint indicated by almost all respondents (95%) was the seed infestation by storage pests, mostly the bruchids. To control the attacks of these insects, producers store Bambara groundnut as seeds or pods in cans (52%), jars (9%), bags (22%) and granaries (6%) and by adding ash and botanicals for insect pests' control. Production sustainability and crop improvement were discussed.

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INTRODUCTION

Vignasubterranea (L.) Verdc commonly known as Bambara groundnut is a leguminous plant grown for its high caloric seeds, rich in minerals, vitamins and proteins (Amarteifio and Moholo, 1998; Minka and Bruneteau, 2000; Amarteifio *et al.,* 2006; Onwubiko *et al.,* 2011). This nutritional value makes it an excellent complement to cereals and tubers and can thus contribute substantially to the food and nutritional security of the populations. In sub-Saharan Africa, it is adapted to various climatic and ecological conditions playing a key role in improving soil fertility through its ability to symbiotic nitrogen fixation in association with Rhizobium bacteria and increased phosphorus bioavailability (Mukumbira 1985, Linnemann and Azam -ali, 1993, Andriamananjara, 2011).

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In addition, some morphotypes are resistant to pest attack and severe drought conditions (Mungate, 1997). Despite its importance as part of the diet of many sub-Saharan Africans, Bambara groundnut has not received significant research interest yet in Togo and remained a neglected crop. There are no established varieties of Bambara groundnut and the crop is still cultivated in different regions of Togo mainly from local landraces, rather than genotype-specific varieties (Massaweet al., 2005). Under the effect of natural and human selection, these local varieties would have accumulated genetic diversity that has been poorly studied and exploited in the management of available resources (Goli, 1997; Baudoin, 2001). In other countries,studies have shown that there are considerable morphological and molecular variabilities (Massawe *et al.,* 2002; Ntundu *et al.,* 2004; Djè *et al.,* 2005; Ofori *et al.,* 2006). In Togo, the diversity map of this species and its organization is not well known, although it may offer opportunities for designing conservation and improvement programs. In addition, very little information is currently available on the

constraints of production and conservation of Bambara groundnut, its genetic diversity in dry savannah zones, the productive area of the crop. In this respect, morphotypes grown by farmers deserve detailed investigation. Therefore, there is the need to assess the existing morphotypes of Bambara groundnuts, farmers' needs and preferences and to make the resulting information and diversity more available to all stakeholders. The objectives of the present study were to evaluate the diversity of Bambara groundnut in the dry savannah zones of Togo in terms of the number of morphotypes cultivated by farmers, crop management practices and challenges faced by farmers in the perspective of their conservation and in crop improvement and production for food security and nutrition.

MATERIALS AND METHODS

Sampling sites: The accessions of Bambara groundnut were collected in the Kara Region (Latitude 09° 26'N and longitude 001° 10'E), one of the most important production zones in the dry savannah of the northern part of Togo. The region is characterized by a unimodal rainfall distribution with precipitations usually between 1000 and 1500 mm rainfall and one cropping season only. In this region, 15 locations covering 7 districts namely Kozah, Assoli, Binah, Dankpen, Bassar, Kéran and Doufelgou were selected. In each location or village, farmers were interviewed with the help of extension service (ICAT) Kara.

Survey and collection of accessions: Survey and collection of the accessions of Bambara groundnut in the dry savannah zone of Togo were carried out among the producers. The method used for the collection consisted of direct and individual interviews with randomly selected producers of Bambara groundnut (Harouna *et al.,* 2014). In each district, at least two villages were selected with the help of extension service agents in the regiondepending on the importance given to the Bambara groundnut and the land size cultivated by the producers in the region. In order to gather maximum information on Bambara groundnut a total of 107 farmers were interviewed using a questionnaire that took into consideration the following aspects: the varieties grown, the criteria of their preference, supply of the seeds (sources and difficulties, etc.), constraints related to production and postharvest management, especially seed storage; marketing and the perception of the farmers on the crop production in terms of sustainability.

During the surveys, farmers were also interviewed to access the amount of Bambara groundnuts harvested in the previous growing season, in which form the seeds are stored, the type of storage module, the storage time, important insect pests and the most efficient protective method to avoid losses. Interviews consisted in direct discussion with farmers and traders in the markets. During the same time, where possible, a sample of seeds is collected from growers and/or purchased from traders in the markets. The description of the seeds of the various accessions collected was carried out on the basis of the variability of the seed coat colour, seed shape and the seed eyes and hilum colour and pattern using the standard descriptors of Bambara groundnut(IPGRI / IITA / BAMNET, 2000; Ndiang *et al.,* 2012). The seeds of the different accessions collected were then put in the plastic bottle of 0.5l, sealed, labelled and stored in the laboratory at 27 ± 2°C and 65% rh.

Data analysis: The questionnaire data were analysed using EpiData 3.1. Correspondence Factor Analysis (CFA) was performed with the XLSTAT version 2014. For the qualitative characteristics of the accessions, codes from 1 to n, according to their number in each morphotype, were used in order to determine their specificities, proximity and distribution (Ndiang *et al.,* 2012) in each district. The quantitative data were analysed by the use of descriptive statistics. All the values obtained were subjected to analysis of variance (ANOVA) using SPSS version 20. When F is significant, the means are separated by the Student Newman Keuls (SNK) test at $P \leq 0.05$. Additionally Corresponding factor analysis was carried out using XLSTAT to define the specificity of morphotypes in each district.

RESULTS

Bambara groundnut morphotypes grown in the dry savannah of Kara region: The Bambara groundnut morphotypes collected in the dry savannah of the Kara region in Togo varied widely in the seed coat colour and pattern. During the surveys 133 accessions either homogeneous or mixtures of different colours of seed coats were collected. After sorted, seed coat colours identified include cream, red, brown, black with or without various coloured stripes and motley.

Table 1. Proportions of the different morphotypes grown across districts in the Kara region

Coat colour	Proportion (%)
Light-cream	5.26
Purple	1.75
Cream	56.58
Cream with light-brown stripes	3.95
Cream with brown stripes	0.88
Black	5.26
Black mottled cream	3.51
Red	14.04
Red mottled cream	3.51
Light red	4.39
Brown speckled	0.44
Dark purple	0.44

Table 1 indicates the proportions of the different morphotypes collected in Kara Region. In the overall sampling zones, the results showed that the most common morphotypes found were cream and red representing ca. 62 and 14% respectively (Table 1). The survey showed furthermore that the main districts producing Bambara groundnut are Bassar, Kozah and Binah representing 28, 22 and 20% respectively (Figure 1). Based on the seed coat colour, 12 Bambara groundnuts morphotypes were collected (Table 1, Figure 2) with significant variability among them at morphological level across districts. Moreover, the seeds were predominantly of oval shape with mostly butterfly eye shapes either black, red or purple (Figure 3). However, morphotypes without eye around the hilum (especially cream and red accessions) could also be found among the accessions. Corresponding factor analysis (Figure 4) showed that Bambara groundnut with red tegument is inherent to Binah district and cream in the four districts surveyed but can also be found in the other districts. However, the red-coloured seeds are inherent to the Binah district; the creamy is more related to Bassar, Kozah, Binah and Assoli districts but can be found in the other districts in the region.

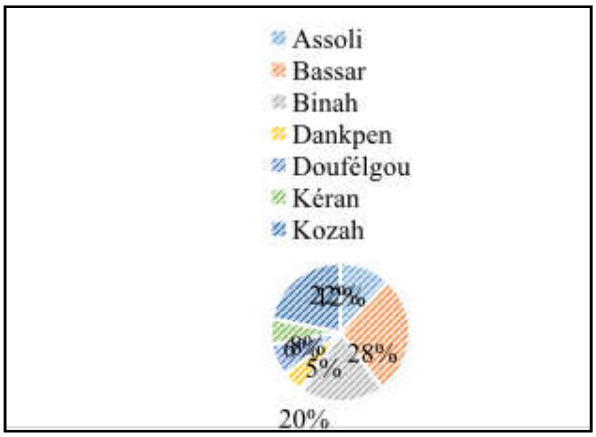

Figure 1. Accessions distribution across districts in the dry savannah of Kara region

Figure 2. Bambara groundnut landrace with seed eye colour around the hilum. A to J and O showed butterfly shape eyes with different colours; K to N morphotypes without eye around the hilum

Figure 3. Bambara groundnut landrace classification into homogenous seed morphotypes using seed coat Color ACC01: Black; ACC02: Black mottled cream; ACC04: Red mottled cream; ACC05: Cream with light-brown stripes; ACC07: Cream with brown stripes; ACC08: Light red; ACC10: Light red; ACC11: Brown; ACC12: Red; ACC13: Cream; ACC14: Purple; ACC15: Dark purple

The black Bambara groundnut and the light red are found in Kéran while the motley red and purple seeds are abundant in Doufelgou and Dankpen.

Factors influencing the choice of Bambara groundnut landraces: The results of the survey indicated that the accession selection for production purpose depends on several factors and on each producer. Apart from colour, taste, market demand, early maturity, availability of seeds and resistance to pests, some farmers mentioned not only heritability but also the size of seeds and high yield. Both men (59%) and women (41%) rely mostly on taste and market demand to choose their variety. Moreover, 36% of the producers choose their variety according to taste, 23% on market demand, 14% on early maturity and 10% on seed availability (Figure 5). Only 2% of the producers choose their varieties, especially black accessions according to their resistance to insect pests.

Constraints of Bambara groundnut production: Several constraints at production and storage levels were listed by the farmers during the survey.

At production level

Production constraints includes:

i) Seed supply and seed quality: 68 % of the farmers sourced their seeds from markets, 23% from neighbouring producers while 8% of them use seeds from their own production. The lack of availability, the poor quality and the high price of seeds of improved varieties are the main problems faced by producers. They (48%) identified the high price of seeds as the major problem of Bambara groundnut seed.
ii) Labour: the results of the surveys showed that Bambara groundnut is cultivated only on small areas (0.12 ha to 1 ha). 25% of the producers pointed out the ploughing as a difficult activity, 61% of them had harvest difficulties since most often soil and plants are usually dry at harvest (Figure 6).
iii) Pests: As for the pests, 13% of the farmers mentioned damage mainly on leaves due to phytophagous insects and snails. They also evoked the melting of seedlings and necrosis on the plants.
iv) Low yield: Most of the producers indicated also the low yield of the morphotypes they used to grow.

Constraints at harvest and postharvest levels: The results of the survey showed that the majority of the respondents (95%) faced the challenges inflicted by postharvest insects, especially bruchids, while only 4% of them mentioned seed rot (Figure 7).

Methods for Bambara groundnut storage: The analysis of the survey data indicated that producers and sellers use diverse methods and facilities to prevent losses caused by insects. Bambara groundnut is mainly stored as seeds in cans, jars, bags and traditional stores. Cans are the most used facilities to store Bambara groundnut. In fact, 52% of the farmers in the Kara region used cans compared to barns (6%) and jars (9%); 22% of the producers used bags to store the seeds and 3% for pods storage. However, producers also associated at least two methods of preservation that can be either cans, jars (3%) or traditional stores, cans (3%) or bags and cans (2%) (Figure 8). Grain protection measures such as the use of ash, insecticide, plant leaves or bark, and sand are generally associated to cans, barns and jars. Plants leaves are also used for seeds conservation and include *Hyptissuaveolens* L. (Lamiaceae), *Azadirachtaindica* Juss (Meliaceae), etc. Additionally, chemical insecticide (Bextoxin, actellic), often as tablets or powder were also used by 20% surveyed farmers.

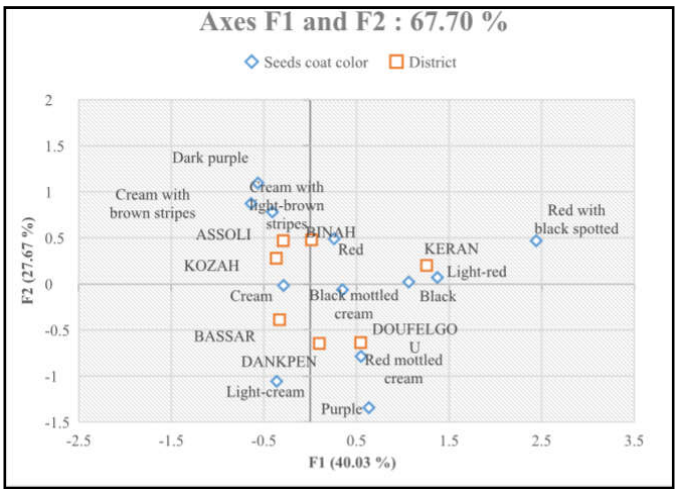

Figure 4. Morphotypes corresponding factorial analysis as for the districts

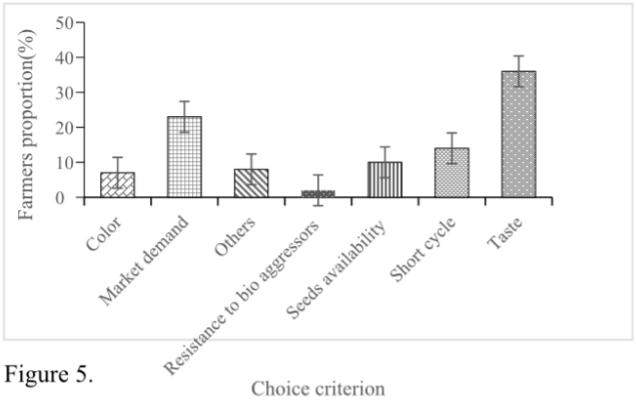

Figure 5.

Figure 5. Factors influencing the choice of the Bambara groundnut accessions in Kara region

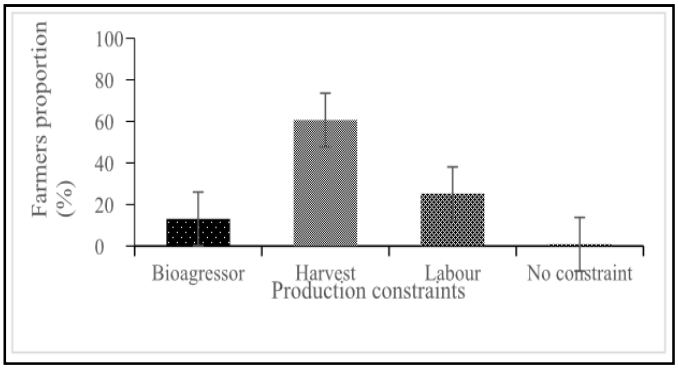

Figure 6. Major constraints of Bambara groundnut production

Farmers' perception on the sustainable production of Bambara groundnut: According to the farmers, the promotion of agro ecological practices such as crop rotation, the use of improved seeds, early planting and the use of plant-based biopesticides for postharvest management of the agricultural product could contribute to improve sustainable

production of Bambara groundnut. For most farmers, crop rotation is the main technique or practice that can lead to good production because it reduces the occurrence of Bambara groundnut seedling melting. For some of the producers (4%), early planting helps to harvest earlier to avoid dry soil rendering the harvest difficult. For others, to increase the yield it is necessary to introduce improved early maturing varieties (17%) and use organic fertilizer (90%) at a recommended dose. They also indicated that extension services should play their role in training them to use botanicals that can increase the duration of storage and to avoid the intoxication due to the use of costly chemical pesticides.

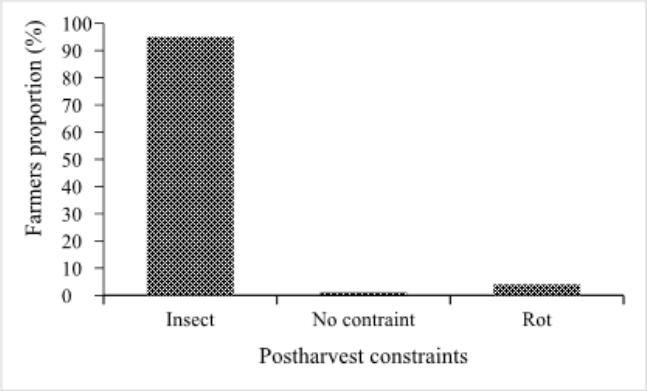

Figure 7. Bambara groundnut postharvest constraints

Figure 8. Bambara groundnut conservation structures: A (traditional structures, Barns); B (Cans)

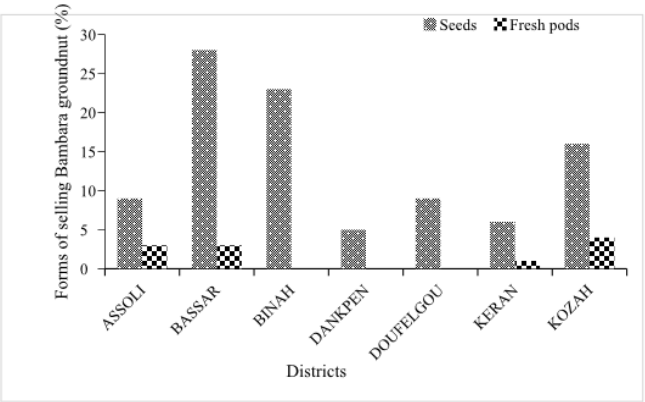

Figure 9. Bambara groundnut sale forms across districts

Bambara groundnut utilization and commercialization: The survey showed that the production was either for home consumption or for sale on local markets. In Kara Region, Bambara groundnut is grown mainly for its seeds and is sold in various forms. In all districts, it is sold in the form of dried seeds or fresh pods. Almost all producers (90%) sell Bambara groundnut in seed form. However, the sales of fresh pods were encountered mostly in Assoli, Bassar, Kéran and Kozah districts as shown in Figure 9. According to the current research results, 81% of producers sell part of their harvest on the local market while 19% use it for self-consumption. Very few farmers, used Bambara groundnut for medicinal reasons (diarrhoea) or for it aphrodisiac virtue. Farmers sold their product to different clients in the local market; 21% of the dried seeds were sold to retailers (mainly women), 72% to individual consumers and only 7% to wholesalers.

DISCUSSION

The results of the current research highlighted morphological diversity of Bambara groundnut in dry savannah of Kara Region. One hundred thirty three (133) Bambara groundnuts accessions with 12 morphotypes were collected among which similarities were observed when compared to accessions from several African countries particularly from west and central Africa. Sampling carried out in Benin by Gbaguidi (2014), pointed out 52 Bambara groundnuts morphotypes. Recent work indicated a significant variability among varieties of Bambara groundnuts at the morphological level (Massawe *et al.,* 2002; Ntundu *et al.,* 2004; Ofori *et al.,* 2006). Similar coloured morphotypes have been found in Niger (Harouna *et al.,* 2014) and Cameroon (Ndiang *et al.,* 2012). The present survey of local Bambara groundnut accessions assessed the current status of the diversity of the species in one region of the country. The high variability of the seed coats observed could indicate the presence of a strong heterogeneity within the local accessions of Bambara groundnut. Moreover these results attest the existence of significant diversity within the species. This important phenotypic variability observed could result from the expression of a strong genotypic heterogeneity but also from the influence of environmental factors or introduction from other countries. The morphological dissimilarities observed between different groups of phenotypic diversity suggest that accessions are maintained under very different evolutionary processes in their respective agroecosystems. Agroecosystems are likely to exert very variable selective pressures on genotypes (Doku and Karikari, 1971, Sadiki and Jarvis, 2005) as well as anthropogenic pressures (Robert *et al.,* 2004). In fact, farmers' management of seeds such as selective sorting, crop recycling and agricultural practices lead to selection expressed as the maintenance or even the creation of significant phenotypic diversity (Robert *et al.,* 2005) or disappearance of some morphotypes.

The sources of the seeds could also affect the diversity of Bambara groundnut in the region. As shown in this study, farmers use seeds from their own production or from markets and neighbours taking into account their taste and market demand. The study of the morphological diversity of Togo accessions revealed a rich and diversified local heritage. The number of accessions varied from one district to another, Bassar being the most important followed by Kozah and Binah districts. Bassar is reputed to be the granary of the region and Kozah district is the county town favouring commercial activities and probable exchange of germplasms. In the region, the creamy and the red morphotypes are the important ones representing ca. 62% of all accessions collected, probably they are the most preferred by the farmers and consumed by individuals. Generally, the creamy morphotypes are the most consumed as fresh pods in the surveyed districts where accessions are abundant. Other studies have shown that the cream-colored seeds are the most consumed in many African

countries (Ramolemana *et al.,* 2004; Ntundu *et al.,* 2004). Berchie *et al.,* (2010) in Ghana, Aviara *et al.,* (2013) in Nigeria and Ouoba *et al.,* (2016) in Burkina Faso found similar results where cream colour remained the most cultivated morphotype. Similarly, in Niger, yellow (creamy) morphotype is the most appreciated by both producers and consumers (Harouna *et al.,* 2014). This information corroborates the observations of Ramolemana *et al.,* (2004) who have shown that in the majority of African regions where Bambara groundnut is grown, the yellow or creamy seeds are the most consumed.

The preference of these cream-colored morphotypes could be explained by their fewer tannins content compared to the other coloured seeds like black seeds (Amarteifio *et al.,* 2006) and their organoleptic, agronomic and aesthetic qualities (Ouoba *et al.,* 2016). However, in the savannah zones of Côte d'Ivoire, Touré *et al.,* (2013) indicated that light brown-seeded morphotypes speckled with dark red are the most cultivated and consumed. This finding suggested that the preference can also depend on other factors and may vary from country to country. Beside the seed coat colour, other factors including taste, market demand, early maturity, availability of seeds and resistance to bruchid pests can influence the choice of preferred morphotypes in the dry savannah of Kara region. According to Mohamed (2014), producers make their choice according to seeds shape (oval) but also and especially according to seeds colour and maturity duration. The survey revealed also several constraints of sustainable production of Bambara groundnut in dry savannah in Togo. Apart from the lack of improved varieties, the main constraint of Bambara groundnut production is postharvest insects including bruchids *Callosobruchusmaculatus* (Fabricius) and *C. subinnotatus* (Pic) [(Coleoptera: Chrysomelidae)], which are the most damaging pest of legumes during storage (Lale and Vidal 2003; Tinkeu et al, 2016). Ayamdoo *et al.,* (2013) also pointed out that *Callosobruchus* species are important challenges for sustainable production of Bambara groundnut. Similarly, Ngamo and al. (2016) found that Bambara groundnuts are attacked by three pests including two primary pests of bruchids which are able to attacking healthy seeds, while the third pest is *Triboliumcastaneum* (Herbst) (Coleoptera : Tenebrionidae) being a secondary pest because it attack only seeds already depreciated. In Cameroon, *C. maculatus*is known to be an important stored seeds pest in dried sub-sahelian zones (Ajayi and Lale, 2000; Ngamo and Hance, 2007). These insects begin to infest field seeds and continue to multiply during storage (White, 2000).

These results demonstrated the vulnerability of this leguminous crop during storage and requires special attention to prevent the total loss. To protect Bambara groundnut seeds or pods from insect attacks in the dry savannah of Kara region, various storage facilities (cans, jars, bags or barns) are used by producers. All these facilities are hermetic and tightly closed allowing for little aeration helping probably to increase the mortality of bruchids in the stores. In addition, in hermetically-closed bags where air diffusion is prevented or reduced, the respiratory process of the biotic components in the bulk (grains, fungi, insects, etc.) removes oxygen (O2) and produces carbon dioxide (CO2) (Bartosik *et al.,* 2001). The resulting atmosphere, rich in CO2 and poor in O2 will suppress, deactivate, or reduce reproduction and/or the development capacity of bruchids as observed in hermetic storage of cowpea seeds using triple bagging in Cameroon: (http://www.entm.purdue.edu/entomology/research/cowpea/Extension%20bulletins/PDF%20publications/Tripple%20Bagging.pdf). In addition to storage facilities, farmers used also ash and plant extracts such as *Hyptissuaveolens* (Lamiaceae), *Azadirachtaindica* A. Juss (Meliaceae*)*. These plants are known to possess insecticidal properties (Schmutterer, 1990; Immaraju, 1998; Carpinella *et al.,* 2002; Isman, 2006) and could affect negatively the biology of the bruchids (Bekele *et al.,* 1997; Lale and Abdulrahman, 1999) when adequately used in stores. In Niger, Harouna *et al.,* (2014) observed that Bambara groundnut is stored in seed form with ash in cans against bruchids. In Côte d'Ivoire, Touré *et al.,* (2013) evoked plants such as *Ocimumcanum (*Labiaceae*), Hyptisspicigera* Lam. (Lamiaceae)*, A. indica*and *Khayasenegalensis* (Meliaceae), which are also used in powder form in Bambara seeds storage. In Cameroon, farmers used traditional insecticides based on four local plants of which *H. spicigera* is the best known to limit the damage of these insects (Ngamo *et al.,* 2016). Ileke *et al.,* (2012) showed bioactivity of some plant extracts on bruchids. Ketoh *et al.* (2000) also researched actively the use of plant essential oil to control postharvest pests. All these research findings from different countries suggested that botanicals could be sustainable means of controlling Bambara groundnut postharvest insect pests.

Conclusion

The present study has highlighted a large diversity of morpho types of Bambara groundnut grown in dry savannah of Kara region. These accessions may constitute genetic resources offering opportunities for designing their conservation and improvement programs. The overall results provided a good understanding of the structure and distribution of the current diversity of Bambara groundnut. This will help to define strategies of future collection missions in the whole country for a better conservation and use of the collection in the breeding and valuing germplasms in the crop diversification program promoted by the Ministry in charge of agriculture. Moreover, detailed studies on the agromorphological characteristics of the collected accessions and challenges faced by the farmers should be addressed to attain a sustainable production.

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