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RESEARCH ARTICLE

Indigenous knowledge and agro-morphological evaluation of the minor crop Kersting's groundnut (*Macrotyloma geocarpum* (Harms) Maréchal et Baudet) cultivars of Benin

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Abstract Kersting's groundnut (*Macrotyloma geocarpum*) locally named "Doyi" is a grain legume of high nutritional and economic value widely consumed in Benin but neglected by the scientific research and the development programmes. In order to document the indigenous knowledge related to the production, diversity and use of this crop and to collect samples for characterisation and evaluation, 30 villages from South and Centre of Benin were randomly selected and surveyed. In each village, 10–15 producing households (374 farmers in total) were chosen as above and interviewed using participatory research appraisal tools and techniques. The study revealed that the production of Kersting's groundnut is particularly concentrated in central Benin (departments of Zou and Collines), but is seriously declining for ten reasons. As reported by farmers, the most important factors of those included the high cost of production (40.7 % of responses), the susceptibility of cultivars to high soil moisture (25.5 % of responses) and the complexity of the cultural practices (25.2 % of responses). Only three local cultivars differing mostly by the colour of seed coat (white, red and black) were recorded. The white seeded cultivar was the most cultivated and preferred for consumption. Gender role analysis indicated that young women were the most involved in the cultivation of *M. geocarpum*. Phenotypical analysis of the different accessions (32 in total) collected during the study revealed only three groups that differ mainly in leaf width, yield and date to 50 % flowering. Agronomic evaluation indicated a significant difference ($p < 0.05$) between grain yields of the three local cultivars displaying a mean of 1062 ± 93, 1197 ± 77 and 1548 ± 102 kg/ha for the white, red and black seeded cultivars, respectively. The study also showed that Kersting's groundnut is very soil selective. Results from the current study will contribute to define appropriate conservation strategies and also to implement adequate breeding programs. These will help to improve and promote local cultivars and the crop in Benin.

Keywords Agro-morphological evaluation · Benin · Cultivar diversity · Indigenous knowledge · Kersting's groundnut · *Macrotyloma geocarpum*

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Introduction

In African regions, efforts to achieve food security are often based on major food crops (sorghum, millet, maize, rice, yams, cassava, groundnut, cowpea, etc.). Grain legumes are recognised as a main source of dietary protein and energy mainly in the developing countries where cost of animal protein is expensive and difficult to afford (Chickwendu 2007). Many grain legume species are neglected and underutilized while they play a crucial role in the food security, nutrition, and income generation of the rural area (Magbagbeola et al. 2010). *Macrotyloma geocarpum* (Harms) Maréchal et Baudet or Kersting's groundnut is a grain legume indigenous originated from West Africa, especially Nigeria, Mali, Burkina Faso, Niger, Togo and Benin (Obasi and Agbatse 2003) where it is widely consumed. It belongs to the Fabaceae family, which produces pods inside the ground. Kersting's groundnut is produced for its edible seeds which contain appreciable quantities of some nutrients such as protein (25 %), 60–70 % of carbohydrate, essential amino acids mainly leucine, lysine, phenylalanine and valine (42 %) (Chickwendu 2007). Seeds are also a good source of mineral salts (iron, zinc, phosphorus, calcium, magnesium and potassium) (Ajayi and Oyetayo 2009). It can be used for complementary food formulation for children to combat malnutrition (Chickwendu 2007; Dansi et al. 2012). Seeds are so important that they are marketed producing a source of income. Seeds are available (One kg costs 2–6 US dollars). Despite its importance, this crop is cultivated only on a small scale in West Africa where it is classified as neglected and under-utilized species (Dansi et al. 2012) and it is even gradually disappearing from traditional food production (Aderanti 2001). In Benin, according to MAEP (2011), production of Kersting's groundnut decreased from 2358 tons in 2005 to 1050 tons in 2010. Moreover, little or no scientific study was carried out on this crop. To improve our knowledge on the production zones, traditional practices and cultural constraints and diversity of this crop for its promotion and valorisation, we used participatory research appraisal tools and phenotypical traits measurement to conduct detailed investigations from 30 villages surveyed. To partially fill the gaps, this study was designed to:

1. Assess the production areas and the importance of *M. geocarpum* in southern and central Benin;
2. Document the indigenous knowledge related to the production, diversity and use of this neglected and underutilized crop;
3. Investigate the major production constraints of this grain legume;
4. Undertake participatory evaluation of local cultivars for agronomic traits;
5. Assess the morphological variation in Kersting's groundnut landraces from southern and central Benin for breeding and conservation purposes

Materials and methods

Study area and selection of the surveyed sites

The Republic of Benin is situated in West Africa between the latitudes 6°100 N and 12°250 N and longitudes 0°450 E and 3°550 E (Akoègninou et al. 2006). It covers a total area of 114,763 km^2 with a population estimated to 7 millions (INSAE 2012). The study was conducted in Southern and Central of Benin located in humid agro-ecological zones characterized by a sub-equatorial climate with two rainy seasons and two dry seasons. Annual mean temperature ranges from 26 to 28 °C and annual rainfall varies between 800 to 1400 mm (Yabi and Afouda 2012) in southern regions and 800–1200 mm in the Centre (Adam and Boko 1993). The main ethnic groups are: Adja, Cotafon, Holly, Ouémènou, Pédah, Saxwè, Tori, Watchi, Xwla, Yoruba, Fon, Mahi, Idaasha, Fè and Tchabè (INSAE 2002). Vegetation included semi-deciduous forests or woodlands and savannah woodlands (Akoègninou et al. 2006). Sites surveyed (30 villages in total; Table 1; Fig. 1) were selected after exploratory study in agricultural research institutions, visits to local and urban markets, discussion with farmers' and sellers' associations and extension agricultural services locally named CARDER (Centre Agricole Régional pour le Développement Rural).

Data collection and analysis

From each village, 12 producers on average were randomly selected in different districts (Ayoola et al. 2011) using the transect method described by Adjatin et al. (2012). In each household, the person interviewed

Table 1 List, locations and ethnic groups of the villages surveyed

Villages	Districts	Departments	Ethnic groups
Adakplamè	Kétou	Plateau	Mahi, Yorouba
Agbondjèdo	Savè	Collines	Fon
Agonhohoun	Djidja	Zou	Fon
Agonlin Kpahou	Kétou	Plateau	Fon, Mahi
Agoua	Bantè	Collines	Fè
Ahokponhoué	Savè	Collines	Tchabè, Fon
Aklankpa	Glazoué	Collines	Mahi
Amakpa	Djadja	Zou	Fon
Banamè	Zagnanando	Zou	Mahi
Bêtêkoukou	Dassa-Zounmè	Collines	Idaasha
Daguè-Daguè	Savè	Collines	Tchabè
Fita	Dassa-Zounmè	Collines	Idaasha, Mahi
Gobada	Savalou	Collines	Mahi
Hoko	Glazoué	Collines	Mahi
Kitikpli	Savalou	Collines	Fon, Ifè
Konou	Glazoué	Collines	Mahi
Kossokanmè	Djidja	Zou	Fon
Kpadji	Savalou	Collines	Fon
Kpakpamè	Zakpota	Zou	Fon
Kpakpkakanmè	Djidja	Zou	Fon
Lahotan	Savalou	Collines	Mahi
Mahou	Dassa-Zounmè	Collines	Idaasha, Mahi
Mougnon	Djidja	Zou	Fon
Sovlègni	Djidja	Zou	Fon
Sowignandji	Glazoué	Collines	Mahi
Tan	Zagnanando	Zou	Mahi
Tangbé	Zakpota	Zou	Fon
Tanvè	Agbangnizoun	Zou	Fon
Za-Adikogon	Zakpota	Zou	Fon
Zounzonmè	Abomey	Zou	Fon

was chosen based on common agreement from the host couple according to Christinck et al. (2000). In each village, interviews were conducted with the help of a local translator. In total, 374 producers including 72 women were interviewed through participatory research appraisal tools and techniques (questionnaire, field visit, direct observation) following Amujoyegbe et al. (2010) and Seasy et al. (2013). Data collection included socio-demographic characteristics (age, sex, ethnic group, religion, areas under cultivation with the crop, etc.); farmers' perception on the evolution of Kersting's groundnut cultivation; cultural practices; zones of production and cultural constraints; causes of the decline of the production; importance and uses of *M. geocarpum*; farmers' preference and varietal selection criteria; seed storage, supply systems and management, and gender role in the production system. Samples of the different cultivars (to be used for morphological trait measurements) were collected directly from farmers' storage structures including granaries.

Field experiments (characterization and agronomical evaluation) were conducted during the short rainy season (July–November) of 2012 and 2013. Seeds were sown on rows in a randomly complete block design with three replications per accession. Accessions were sown in rows of 3 m long with 30 cm spacing between individual plants and between rows according to Bampuori (2007). In total twenty morphological characteristics (15 quantitative and 5

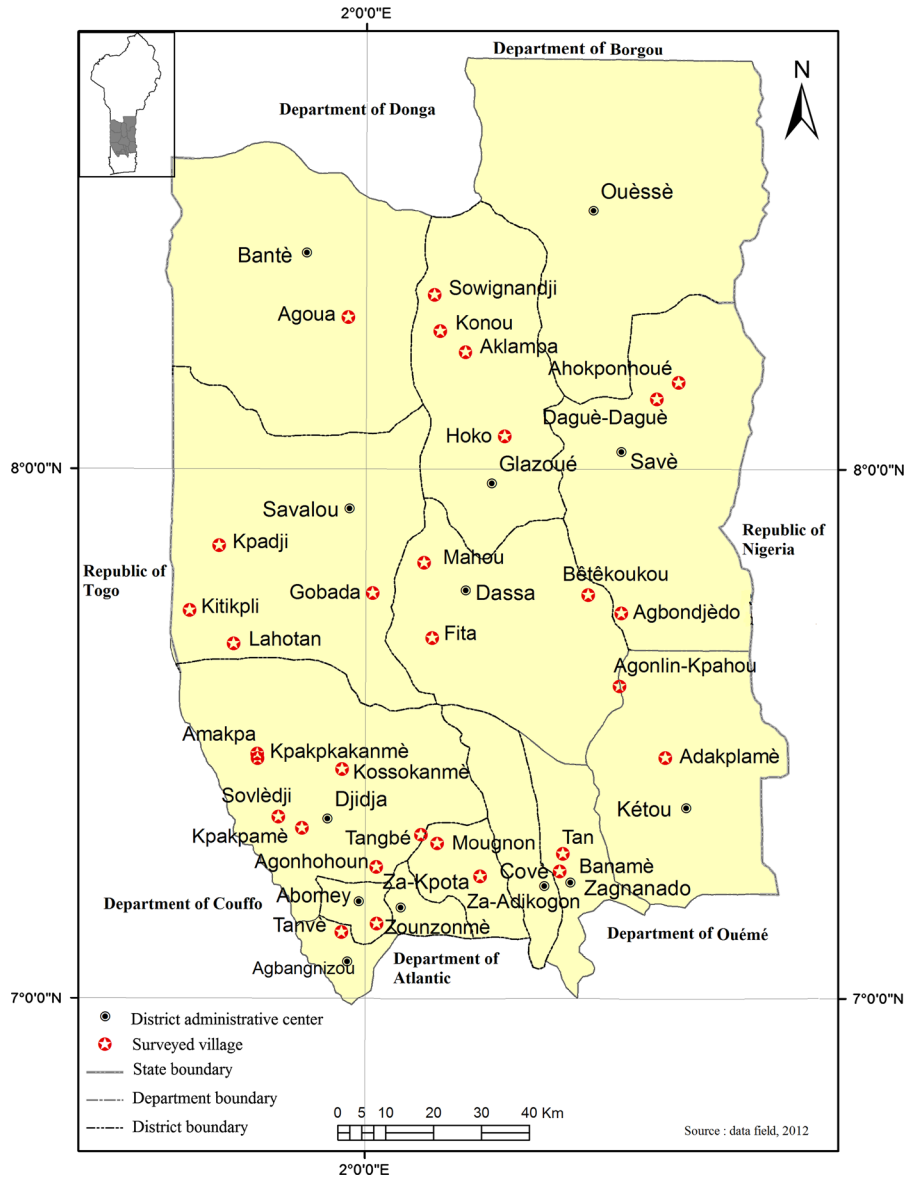

Fig. 1 Map showing the geographical location of the villages surveyed

qualitative traits; Table 2) were measured to assess the variability of the accessions. In total 12 plants were recorded per accession following IPGRI et al. (2000). For agronomical evaluation, the yields, the susceptibility of the cultivars to weeds (effect of weeds on plant yield) and to poor soils were the parameters measured.

Survey data were analysed using descriptive statistics. The analysis of agronomic and morphological data from evaluation and characterization trials was done to describe the variability of each trait and to define groups of individuals with similar morphological characteristics using both descriptive and multivariate analysis (mean; variance, standard deviation, analysis of variance, student and Newman-Keuls test, Principal Component Analysis, etc.) using STATISCA software package (Statistica 2005). Coefficients of correlation and associated probabilities between pairs of characters were calculated using the statistical software MINITAB and a correlation is generated. This helps to determine characters that vary in the same or opposite directions for breeding purposes.

Table 2 Quantitative morphological traits recorded in the accessions of Kersting's groundnut analysed

Quantitative traits	Code	Measurement techniques
Days from sowing to 50 % emergence (d)	DTL	Determined by noting the number of days (d) from sowing that 50 % of plants had sprouting
Days from sowing to 50 % flowering (d)	DTF	Determined by noting the number of days (d) from sowing that 50 % of plants had at least one flower
Plant height (cm)	PHT	Length from soil to the tip of terminal leaf
Petiole length (cm)	PEL	Measured from the main stem to the base of the third fully opened leaf
Diameter of plant (cm)	DIP	An horizontal distance between two opposite points
Leaflets length (cm)	LEL	Distance between the leaflet tip and base measured on the third fully opened leaf from the tip
Leaflets width (cm)	LEW	Width of the broadest portion of the third fully opened leaf from tip measured
Days from sowing to first fructification (d)	DFF	Determined by noting the number of days from sowing that at least one plant had fruit
Days from sowing to maturity (d)	DTM	Determined by noting the number of days from sowing that at least one plant reaches maturity
Number of seeds per plant	NPP	Count of the number of seeds developed per plant
Seeds length (mm)	SEL	Distance between two opposite points of the seed
Seeds width (mm)	SEW	Thickness of one seed from each plant
Yield per plant (g)	YPP	Weight of goods seeds from each plant
100 seed weight (g)	HSW	Weight of thousand goods seeds from each plant
Grain yield (kg/ha)	GRY	Weight of seeds from 100 m^2 area field

Results

Socio-demographic characteristics

A proportion closed to 81 % of respondents was male while females were 19 % with in average 10 years of experience in Kerstings' groundnut production. Farmers interviewed (respectively 50.4, 30.3, 18.4 %) speak Fon, Mahi and Idaasha/Fè. This crop is produced in association with others; area under cultivation with Kersting's groundnut was found to vary from 100 m^2 to 4 ha per household (0.48 ha on average). The ethnic group F on produced the largest areas with an average of 0.76 ha of field per household followed by Mahi ethnic group (0.28 ha per household) and Idaasha/Fè ethnic group (0.16 ha per household). Age of the farmers surveyed varied from 20 to 64 years with an average of 40 years. 14.1 % of the producers were between 20 and 30 years of age, 41.1 % had of 30–40 years, 39.3 were between 40 and 50 years and only 5.5 % of the farmers surveyed are older than 50 years.

Reasons of the decrease of Kersting's groundnut production

Some farmers (15.4 %) interviewed reported that the production of Kersting's groundnut is increasing while the majority (84.6 %) reported a constant decrease in the production. A total of ten reasons belonging to four categories justify the decrease of production (Table 3). Among these, the most important were high costs of inputs (40.7 % of responses), susceptibility to high soil moisture (25.5 % of responses) and high labour requirement (10.8 % of responses).

Cultural practices and pests knowledge

Farmers reported that Kersting's groundnut is planted between June and August on mound sand sole cropping. However, few producers (2 %) intercrop this plant with cassava or maize and obtain low yield. No fertilizers or pesticides were used. The majority (88.5 %) of farmers interviewed weeds their fields at least twice (fourth and tenth weeks after sowing). A

Table 3 Reasons of decrease of the production of Kersting's groundnut in Benin

Categories	Reasons	Percentage of responses (%)
Economic (55.9 %)	High production costs	40.7
	High labour requirement	10.8
	Lack of good market for seed supply	2.7
	High costs of seeds	1.7
Agronomic (29.3 %)	Susceptibility to high soil moisture	25.5
	Inadaptability to all types of soil	2.7
	Difficult post-harvest storage	1.0
Technological (14.4 %)	Difficulty of harvest	8.1
	Difficulty of seeds hulling	6.4
Cultural (0.4 %)	Traditional consideration (myth, taboo)	0.4

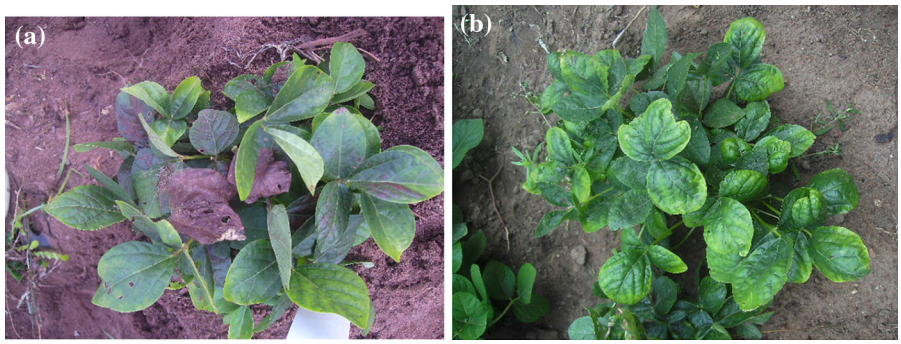

Fig. 2 Diseases observed on *Macrotyloma geocarpum*in the field. **a** Rust, **b** Viruses

great proportion of respondents (87.7 %) did not apply crop rotation. Yellowing and leaf and petioles wilt indicated plant maturity. Harvest is carried out during the dry season on November and December. The late harvested pods are often the most infested and they constitute sources of seed contamination by weevils. Some pests and diseases were reported by producers. Among these, the most important were virus, early yellowing of leaves and petioles (Fig. 2). Most of farmers reported that these attacks had no great effect on the yield of this crop.

Diversity, uses and economic importance of Kersting's groundnut in Benin

Three traditional cultivars differing by seed colour were recorded (Fig. 3). Among them, only the white seed was the most cultivated and in demand for consumption. Black and red cultivars are disliked due to their meal colour. The same common local name of this crop is "doyi" (in Fon and Mahi ethnic groups) or "Atchaka" (Nagot and Idaasha ethnic groups). White cultivar was named "doyiwé", the black cultivar was however named "doyi wiwi" while the red one was called "doyi vovo".

Seeds are usually used in the preparation of delicious foods for special days (New Year, Christmas, funeral ceremonies, anniversary, etc.). Consequently, it sells expensive in the period of its consumption. However, a few producers (4.7 %) from the ethnic group Fon have reported that the cooking water from black-seeded cultivar is used to treat diarrhoea, stomach troubles, ulcer and cough. Decoction of plant leaves constitute a veritable vermifuge.

Many farmers (91 %) interviewed reported that Kersting's groundnut constitutes an important source of household incomes. The mean annual revenue of a producer varies from 100 to 300US$ per year (Fig. 4). *M. geocarpum* seeds trade was one of the main activities which generate income to market women.

Fig. 3 The three types of Kersting's groundnut cultivars cultivated in Southern and Central of Benin

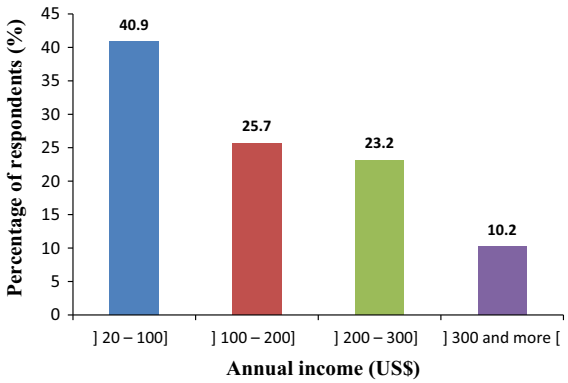

Fig. 4 Benefits of Kersting's groundnut in rural populations

Wholesalers taked their stock directly from farmers' fields or from three main food markets of Benin (Glazoué, Bohicon, Dantokpa). Individual survey of market women selling Kersting's groundnut (12 wholesalers and retailers per market; Fig. 4) indicated that the price of one kg of seeds varied during the year andalso depends from the supply sites. In Glazoué market (central Benin) for example, it was between 2 and 4 $ while the seeds cost 2.5–6 $ in south of Benin (Dantokpa market in Cotonou). The mean quantity of seeds sold per month and per market woman varied from 51.25 to 400 kg (125 kg on average) producing a benefice of 20–160 $ on average (Table 4; Fig. 5). Sowing period and December were the high-selling times of this grain legume. No market woman sold only Kersting's groundnut. All of sellers interviewed associate other food products such as maize (98 % of the sellers), cowpea (100 % of the sellers), bambara groundnut (100 % of the sellers), rice (75 % of the sellers), groundnut (27 % of the sellers), peanut (42 % of the sellers), soybean (42 % of the sellers), sorghum (25 % of the sellers), cassava flower (10 % of the sellers), and egusi (African grain legume of Cucurbitacae family used for the traditional soup also called melon soup) (8 % of the sellers).

Seeds management and gender role in crop production

Farmers used various traditional conservation tools (plastic buckets, maize bags, etc.) to store this crop seeds (Figs. 6, 7). Farmers reported that seeds stored were very susceptible to insects (beetles, etc.). To minimize pest effects, producers used many products (Fig. 8) among which cotton insecticide (liquid and powder) (19.6 % of responses), ash (19 % of responses), chemical black solid insecticide called sofa grain (19 % of responses), warm sand (17.2 % of responses), and solid insecticide (named canfo) (11.1 % of responses). Storage period varied from 5 to 12 months, depending on products used. Sofa grain, endosulfan (liquid cotton insecticide), small chili pepper fruit have been identified as the most efficient. Their storage duration ranged from 8 to 12 months. Sofa grain and endosulfan are chemical (Fig. 8) and very dangerous for the human health.

In terms of gender analysis, our study revealed that both females and males were knowledgeable about crop production and management. Land preparation was mainly a male activity while processing and seed commercialization were females' activities. Sowing, weeding, harvest, seeds storage were equally done by both men and women.

Phenotypic characterization

Two classes of Kersting's groundnut were distinguished on the basis of the qualitative traits. The first one (84.4 % of accessions) grouped white seeds accessions which produced white flowers and pods and green petioles. The second group (15.6 % of

Table 4 Market valuation of Kersting's groundnut seeds

Type of sellers	Quantity sold (per month/kg)				Monthly income (in US$)			
	Minimum	Mean	Maximum	SD	Minimum	Mean	Maximum	SD
Wholesalers	160	400	800	281.42	64	160	320	112.86
Retailers	5	51.25	150	67.62	2	20	60	26.88

Fig. 5 Kersting's groundnut seeds wholesaler in Glazoué market (**a**) and retailer in Dassa-Zoumè. Seeds are packaged by kg in small plastic bags (**b**)

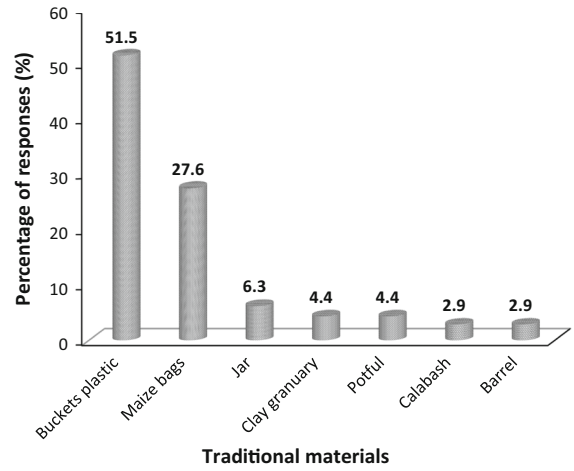

Fig. 6 Seeds conservation methods

accessions) including red and black seeds accessions that produce purple flowers and pods with a mixture of green and purple petioles (Figs. 9, 10).

A significant variation ($p < 0.05$) was noted among accessions for the following quantitative parameters: leaflets width, petiole length, diameter of plant and number of pods per plant (Table 5). Data analysis showed that black seeded cultivar (s) produced the widest leaflets (5.39 cm on average). The white seeded accession collected at Kpadji village presented the lengthiest petiole (26.36 cm) and the high pods yield per plant (342 pods) while that of Adakplamè site was identified as displaying the highest plant's diameter (63.3 cm on average). Hundred seed weight, dates to 50 % flowering, dates to 50 % emergence, dates of first fructification and maturity of the plants were however not significantly variable between landraces (Table 5). Coefficients of variation were low for most (80 %) of the studied quantitative traits (CV < 20 %) (Table 6). Correlations between quantitative traits

Fig. 7 Some traditional structures for seeds storage. **a**, **b** Plastic buckets; **c** Calabash; **d** Jar; **e** Barrel

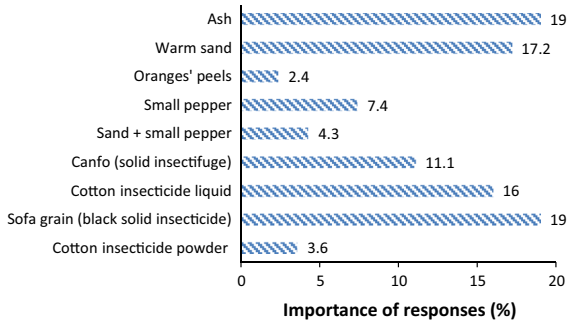

Fig. 8 Products used for seeds conservation

revealed negative correlations between date of 50 % plants in flowering stage and yield parameters (number of pods per plant, seeds weight per plant and grain yield). Generally, the accessions which flowered earlier displayed the highest yield (Table 5). High correlations ($r \geq 90$) were however noted between yield parameters while low relation was recorded between petiole length (PEL) and yield (Table 6).

In total three groups G1, G2 and G3 of Kersting's groundnut were identified following the two first axes of PCA (representing 42.2 % of the total variance; Fig. 11). The multiple comparison of means of the different groups for each morphological trait revealed significant differences ($0.001 < p < 0.05$) for only five parameters such as leaflets width (LEW), number of pods per plant (NPP), seeds weight (SEW), grain yield per hectare (GRY)and date of 50 % flowering plants (DTF). Characteristics of each group were identified and highlighted (Table 7). The group G1 with 16 accessions was characterized by very wide leaflets (4.86 ± 0.24 cm). The second agro-morphological group (six accessions in total) yielded a high value (224.17 ± 64.36 of pods per plant; 26.66 ± 6.25 grams of seeds per plant and 2693.33 ± 626.95 kg/ha) and G3 included 10 late flowering accessions (63.18 ± 0.87 days).

Agronomical evaluation of *M. geocarpum*

The accessions collected were significantly different in grain yield production ($p < 0.05$). It varied from 617 to 3840 kg/ha (1588.46 kg/ha on average). Yields were significantly variable among white seeds accessions ($p = 0{,}001$) and between the three local cultivars ($p = 0.015$). Means of 1062 ± 93, 1197 ± 77 and 1548 ± 102 kg/ha were obtained respectively for white, red and black seeds cultivars. Black-seed was the best yielder. About Kersting's groundnut field weeding, no significant difference (p value $= 0.71$) of yield was observed with respectively 1525.21 ± 770.68, 1692.65 ± 971.10 and 1588.46 ± 699.86 kg/ha for 2, 3 and four weedings.

Grain yields were also significantly variable ($p = 0.019$) with the growing zones. The accessions cultivated in Central Benin produced the highest yield (1381.13 ± 112.436 kg/ha; Table 8). This zone was the most appropriate for this legume in Benin. Highly significant variations ($p < 0.05$) exist also between yields of Kersting's groundnut depending on type of soil. Most (60 %) of the accessions yielded low on poor soils compared to fertilized soils (Table 9). However no significant variation of yield was

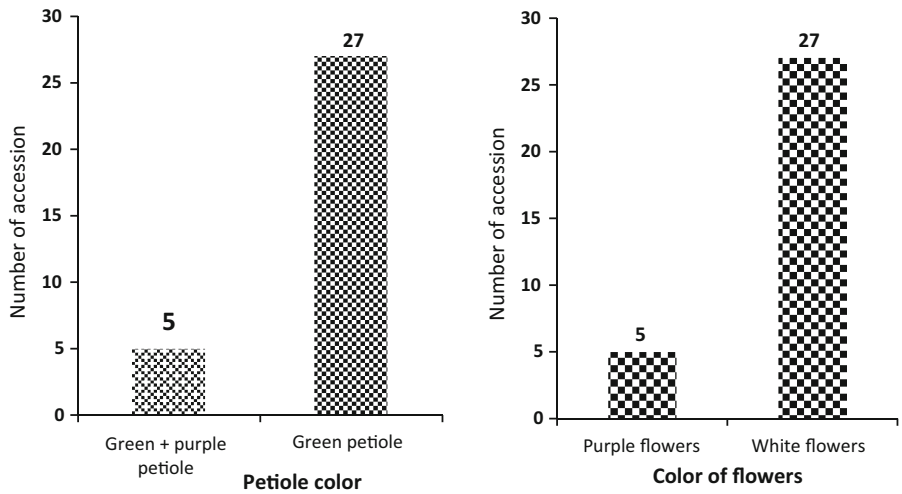

Fig. 9 Importance of the qualitative traits within the accessions collected

Fig. 10 Classification of the three local cultivars based on qualitative variables

observed with the accessions collected at Gobada, Lahotan, Zounzonmè, Sovlègni, Kpakpakanmè and Adakplamè sites.

Discussion

Current state of the crop production and utilization

In Benin both young and old farmers were involved in the production of this legume because its cultivation requires much physical investment, but seeds commercialization generates high income that help resolving urgent problems such as children education, funerary ceremonies, etc. On the other hand, Bampuori (2007) in Ghana and Amujoyegbe et al. (2010) in Nigeria reported that Kersting's groundnut was cultivated by elderly farmers. The role of women in the value chain of this crop was expected as women are known to play vital roles in food production, processing and marketing (Ayoola et al. 2011; Ogato 2011; Dansi et al. 2012). The study revealed that *M. geocarpum* is produced on relatively small areas in Benin and is being abandoned mainly because of its high production costs, susceptibility to high soil moisture and high labour requirement. These results are in agreement with those reported by Bampuori (2007) in Ghana and Amujoyegbe et al. (2010) in Nigeria. Seeds storage infested by insects constitute a serious problem for storing Kerstings' groundnut

Table 5 Descriptive analysis of the 15 quantitative variables measured between accessions

No.	Characters	Code	Minimum	Maximum	Means	SD	CV (%)
1	Plant height (cm)	PHT	31.30	40.33	35.22	2.06	5.86
2	Leaflets length (cm)	LEL	6.23	7.38	6.79	0.28	4.25
3	Leaflets width (cm)	LEW	4.31	5.39	4.80	0.23	4.97
4	Petiole length (cm)	PEL	14.16	26.36	20.27	3.32	16.38
5	Diameter of plant (cm)	DIP	23.40	86.00	67.57	13.39	19.82
6	Number of seeds per plant	NPP	49.00	342.00	131.71	61.64	46.80
7	Seeds length (mm)	SEL	3.50	6.67	4.78	0.71	14.97
8	Seeds width (mm)	SEW	1.62	3.15	2.53	0.40	15.83
9	Yield per plant (g)	YPP	6.17	38.40	15.83	7.04	44.52
10	100 seed weight (g)	HSW	10.70	14.71	13.05	1.03	7.90
11	Grain yield (kg/ha)	GRY	617.00	3840.00	1588.46	699.86	44.06
12	Days to 50 % emergence(d)	DTL	5.00	6.66	5.46	0.49	9.00
13	Days to 50 % flowering (d)	DTF	61.00	64.00	62.71	0.88	1.42
14	Days to first fructification (d)	DFF	112.00	120.00	117.53	2.03	1.73
15	Days to maturity (d)	DTM	144.00	150.00	148.68	2.36	1.59

seeds. This is a common fact with almost all the grain legumes (Baco et al. 2008), as reported by Gbaguidi et al. (2013) on cowpea and by Ouédraogo et al. (2008) on bambara groundnut. Breeding programs should work towards developing new cultivars that are tolerant or resistant to storage insects for promotion in traditional agriculture. Actually, farmers use some non-toxic and toxic products to protect seeds. There is a need for sensitization in order to bring them to avoid toxic products or use them only for seeds devoted for sowing, not for consumption. Ash, sand, small chili pepper (named pili–pili) and oranges' peels are natural/safe and can be recommended for storing seeds for consumption. Economic analysis showed that Kersting's groundnut, is an essential source of household income which can contribute to poverty reduction in Benin. Plant leaf and black seeds have medicinal properties as reported Achigan Dako and Vodouhè (2006). Kersting'sgroundnut is consumed traditionally mainly during celebrations of important events and no product derived from its seeds ("ata", "akara", "mixed flour" and traditional cakes) in Benin. This is due to ignorance by both consumers and processors of the high nutritional value of the crop and its capacity to fight malnutrition when appropriately used. This call for sensitization actions and the development of strategic action plan to enhance its value chain as indicated by Dansi et al. (2012).

Agromorphological variation in Kersting's groundnut accessions

In rural communities, only three cultivars differing by seed colour are cultivated. This low diversity, which was also observed on this crop in Ghana (Bayorbor et al. 2010), is contrary to what is known on other pulses such as Bambara groundnut (Ouédraogo et al. 2008; Bonny and Dje 2011; Olukolu et al. 2011) and cowpea (Baco et al. 2008; Gbaguidi et al. 2013). White seeded accessions were the best known and consumed in the majority of the households surveyed. Red and black seeds were disappearing while they can be useful in genetic breeding and varietal selection programs (Ghalmi et al. 2010). It is therefore urgent to define some strategies to preserve such cultivars against loss. This may be through development of new food products but this requires comparative nutritional value assessment, as black and red cultivars may have special nutritional values.

Principal Component Analysis of quantitative traits showed three clusters as recorded in Ghana (Bayorbor et al. 2010). The low coefficients of variation obtained for most characters indicate the existence of a low amount of variability (Bennett-Lartey et al. 2002). Molecular characterization may help to better understand the genetic structure. Morphological markers have been used to identify cultivar genotypes and

Table 6 Correlations between quantitative agro morphological traits measured on accessions

	PHT	LEL	LEW	PEL	DIP	NPP	SEL	SEW	YPP	HSW	GRY	DTL	DTF	DFF	DTM
PHT	1														
LEL	0.50*	1													
LEW	0.39*	0.75*	1												
PEL	−0.26	−0.14	−0.11	1											
DIP	0.27	0.31	0.22	0.04	1										
NPP	−0.15	0.26	0.14	0.31	0.23	1									
SEL	0.12	−0.03	0.05	−0.05	−0.05	0.03	1								
SEW	0.09	0.11	0.27	0.17	0.03	0.27	0.72*	1							
YPP	−0.12	0.32	0.25	0.37*	0.26	0.94*	−0.09	0.21	1						
HSW	0.08	0.26	0.14	0.12	0.09	0.15	0.19	0.27	0.28	1					
GRY	−0.12	0.31	0.25	0.42*	0.27	0.90*	−0.15	0.15	0.97*	0.26	1				
DTL	0.05	0.18	0.22	−0.02	0.28	−0.18	−0.09	−0.01	−0.24	−0.1	−0.19	1			
DTF	−0.09	−0.22	−0.13	−0.3	0.12	−0.45*	0.02	−0.23	−0.4*	0.26	−0.39*	0.24	1		
DFF	0.13	−0.04	−0.01	−0.05	0.12	−0.17	0.25	−0.02	−0.13	−0.02	−0.20	−0.10	0.17	1	
DTM	−0.24	0.09	0.06	0.06	−0.02	0.27	0.29	0.12	0.31	0.08	0.28	−0.06	−0.09	0.38*	1

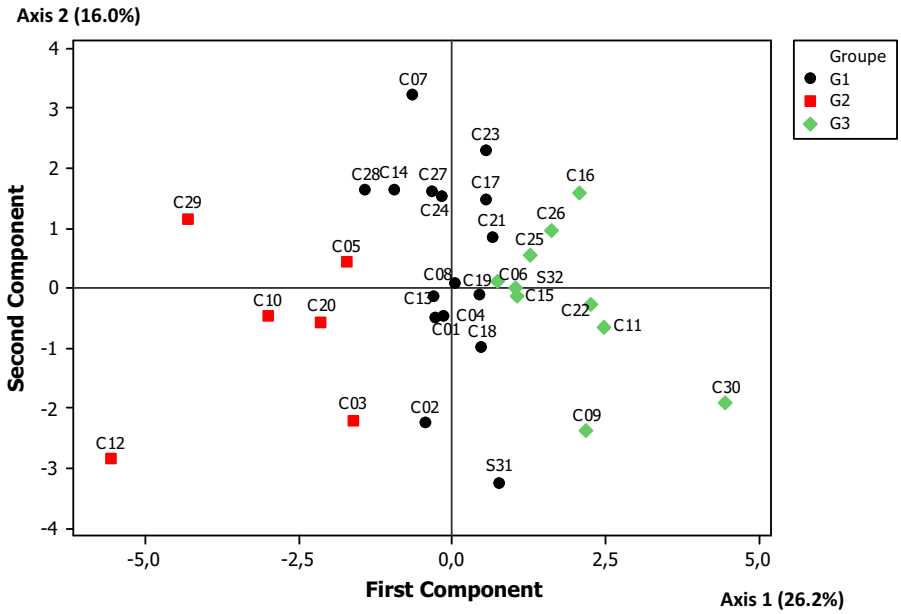

Fig. 11 Principal component analysis showing the different grouping of the accessions

Table 7 Comparison of means of the different groups of Kersting's groundnut

Traits	Group 1	Group 2	Group 3	F
PHT	35.27 ± 1.70	33.50 ± 1.76	34.45 ± 2.33	1.834 ns
LEL	6.78 ± 0.32	6.88 ± 0.16	6.61 ± 0.26	2.018 ns
LEW	**4.86 ± 0.24b**	4.72 ± 0.17ab	4.60 ± 0.16a	5.320*
PEL	19.00 ± 3.20	22.00 ± 3.46	19.64 ± 2.80	1.998 ns
DIP	64.67 ± 16.03	74.67 ± 9.43	67.18 ± 10.49	1.210 ns
NPP	127.4 ± 28.59b	**224.17 ± 64.36c**	87.18 ± 35.02a	23.951***
SEL	4.70 ± 0.67	4.65 ± 0.33	4.92 ± 0.92	0.393 ns
SEW	2.49 ± 0.35	2.68 ± 0.27	2.46 ± 0.52	0.611 ns
YPP	15.53 ± 2.56b	**26.66 ± 6.25c**	9.46 ± 2.86a	45.157 ***
HSW	12.33 ± 1.23	13.17 ± 0.75	12.45 ± 0.93	1.355 ns
GRY	1610.8 ± 231.42a	**2693.33 ± 626.95ab**	390.09 ± 323.52b	4.506 *
DTL	5.44 ± 0.41	5.21 ± 0.40	5.59 ± 0.59	1.170 ns
DTF	62.67 ± 0.82ab	62.00 ± 0.63a	**63.18 ± 0.87b**	4.203 *
DFF	117.67 ± 1.49	116.17 ± 2.40	118.09 ± 2.30	1.910 ns
DTM	149.33 ± 1.79	149.00 ± 2.44	147.63 ± 2.80	1.790 ns

Performances are indicated in bold

ns not significant

* $p < 0.05$; ** $p < 0.01$; *** $p < 0.001$

Table 8 Kersting's groundnut (white seeds variety) yield in the two agrogeographical zones

Zones	Yield (kg/ha)			
	Minimum	Maximum	Mean	Standard error
Centre of Benin	617	3840	1381.13	112.436
South of Benin	500	2600	1075.44	61.401

Table 9 Yield variation between accessions in relation with the types of soil used

Accessions of Kerstings' groundnut	Collection site	Means yields		*p* value
		Poor soil	Fertile soil	
C03	Fita	831.00 ± 178.97	2247.33 ± 398.31	0.032
C06	Hoko	178.67 ± 40.82	1248.33 ± 219.10	0.009
C09	Ahokponhoué	472.67 ± 148.13	1011.67 ± 143.59	0.050
C10	Agbondjèdo	1179.33 ± 153.33	2322.67 ± 106.20	0.004
C11	Agbon	319.33 ± 111.48	867.33 ± 168.14	0.050
C12	Kitikpli	264.67 ± 84.00	1542.00 ± 61.28	0.000
C15	Gobada	810.00 ± 157.00	1024.00 ± 120.73	0.341
C16	Lahotan	371.67 ± 69.83	838.33 ± 165.42	0.060
C17	Zounzonmè	529.33 ± 148.83	1538.67 ± 400.62	0.078
C19	Sovlègni	409.00 ± 96.81	1264.67 ± 368.27	0.088
C20	Sodokpa	379.67 ± 147.51	1271.67 ± 307.06	0.050
C22	Kpakpakanmè	227.33 ± 30.83	720.67 ± 201.51	0.073
C29	Za–Adikogon	537.00 ± 152.71	2254.00 ± 410.19	0.017
C30	Agonhohoun	183.67 ± 87.14	615.00 ± 99.43	0.031
S31	Adakplamè	523.33 ± 131.955	1950.67 ± 958.496	0.214

genetic purity based on the assessment of phenotype characteristics. They have played an important role in crop improvement since the beginning of modern breeding programmes (Bayorbor et al. 2010). As reported by Bayorbor et al. (2010), large agronomical differences were noted between accessions. The yields range between 617 and 3840 kg/ha. Among local cultivars, black seeded Kersting's groundnut provided the highest yield. Similar results were found in Ghana (Bampuori 2007). Agronomic characterization constitutes the first step in appreciating genetic diversity (Bayorbor et al. 2010). Therefore knowledge of yield per plant is essential in breeding decisions making (Witcombe et al. 2001; Ouédraogo et al. 2008). The negative correlation observed between flowering date and yield revealed that early maturing accessions showed the highest yields. According to Bonny and Dje (2011), correlations values are primordial tools for choosing characteristics that may be included in plant selection programs.

Yield of the plant depends on the number of weedings. A minimum of two was shown to be optimal. Poor soil generally leads to low productivity (Bampuori 2007; Buah and Huudu 2007; Félix et al. 2012). As reported by the farmers interviewed, the type of soil constitutes a key factor limiting Kersting's groundnut productivity.

Conclusion and perspectives

This study revealed that Kersting's groundnut production is decreasing mainly for high cost of production, plant susceptibility to high soil moisture and high labour requirement. Varietal diversity was very low and two cultivars are being disappeared. The existing variability through seeds collected from the field experiments, is conserved in genebank of the Laboratory of Biotechnology, Genetic Resources and Plant and Animal Breeding (BIORAVE), Faculty of Sciences and Technology of Dassa (FAST-Dassa), Centre of Benin. This study has contributed to a better understanding of cultivation techniques of *M. geocarpum* in Benin. Lower yields reported by farmers were due to the traditional cultural practices used. Yield potential varies between local cultivars and among white-seeded accessions. In order to better appreciate the genetic structure of the plant, molecular characterization of the accessions is necessary. Appropriate strategies and policies need to be urgently developed to conserve rare cultivars. Diversity within *M. geocarpum* must be strengthened by creating and/or introducing improved cultivars adapted to local climate conditions. Biochemical analysis (nutritional value, phytochemical screening and toxicity analysis) of the existing cultivars are recommended as it can

help enhancing the value chain of this neglected and underutilized species.

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