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Table of Contents: Volume 10 Number 8 September 2018

ARTICLES

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Full Length Research Paper

Farmer's traditional practices and management methods of stored common bean (*Phaseolus vulgaris* L.) insect pests in the central region of Benin Republic

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Common bean (*Phaseolus vulgaris* L.) is a legume that contributes to food security and poverty reduction in Benin. However, there is very little information on its production constraints, varietal diversity, storage practices, storage insect management, and seed system. While these information are necessary for use in breeding programs and a better conservation of this legume. To fill these gaps, ethnobotanical surveys were conducted in 23 villages selected through central Benin using participatory rural appraisal tools and techniques. The number of beans landraces ranged from 3 to 5 per village (4.7 on averages) and from 1 to 4 per household (1.7 on average). A total of 26 common beans folk varieties, corresponding to 12 climbing bean landraces were recorded in the study area. A high rate of threat of landraces disappearance was recorded through surveyed villages. Various seeds storage tools were recorded and the seed system was essentially informal. The use of inert substances, chemical insecticides and insect repellent/insecticidal plants to control storage insects has been reported in the study area. Farmers noted a differential susceptibility of common bean landraces to storage insect pest. Our findings showed that there is an urgent need of development of integrated bean storage insect management strategies.

Key words: Constraints, common bean, insect pests, seed system, varietal diversity.

INTRODUCTION

Common bean (*Phaseolus vulgaris* L.) is a worldwide-cultivated legume, with world production of 26,833,394 tons in 2016 (FAO, 2016). This legume is highly appreciated in gastronomy for its texture due to their high protein and starch content (Pujolà et al., 2007). Common bean are also an excellent source of important nutrients such as iron, copper, phosphorus, magnesium, zinc, calcium, potassium and vitamins (Mojica and de Mejía, 2015; Beans are inexpensive sources of nutrients for people of lower socio-economic status in African and Latin American countries (Mojica and de Mejía, 2015). It is widely cultivated in the tropics for its green edible

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leaves, green pods consumed as vegetables, dried seeds harvested at maturity (van De Luque et al., 2014).

Widely cultivated in Central and South America where it originates, common bean production in Benin is done on small plots with an annual production of 101821 tons in 2016 (FAO, 2014). In Central Benin, *Phaseolus* beans are grown because they improve soil quality and make a major contribution to household food security, especially for the poorest and most vulnerable (Missihoun et al., 2017). Cultivated mainly for their edible seeds, the production of common beans in Benin seems to be experiencing a regression in recent years (FAO, 2014), to the point of being threatened with extinction in certain regions of the country (Missihoun et al., 2017). In fact, the production of this legume is subject to several constraints during its cultivation and storage which lead to the disappearance of landraces and thus, to significant genetic erosion (Martínez-Castillo et al., 2008; Missihoun et al., 2017). These constraints remain very little documented in Benin, while their knowledge is an important step in the effort to develop technologies and knowledge to help improve yields and farmer income (van De Luque et al., 2014). Moreover, to develop an efficient strategy of conservation of this genetic resource, an assessment of diversity and analysis of distribution of extend of common bean landraces in Central Benin is a necessity (Loko et al., 2018).

The attack of stored common bean by insect pests is an important biotic constraint, which cause significant losses (Jones, 2016). Such losses could be quantitatively related to consumption of seed or qualitatively related to contamination from rests of insect excrements (Silva and Costa, 2016). Very little research attention has been given to storage insect pests of common bean and their traditional management practices in Benin. Consequently, farmers' knowledge of the insect species in the stored common bean and farmers' perception of the importance of insect damages in the stocks has never been assessed. Traditional practices and management used to prevent or control insect infestations have also not been documented.

It is known that, the control of insect pests in stored common bean is commonly done by chemical insecticides which, however have negative effects on health and environment (Keneni et al., 2011; Luz et al., 2017). One of the alternative approaches to use of chemical insecticides is the adoption of resistant cultivars (Luz et al., 2017). It is the best way of overcoming insect pests of common bean in an environment-friendly manner (Keneni et al., 2011). In order to develop common bean varieties resistant or tolerant to storage insect pests through varietal creation or improvement, knowledge of existing diversity remains essential (Acosta-gallegos et al., 2007; van De Luque et al., 2014). Unfortunately, apart a study of Missihoun et al. (2017) on the diversity of cultivated *Phaseolus* conducted in only four villages choose in 2 districts of the 6 representing the central Benin, very little information exists on the diversity of common bean and seed system prevalent in this region. Similarly, traditional storage practices of common bean remain poorly documented. On the other side, appropriate storage helps to reduce the effects of seasonality and variation in prices over the growing season and to maintain the quality of the seeds over time (Brackmann et al., 2002). It is therefore urgent to fill these gaps in order to better preserve the diversity of common beans in central Benin. The objectives of this study is to document the production constraints, varietal diversity, storage practices, storage insect management, and seed system of common bean in central region of Republic of Benin.

MATERIALS AND METHODS

Study area

Central Benin, is an area located between latitude 7° 45' and 8° 40' North and longitude 2° 20' and 2° 35' East. This region belongs entirely to the Sudano-Guinean climate transition zone with a bimodal rainfall unevenly distributed between two rainy seasons. The soils are mainly ferruginous tropical soils with concretions of crystalline basement relatively rich in minerals with very variable characteristics (Azontonde, 1991). The vegetation varies from open Savannah woodland in the south to a semi deciduous forest in the northwest. The main sociolinguistic groups are Idaatcha, Mahi, Tchabè, and related sociolinguistic groups.

Study design

A total of 23 villages were prospected in this study. These villages were selected through the six districts (Bantè, Dassa-Zoumè, Glazoué, Ouèssè, Savalou and Savè.) of central Benin the manner to ensure a good coverage of the study area and to cover all sociolinguistic groups (Figure 1). In each village, focus group discussions was made up of between 5 to 7 common bean producers of both sexes and different ages selected with the help of the village chief or farmers' organization leaders. After group discussions, farmers were interviewed individually (Orobiyi et al., 2017).

Data collection

The data was collected in the 23 selected villages through participatory research appraisal tools and techniques (individual interviews, group discussions, and direct observation) using a semi-structured questionnaire (Orobiyi et al., 2017). Interviews were conducted with the help of local translators in each village to facilitate discussions with farmers (Kombo et al., 2012). In each village, focus group discussions was made up of between 5 to 7 common bean producers of both sexes and different ages selected with the help of the village chief or farmers' organization leaders. Prior to the group discussions, farmers were asked to bring in advance a seed sample of common bean they grow or know (Loko et al., 2015; Orobiyi et al., 2017). After a detailed presentation of the objectives of the research to farmers they were asked to submit the samples of different common bean landraces. Based on this, the list of common bean folk varieties grown by farmers in the village level were obtained. The distribution and extent of the

Figure 1. Map of Central Benin showing the surveyed villages.

common bean folk varieties listed were assessed using the participatory four-square analysis method according to Gbaguidi et al. (213) and Orobiyi et al. (2017). This approach allows to classify into four categories based on relative area (large or small) devoted to a folk variety and to the relative number of households (few or many) (Gbaguidi et al., 2013; Orobiyi et al., 2017). Popular folk varieties are cultivated by many households on large areas, while threatened landraces are cultivated by few households on small areas.

The data were collected during individual interviews on the base of a semi-structured questionnaire. Collected data included socio-demographic data (age, sex, household size, years of experience in common bean production, educational level), cultivated area, constraints related to common bean production, diversity maintained at the household level, the abandoned folk varieties and the reasons of their abandonment, seed system (production, supplier, conservation methods, and duration of conservation), cropping system, storage constraints, damages caused by insects, the period of the infestation, the farmers' knowledge of the storage insect species, and the traditional management practices of the infested stored beans. According to Loko et al. (2018) after interview with each farmer, common bean folk varieties were collected and classified at laboratory using visual technique following similar procedures by Mohammed et al. (2016), based on seed's morphological description characteristics (coat colour, size, coat pattern, and hilum colour).

Data analysis

The data obtained during the surveys were analysed by the descriptive statistics (mean, percentage, variance, etc.) using Microsoft Excel 2010 software to generate figures and tables. The rate of threat of landraces disappearance (RTLD) at the level village was calculated following Kombo et al. (2012), and Orobiyi et al. (2017) according to the formula:

$$RTLD = [(n-k) / N] \times 100$$

With n: number of common bean folk varieties threat of disappearance, k: number of newly introduced common bean landraces (less than a year) and N: the total number of common bean landrace recorded in the village. The correlation between sociodemographic characteristics of surveyed farmers and diversity of common bean landraces held at household level were calculated using the Statistical Package for Social Sciences (IBM SPSS version 23.0).

RESULTS

Sociodemographic and farm characteristics of the surveyed farmers

A total of 101 common bean producers were interviewed through the 23 prospected villages. The surveyed farmers were in majority (77.2%) men. A great majority of surveyed farmers had no formal education (80.2%), most farmers attained primary level of education (14.9%), and only 4.9% of the respondents had secondary level of education. More than half of the respondents were aged between 35 and 56 with middle age, average of 51.4

Table 1. Socio-demographic characteristics of surveyed households in the study area.

Demographic characteristics	Variables	Number of farmers	Percentage (%)	Mean ± SE
	No formal education	81	80.2	
Level of education	Primary	15	14.9	
	Secondary	5	4.9	
	[35-56[	66	65.4	
Age (years)	[56-66[	28	27.7	51.4 ± 0.9
	[66-76]	7	6.9	
Gender	Male	78	77.2	
	Female	23	22.8	
	[1-11[	34	33.7	
Experience (years)	[11-22[	60	59.4	14.5 ± 0.6
	[22-32]	7	6.9	
Land size	[0.02-0.1[	90	89.1	0.08 ± 0.01
	[0.1-0.8]	11	10.9	

*n= number of interviewed household heads; SE= standard error of the mean.

years (Table 1). The experience of surveyed farmers in common bean production ranges from 01 to 32 years with an average farming experience of 14.5 years. The land size of common bean averaged 0.08 ha with a minimum of 0.02 ha and a maximum of 0.8 ha. The majority of farmers (89.1%) grow beans on small plots of size between 0.02 and 0.1 ha (Table 1). The great majority of farmers (72.28%) grow common beans in monoculture. While only 27.72% of surveyed farmers grow common bean intercropping with maize at the maturity stage (70.37%) or cassava (29.63%). Several ethnic groups were represented: Mahi (31.7%), Idaatcha (21.8%), Fon (17.8%), Nago (10.9%), Ifê (7.9%), Tchabè (5.9%), and Adja (4%).

Constraint of common bean production

In central Benin, farmers face several constraints related to common bean production. In total, 12 constraints were identified and prioritized in the study area (Figure 2). Among them, availability of staking materials (29.7%), lack of market (18.9%), lack of seeds (15%), drought (12.9%), soil poverty (9.1%), and harvest difficulties (7.3%) were the most important (Figure 2).

Common bean landraces richness

A total of 26 vernacular names of common bean were recorded in the study area, which correspond subject to synonymies at 12 landraces, classified by farmers mainly by the colour of their seed coat (Table 2). Farmers notified that, all landraces grown in their fields are climbing beans. At the household level, the number of common bean landraces held by farmers ranges from 1 to 5. Most of surveyed farmers (43.5%) cultivated only one common bean landrace, while 48.5% cultivated 2 landraces and 5.9% cultivate 3 to 4 landraces. The highest number of common bean landraces (5) per household was reported in Atchakpa and Igbodja villages maintained by only 2% of surveyed farmers. There was significant positive correlation (r=0.277, p=0.005) between the level of education and the number of common bean landraces held by household. While, there was no significant correlation between the number of landraces held by household and age of farmers (r=-0.079, p=0.435), sex of respondent (r=0.089, p=0.376), farming experience (r=-0.050, p=0.618) and land size (r=-0.157, p=0.116).

Distribution and extent of common bean landraces

The number of common bean landraces per village ranged from 3 to 7 with an average of 4.7 per village. The Sako, Djegbe and Gobada villages recorded the smallest number (3) of landraces, while the Doyissa, Enseke villages showed the greatest varietal diversity (Table 3). Within the 12 common bean landraces collected, subject to synonymy, the landrace with large flat seed and white seed coat colour called Akpakoun wéwé and those with small seed with brown seed coat colour and dark hilum colour called Séssé were registered as popular landraces

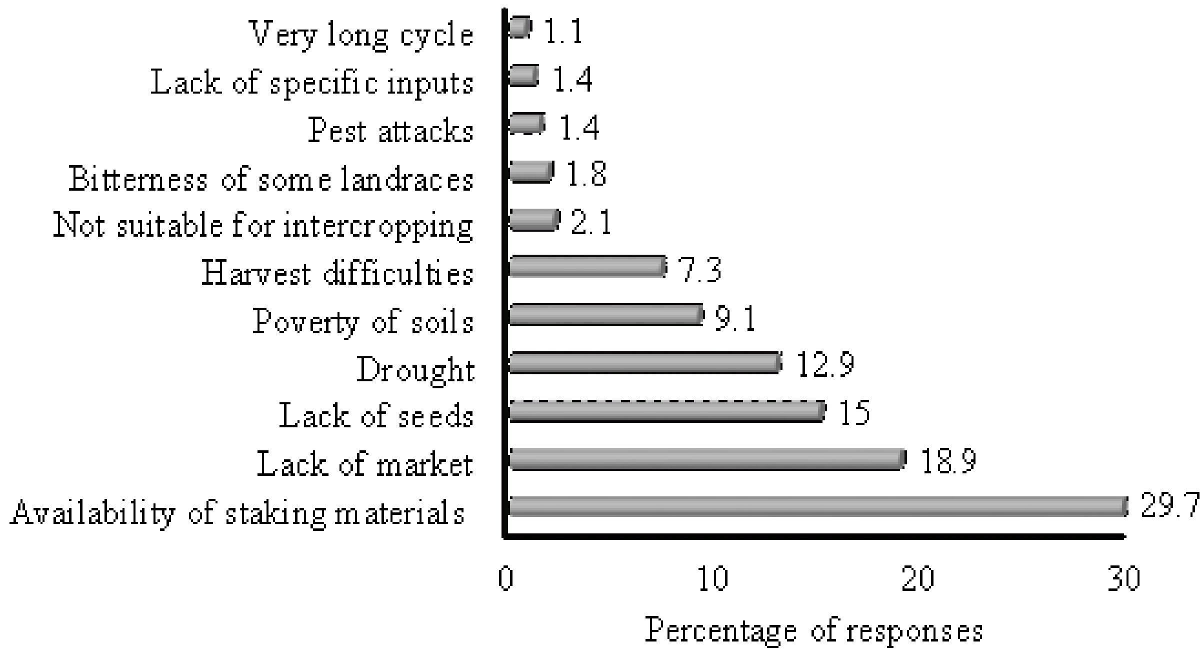

Figure 2. Constraints related to common bean production in central Benin.

and found in several villages (Table 2). It was noted that no common bean landraces were newly introduced at the village level. The majority of common bean landraces found in the study area were threatened of disappearance. The rate of threat of landraces disappearance varied from 25 to 100% with an average of 62.7%. The villages of Enssèkè, Lahotan and Awaya recorded the highest rate of varietal diversity in disappearance. Across the study area the majority of respondents (54.5%) listed landraces that they abandoned for various reasons. Akpakoun wiwi (34.6%), Séssé (29.1%), Akpakoun vovo (21.8%) and Akpakoun wéwé (14.5%) were totally abandoned by some farmers in the study area. In total, 11 reasons justifying the loss of common bean varietal diversity in the study area were listed by surveyed farmers. These reasons can be grouped into four categories, agronomic (35.5% of responses), culinary (22.6% of responses), commercial (25.8% of responses) and religious (16.1% of responses). The main reasons that threaten bean diversity in the study area were: slumps of sales (25.8% of responses), bitter taste of some common bean landraces (22.6% of responses), religious prohibitions (16.1%), lack of tutors (8.1% of responses), and seed colour (6.5% of responses) (Figure 3).

Seed system

Most of surveyed farmers (51.8%) saved seeds obtained from the previous season for the next season. Some farmers (44.6%) use seeds bought at the market, while few farmers obtain seeds through donations (1.8% of farmers) or inheritance from parents (1.8% of farmers). In the context of seed conservation, only a few surveyed farmers (20.8%) do not make any selection of bean seeds before storage. On the other hand, the vast majority of farmers (79.2%) select the seeds before their conservation for several reasons, the most important of which was to obtain quality seeds (40.2% of responses), vigorous plants after sowing (26.4% of responses), a high germination rate (19.5% of responses), and a good yield (8.1% of response). Very few producers select seeds for healthy plants (4.6%) or to prevent the risk of insect attack (1.2%). The selection of the seeds that will constitute the seeds of the next season generally relates to several criteria (Figure 4). Farmers mainly orient their choice on unperforated seeds (63.6%) or large pods (26.5%) and pod length (3.3%).

Several storage methods were chosen by the surveyed farmers for seeds conservation such as polyethylene bags (41.2% of responses), cans (29.8% of responses), gourds (13.2% of responses), plastic bottles (12.3% of responses), jars (2.6% of reponses) and clay pots (0.9% of responses). Storage methods of common been seeds identified in the study area were living houses (90.4%), granaries (8.7% of farmers) and hanging on the roof kitchen (0.9%). Most of surveyed famers (75.9%) perceived that bean seeds can be kept for 5 to 7 months and only a few farmers (3.6%) note a conservation of about one year (Figure 5a). Few surveyed farmers (1.8%) reveal that stored common bean seeds were attacked by insects from the first days of storage. However, the majority of them report that heavy insect infestations occur during the second (35.9% of responses) and third

Table 2. Local names, characteristics, distribution and extent, and picture of common bean landraces cultivated in the study area.

Vernacular names	Ethnic groups	Characteristics	Distribution and extent (villages)	Pictures
Akpakoun wéwé Kpalakoun founfoun Kpakpalaegui	Fon, Mahi Idaatcha, Tchabe Adja, Nago	Large flat seed with white seed coat colour	+ + (Agao, Enssekè, Vossa, Avokangoudo, Djegbé, Odougba, Aklamkpa, Doyissa) + - (Kpota, Fita, Atchakpa, Kpakpa-zoumè, Agbodjedo) - - (Gobada, Igbodja, Béssé, Djabata, Malomie, Lahotan)	
Akpakoun vovo	Fon, Mahi	Small smooth and shiny seed with red seed coat colour	+ - (Agao, Gobada, Awaya) - - (Kpota, Fita, Enssekè, Atchakpa, Igbodja, Besse, Djabata, Sako, Atokolibe, Kpakpa-zoumé, Odougba, Agbodjedo, Avokangoudo, Aklamkpa, Doyissa)	
Kpalakoun kpikpa	Idaatcha, Nago			
Kpankoui rouge	Adja			
Kpokpodo	Tchabè			
Séssé	Fon, Mahi, Idaatcha, Tchabè, Nago, Ifé	Small seed with brown seed coat colour and dark hilum colour	+ + (Besse, Atokolibe) + - (Atchakpa, Igbodja, Gbedje) - + (Agao) - - (Kpota, Fita, Gobada, Enssekè, Djabata, Sako, Malomie, Kpakpa-zoumé, Agbodjedo, Lahotan, Avokangoudo)	
Kpalagui	Ifè	Small flat seed with white seed coat colour	+ - (Atokolibé) - - (Kpota, Agao, Atchakpa, Sako, Djegbe, Odougba, Aklamkpa, Doyissa)	
Akpalakoun founfoun	Idaatcha, Tchabè			
Akpakoun sonhouékan Alawoaho	Fon Tchabè	Small seed with marginal seed coat speckled of red and a red colour around hilum	+ - (Gbedje, Malomi) - + (Gobada) - - (Fita, Ensseke, Atchakpa, Igbodja, Besse, Atokolibé, Djegbe, Doyissa)	
Akpakoun Kpalakoun	Fon, Mahi Idaatcha, Tchabè	Small seed with red broad striped seed coat pattern and red colour around hilum	- - (Awaya, Enssekè, Lahotan)	
Akapakoun rouge	Mahi, Nago			
Akpakoun djihikoun	Fon, Mahi	Small seed with brown seed coat and red colour around the hilum	- - (Ensseke, Sako, Vossa, Lahotan, Doyissa)	
Ewaarigui	Nago			

Table 2. Contd.

Akpakoun wiwi	Fon	Small seed with black broad striped seed coat pattern and black colour around hilum	- - (Fita, Awaya, Igbodja, Kpakpa-zoumé, Odougba)	
Akpakoun wiwi Kpankoui	Fon Mahi	Large seed with black seed coat	- - (Kpota, Fita, Agao, Awaya, Djabata, Vossa, Kpakpa-zoumé, Aklamkpa) + - (Ensseke, Agbodjedo,	
Mitohikoun Djihikoun	Fon Mahi	Small shiny round brown seeds with black colour around hilum	- - (Djegbé, Aklamkpa)	
Akpakouin kpikpa	Tchabé Idaatcha	Large flat seed with red seed coat	- - (Kpota, Atchakpa, Kpakpa-zoumè, Agbodjedo, Aklamkpa, Doyissa)	
Mitohikoun Akpakoun wéwé gbagba	Mahi Fon	Small white smooth seed with black colour around hilum	- - (Agao, Awaya, Igbodja, Vossa, Djegbe)	

++ Landrace cultivated by many households on large plots ; + - Landrace cultivated by many households on small area; - + Landrace cultivated by few households on large plots; - - Landrace cultivated by few household on small plots.

(50% of responses) months of storage (Figure 5b).

Constraints of common bean post-harvest conservation

Most of surveyed farmers (68.3%) report constraints related to the storage of bean seeds, mainly insect attacks by seeds (78.3%) and grain discoloration due to fungi (21.7%). Only a few farmers (35.2%) were able to identify a single storage insect related to stored common bean. The bean weevil *Acanthoscelides obtectus* (Say) (Coleoptera: Bruchidae) known locally as Kokoroêwa (Nago), Kpokpoui (Adja) Phophoro (Idaatcha) and Wanvou (Fon and Mahi) was the only insect pests reported by farmers. Some farmers (9%) notified that insect pests don't cause damage in stored common beans. However, most of surveyed farmers estimate losses due to storage insects at around 25% of stocks (68.5% of respondents) and only a few farmers estimate losses at around 50% (16.9% of respondents), and 75% of stocks (5.6% of respondents). Surveyed farmers listed 8 factors favouring the attack of stored common bean seeds by insects. Among them, seeds with high moisture (40.8%), the lack of adequate storage tools (20.8%) and the high temperature in the storage structure that allow rapid multiplication of some insects (16%) were the most important factors (Figure 6). These heavily infested seeds were discarded by the majority of farmers (85.8%). However, some farmers (8.1%) after drying over several days used these seeds for consumption. Few surveyed

Table 3. Diversity, distribution, extent and rate of threat of common bean landraces disappearance at the level of villages.

Villages	TNL	Distribution and extent				NNIL	NLD	RTLD (%)
		H+A+	H+A-	H-A+	H-A-			
Sako	3	1	0	0	2	0	2	66.7
Gbedje	4	2	1	0	1	0	1	25
Atokolibe	4	1	1	0	2	0	2	50
Malomie	4	1	1	1	1	0	1	25
Vossa	4	1	0	2	1	0	1	25
Djegbe	3	1	0	0	2	0	2	66.7
Ensseke	7	1	0	0	6	0	6	85.7
Odougba	4	0	1	0	3	0	3	75
Atchakpa	6	0	2	0	4	0	4	66.7
Igbodja	6	0	1	0	5	0	5	83.3
Besse	4	1	0	0	3	0	3	75
Djabata	4	0	1	0	3	0	3	75
Aklamkpa	5	0	1	0	4	0	4	80
Kpota	5	0	1	0	4	0	4	80
Kpakpa-zoume	6	0	1	0	5	0	5	83.3
Fita	5	1	0	0	4	0	4	80
Agbodjedo	5	0	1	0	4	0	4	80
Agao	6	0	1	0	4	0	4	66.7
Awaya	5	0	0	0	5	0	5	100
Gobada	3	0	1	0	2	0	2	66.7
Lahotan	5	0	0	0	5	0	5	100
Doyissa	7	0	1	1	5	0	5	71.4
Avokangoudo	3	0	2	0	1	0	1	33.3

TNL: Total number of landraces; H+A+: Landraces cultivated by many households on large plots; H+A-: Landraces cultivated by many households on small plots; H-A+: Landraces cultivated by few households on large plots; H-A-: Landraces cultivated by few household on small plots; NNIL: number of newly introduced landraces; NLD: number of landraces threat of disappearance; RTLD: Rate of threat of landraces disappearance

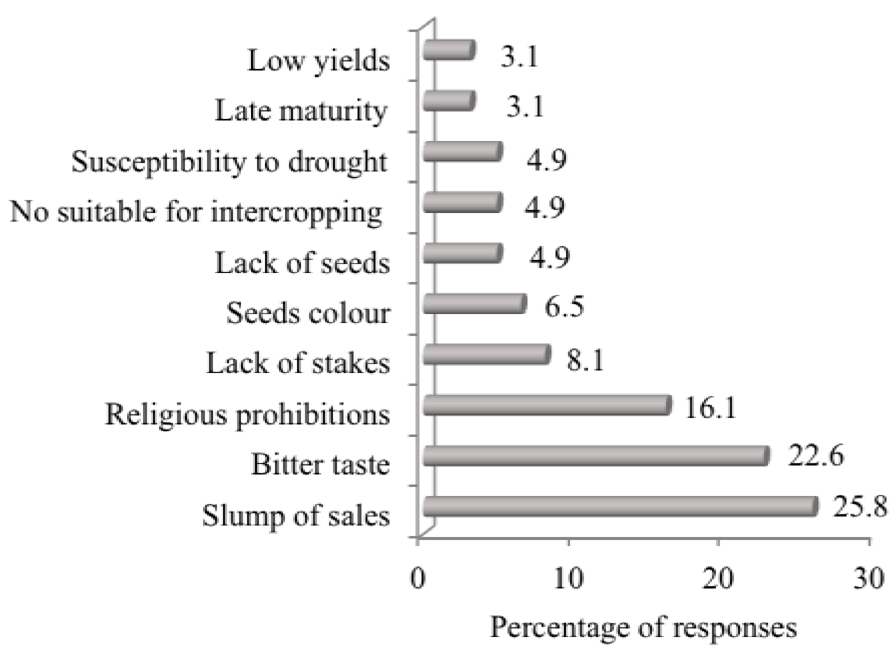

Figure 3. Reasons of common bean landraces loss in the study area.

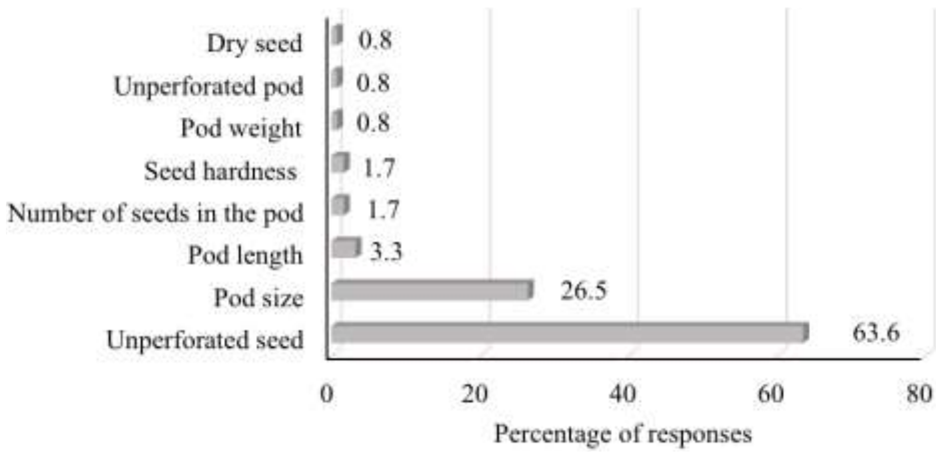

Figure 4. Famers' selection criteria of common bean seeds in the study area.

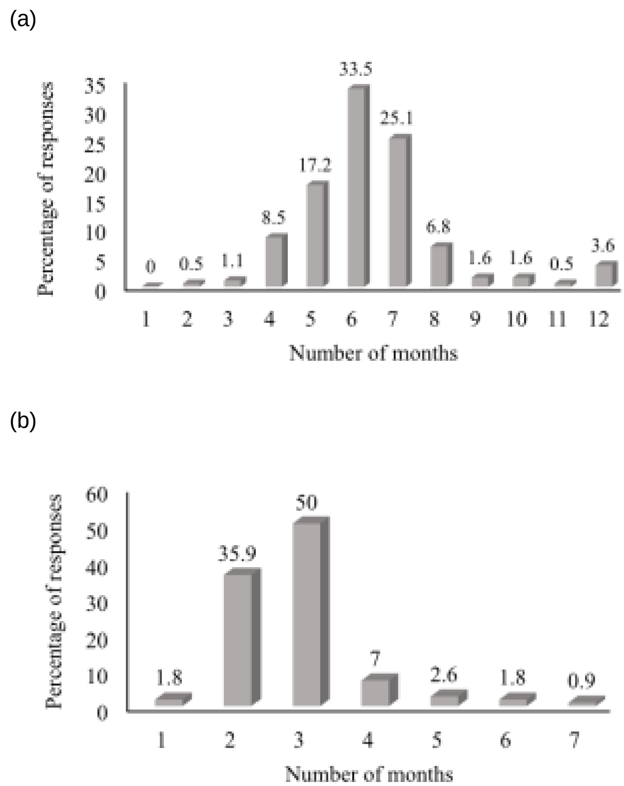

Figure 5. Farmer perception of (a) the duration of post-harvest conservation of common bean seeds; (b) the period of infestation of stored common bean by insects.

farmers (6.1%) used infested seeds for animals feed.

Insect pest management methods used by farmers

Across the study area, most of surveyed farmers (58.4%) take precautions to prevent insect pests attack in stored common bean. The majority of them use medicinal plants with insecticidal or insect repellent effect (88.7% of responses). The study found that six plant species that were used to prevent infestation of bean seeds. Of these species, four (*Cinchona officinalis* L., *Khaya senegalensis* (Desr.) A.Juss., *Xylopia aethiopica* (Dunal) A.Rich., and *Capsicum frutescens* L.) were reported as insect

Table 4. List of repellent and/or insecticidal plants used to protect stored common bean seeds against insect pests and their utilisation.

Plants	Percentage of farmers	Part used	Method of utilisation	Role
Azadirachta indica	30.8	Leaves and seeds	Leaves or seeds dried then ground and mixed with seeds beans	Insecticide and insect repellent
Combretum micranthum	20.4	Leaves	Dried and ground leaves then mix with seeds beans	Insect repellent
Khaya senegalensis	15.4	Leaves	Dried and ground leaves then mix with seeds beans	Insect repellent
Xylopia aethiopica	15.4	Fruits	Fruits dried, crushed and mixed with seeds beans	Insect repellent
Capsicum frutescens	10.3	Leaves and fruits	Leaves and dried fruits, then ground and mixed with seeds beans	Insect repellent
Ocimum gratissimum	7.7	Leaves	Grind dried leaves in preserved seeds beans	Insecticide and insect repellent

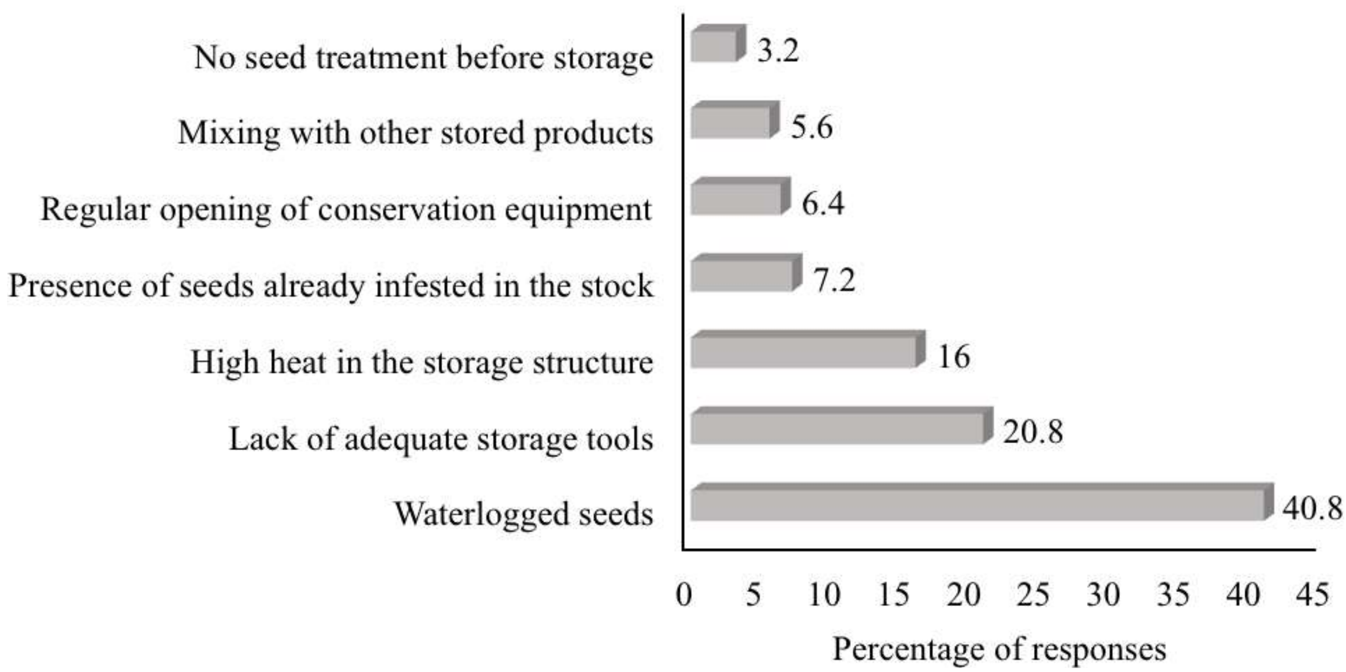

Figure 6. Farmers' perceptions of factors favouring attacks of stored common bean seed by insects.

repellents, while the other (*Azadirachta indica* A. Juss., and *Ocimum gratissimum* L.) were considered both insect repellents and insecticides (Table 4). Neem (*A. indica*) was the most used by farmers (30.8% of respondents) and *O. gratissimum* was the less used by farmers (7.7% of respondents). The parts of the plant (leaves or fruit) used and methods of application (ground or crushed) are summarized in Table 4. Some farmers (2.3% of responses) used well-sorted runoff sand dried in the sun for storage at half the volume of seed to be stored for common bean preservation. Other farmers used ash (4.5% of responses) which was well leached and dried to prevent discoloration and the loss of seed germination potential. Other farmers (4.5%) used chemicals for stored common bean protection such as Sofagrin and insecticides used for cotton protection such as Andosulfan, and Lamda super 2.5 EC.

Farmer perception of the resistance of common bean landraces to storage insects

All surveyed farmers in the study area pointed out that unlike other legume seeds such as cowpea, soybean or

Kersting's groundnut, common bean landraces were resistant to storage insects. However, they noted that four common bean landraces were very resistant to storage insect attacks. These are the Séssé (57.8% of farmers), Akpakoun vovo (33.3% of farmers), Akpakoun wiwi (6.7% of farmers), and Mitoyikoun (2.2% of farmers) landraces. For farmers the resistance of these common bean landraces was due to the hardness (Séssé landrace), thickness (Mitohikoun landrace) and black colour (Akpakoun wiwi landrace) of seed coat, and the seed bitter taste (Akpakoun vovo). Nevertheless, some landraces were noted as being very sensitive to storage insect attacks. The small-seeded white bean (Kpalagui) and the large flat white seed (Akpakoun wéwé) were the most susceptible landraces as reported by 40% of famers respectively. Akapakoun rouge was also considered to be very susceptible to storage insect pest attacks as reported by some farmers (20%). For farmers, the susceptibility of these three common bean landraces is due to the fact that they have high moisture content in seeds.

DISCUSSION

In the study area, common bean production was confronted to several constraints. The availability of staking materials was the biggest problems for farmers, which was hampering common bean production in central Benin. Similar results have been reported by several authors in other African countries (Ruganzu et al., 2014; Gichangi et al., 2012; Musoni et al., 2014; Rujamizi et al., 2017). The reduction of tree plantations associated with the high cost of stick staking explains the unavailability of sticks for staking (Ntukamazina et al., 2014). In fact, in the study area the use of trees as stakes does not allow all farmers to grow common beans because few of them have trees in their fields. Similarly, this factor limits women's production of beans because the ownership of trees in the fields was the responsibility of the men, thus justifying the high number of surveyed men in this study. These staking needs in climbing beans production therefore, could lead to deforestation and subsequent environmental degradation (Gichangi et al., 2012; Musoni et al., 2014). However, some studies shown that farmers use alternative staking material such as stalks of maize and sorghum (Gichangi et al., 2012; Takusewanya et al., 2017). To improve common bean production in central Benin, the training of farmers on climbing beans intercropping production practises turns out to be necessary.

Interviews of farmers also revealed that lack of market was an important constraint in common bean production. Similar results were found by van De Luque et al. (2014) which show that lack of market access, price instability, and lack of credit were important common bean constraints. A common bean market study in central Benin must bean done because the knowledge of market dynamics are crucial to define a breeding strategy that meets the need of the farmers (Asfaw et al., 2013). Third constraint in the study area, the lack of seeds was also notified by some farmers in Uganda (Ronner et al., 2017), and Burundi (Birachi et al., 2011) and can be due to the poor yields in the previous season. There is an urgent need to train farmers associations of central Benin in common bean seed production, promote improved seeds and facilitate seed imports by government.

The study revealed subject to the synonymy, the existence of 12 common bean landraces across the study area. Although varietal diversity is important across the study area, it is low compared to that found in villages in Northern Malawi (15 landraces) (Martin and Adams, 1987), but higher than the number of landraces found is southern Ethiopia (6 landraces) (Asfaw et al., 2013). Education level was correlated to the number of common bean landraces held at household level. Similar results were obtained by Gichangi et al. (2012) which reported positive impact of education level on adoption and production of climbing beans. In fact, the level of education increases farmers' ability to obtain information and increase the probability to adopt good practises relevant to the production of climbing beans (Gichangi et al., 2012). To boost common bean production in central Benin, creating awareness and building capacity of farmers is necessary.

The mean number of common bean landraces held at the village level was higher than others pulses in Benin such as pigeonpea (Ayenan et al., 2017), and Kersting's groundnut (Assogba et al., 2015), but lower than that of cowpea (Gbaguidi et al., 2013). The loss of common bean diversity in the study area remains significant. A conservation programs (*in situ* and *ex situ*) of the existing diversity should therefore be put in place. The Doyissa and Enssèke villages had the highest varietal diversity and were therefore, best suited for *in situ* conservation programs for common bean genetic resources in central Benin. In this region, many common bean landraces have been abandoned by farmers and the documented abandonment reasons will guide breeders on the type of varieties to be created for the happiness of farmers.

The survey reveals that seed system was informal with majority of self-saved seed from the previous harvest or purchased from local markets. Similarly, common bean seed system in Ethiopia (Asfaw et al., 2013; Oshone, 2017), and Kenya (Opole et al., 2006) is essentially informal. In this informal seed system access to improved varieties is still a challenge to farmers leading to low production levels (Birachi et al., 2011). There is an urgent need for the development of formal seed system and by setting up production of breeder, pre-basic, and basic seed. Similarly to the result of this study, farmers in Ethiopia (Oshone, 2017) mainly used polyethylene bags for common bean post-harvest conservation probably because of their availability in the local markets and cheaper price.

Farmers mentioned that attack of stored common bean seeds by insects was the principal storage constraints. The bean weevil *A. obtectus* was the only insect pest of stored beans reported by farmers. This cosmopolitan insect pest has also been reported as the most important pest of stored beans in Asia (Thakur, 2012), America (Quentin et al., 1991; Silva and Costa, 2016 and Baldin et al., 2017), Africa (Rugumamu, 2014), Europa (Rugumamu, 2014) and Oceania (Daglish et al., 1993). In fact, larvae of *A. obtectus* enter the common bean seeds from the first instar stage and consume the reserves contained in the cotyledons which causes great losses (up to 30%) (Baldin et al., 2017). Infestation of stored common beans by the bean weevil gives a characteristic pungent odour, making them unfit for consumption and reducing their market value (Paul et al., 2009). There is a need, therefore, to found environment friendly methods to protect stored common bean against bean weevil. Moreover, several studies shown the presence of another important common bean storage insect pest *Zabrotes subfasciatus* (Boheman) (Coleoptera: Bruchidae) in West Africa (Ayamdoo et al., 2013; Williams, 1980; Taylor, 1981). It is so essential to evaluate the diversity and abundance of insects associated with stored common beans in central Benin. Some farmers in the study area use chemicals insecticides to conserve their common bean seeds.

However, the use of these chemical pesticides in common bean preservation can cause damage to health by residual effects remaining in the grains. The use of plants for the protection of stored beans represents an alternative to the use of pesticides and is practiced by most farmers in central Benin. Except *C. officinalis*, all the others plants used by surveyed farmers for the protection of stored beans have proved insecticidal or insect repellent properties. Indeed, Rugumamu (2014), Niber et al. (1992), and Facknath (2006), proved the insecticidal effect of *A. indica* against *A. obtectus* in stored common beans. Similarly, the results of Rugumamu (2014) revealed direct contact toxicity of *O. graticimum* on *A. obtectus*. *C. frutescens* are commonly used for protection of common bean seeds in Northern Tanzania (Paul et al., 2009) and their insecticidal activity was proved on several storage insect pests such as *Callosobruchus maculatus* (F.) (Lale, 1992), and *Sitophilus zeamais* Motschulsky (Akinbuluma et al., 2015). The efficacy of *K. senegalensis* seed oil and powder as insecticide was demonstrated by Bamaiyi et al. (2007) as well as Nguemtchouin et al. (2010) shown the toxicity of *X. aethiopica* on *S. zeamais* in stored maize. It is therefore, important to evaluate the insecticidal and insect repellent properties of the 5 medicinal plants used by farmers of central Benin for the control of *A. obtectus* to broaden the range of available botanical insecticides for this pest.

A differential susceptibility of common bean landraces to storage insect pests was notified by surveyed farmers. In fact, Dobie et al. (1990) shown that the use of anti-lectin-like protein antibodies are a useful tool for distinguishing between resistant and susceptible bean varieties to *A. obtectus* and *Z. subfasciatus*. High moisture content of seeds was indicated by farmers as the susceptibility factor to storage insect attacks. This farmers' perception is corroborated by Delouche (1968) which notified that insect activity and damage also increases if seed moisture increase. As signalled by surveyed farmers the hardness (Stamopoulos and Huignard, 1980), and thickness (Stamopoulos and Huignard, 1980; Maldonado et al., 1996) of seed coat could be factors related to the resistance of common bean seeds to storage insects attack. Knowing that black seeds of some pulses such as Bambara groundnut (Baidoo et al., 2015) has shown resistance to *C. maculatus*, it is important to evaluate the preference of *A. obtectus* for a particular bean seed coat colour to confirm or refute farmers' perception of the black bean seeds' resistance to this pest.

Conclusion

This study has shown that several constraints hampered common bean production in central Benin with the lack of staking materials as the main constraint. The training of farmers on climbing beans intercropping production practises, and in common bean seeds production are important for the improvement of common bean production in the study area. An important common bean landraces diversity exist in central Benin with subject to the synonymy 12 common bean landraces recorded. However, morphological and molecular characterizations must be done to evaluate the existing common bean diversity. A high rate of threat of common bean landraces disappearance was recorded and the documented reasons of this disappearance will guide breeders on the type of varieties to be created for happiness of farmers. The Doyissa and Enssèke villages had the highest varietal diversity and are therefore best suited for *in situ* conservation programs for common bean genetic resources in central Benin. The seed system was essentially informal and thus, there is an urgent need for the development of formal seed system. The bean weevil *A. obtectus* was the only pest recognised by farmers. It is important to evaluate the diversity and abundance of insects associated with stored common beans in central Benin. Medicinal plants were used by most of farmers to control storage insect pest. The efficiency of the 5 medicinal plants recorded on the control of *A. obtectus* in this study should be tested to broaden the range of available botanical insecticides for this pest. The susceptibility of the four common bean landraces listed by farmers as resistant to storage insects must be evaluated.

CONFLICT OF INTERESTS

The authors have not declared any conflict of interests.

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Full Length Research Paper

Impact of land-use on tree and fruit morphometric variation of the bitter kola (*Garcinia kola* Heckel) in Benin: Insight for domestication and production.

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Garcinia kola **is an IUCN globally vulnerable species native in Benin where it is extinct in the wild. It is also one of the top ten priority non-timber forest products in Benin because of its socio-economic and medicinal values. Still, *G. kola* is neglected and underutilized. The morphological variation of *G. kola* traits was investigated in two land-use types (home gardens versus farmlands) where it is found in Benin with the goal of informing its domestication and production. A total of 79 trees identified in both land use types were characterized based on seventeen tree growth, leaves, fruit and seeds descriptors. Results found no significant difference between land-use types for tree height, first ramification height, crown height, crown diameter growth, blade width, petiole length, petiole diameter and number of seeds. However, stem diameter, blade length, fruit length, fruit width, husk weight, seed length, seed width and seed weight showed significant differences between land-use types. Eight (stem diameter, blade length, fruit length, fruit width, husk weight, seed length, seed width and seed weight) out of the initial descriptors were the most discriminant of trees according to land-use types. Values of most discriminant descriptors were low in home gardens and higher in farmlands. This study shows that land-use management can affect *G. kola* production, highlights the potential of domestication of the species, and suggests the need to fix morphological traits of fruits and nuts which are the most sought *G. kola* products.**

Key words: Benin, Clusiaceae, land-use management, morphological diversity, threatened species.

INTRODUCTION

Garcinia kola Heckel (Clusiaceae) is a medium size tree that grows up to 15-17 m high (Agyili et al., 2006). It is commonly known as "bitter kola" in English, "faux kola" or "petit kola" in French. The tree is endemic to humid lowland rainforest vegetation of central and western Africa (Akoegninou et al., 2006; Agyili et al., 2007;

Kanmegne and Omokolo, 2008). *G. kola* is one of the most valuable trees because of its socio-economic importance and medicinal attributes. The seed, commonly known as bitter kola, is a masticatory and a major kola substitute shared at social ceremonies. Bitter kola is a stimulant that has a bitter astringent and resinous taste when eaten (Yakubu et al., 2014). The seeds are often used as aphrodisiac. They are used in folk medicine and in many herbal preparations for the treatment of ailments such as laryngitis, liver disorders, and bronchitis (Farombi and Owoeye, 2011). Because of its high interest, harvesting of the different organs of *G. kola* has been very heavy (Akoegninou et al., 2006; Agyili et al., 2007; Assogbadjo et al., 2017), making it extinction-threatened in several West and Central African countries (Yakubu et al., 2014).

Garcinia kola is found in Benin and belongs to the top ten priority non-timber forest products in Benin (Assogbadjo et al., 2017). It is only found in the Southern part of the country which corresponds to the sub-humid Guinean zone (Akoegninou et al., 2006) where population density is the highest with the most destructive anthropogenic activities. Bitter kola is an IUCN globally vulnerable species but extinct in the wild in Benin (Neuenschwander et al., 2011). The genetic diversity of the species might therefore be strongly reduced in the future if no appropriate conservation measures are taken. From a phytogenetic viewpoint, characterization and evaluation of morphological and agronomic traits are essential to the identification, conservation and utilization of genetic resources (Gepts, 2006). Studies on morphological variation of *G. kola* are however scarce. Dah- Nouvlessounon et al. (2016) recently explored the intra specific variability in one of the occurring region of the species, namely the Ouémé Region and reported a strong variation. They suggested a strong potential of the species for domestication. However, intra-specific variation may be caused by several factors which if captured could optimize the species domestication.

So far, no quantitative assessment is available on factors that are responsible for the observed variation in trees and fruits in the species. Previous studies demonstrated that land-use types can affect population structure and morphometric traits of multipurpose trees such as *V. paradoxa* (Djossa et al., 2008; Akpona et al., 2015). An exploratory survey in its occurrence areas in Benin shows that *G. kola* is found in home gardens and fields close to houses (Dah-Nouvlessounon et al., 2015). Assuming that land-use could also have an impact on *G. kola*, the current study aims at understanding how in its area of distribution, land-use types affect tree and fruit characteristics of *G. kola*.

MATERIALS AND METHODS

Studied species

G. kola (Heckel) in the Clusiaceae or Guttiferae family, known as bitter kola, is a perennial tree occurring in West and Central Africa forests. In West Africa, *G. kola* grows in Benin, Côte d'Ivoire, Ghana, Liberia, Nigeria, Togo, Senegal and Sierra Leone. In Central Africa, it is found in Cameroon, Democratic Republic of Congo, Gabon, Central African Republic and Equatorial Guinea. It is a dicotyledonous plant naturally found in the coastal areas and low land plains up to 300 m above sea level with an average of 2000-2500 mm of rainfall. The species occurs where temperatures are uniformly 30 to 32°C and the relative humidity ranges between 76 and 93% (Agyili et al., 2006). It is a medium sized evergreen tree, up to 30 m tall and with a fairly narrow crown (Figure 1) (Agyili et al., 2006; Akoegninou et al., 2006). The leaves are simple, 6-14 cm long and 2-6 cm across, shiny on both surfaces and spotted with resin glands. The small flowers are covered with short, red hairs (Iwu, 1993). The fruit is a drupe of 5-10 cm in diameter and with weights of 30-50 g (Figure 1). It is usually smooth and contains a yellow red pulp. The fruit changes color during maturation from green to orange, and each fruit contains 1-4 white seeds covered by a brown coat (Figure 1) (Agyili et al., 2006).

Study area

In Benin, *G. kola* occurs in the Guinean ecological zone as defined by White (1983). This zone is located in the Southern part of Benin between latitude 6°25 N and 7°30 N. The present study was conducted in the three administrative regions (Atlantique, Ouémé and Plateau) where the species was identified in Southern Benin (Figure 2). Southern Benin has a subequatorial climate with two rainy seasons and two dry seasons of unequal length. The region is characterized by a rain fall gradient from 900 mm in the West to 1300 mm in the East (Adomou et al., 2007). The mean annual rainfall is 1200 mm. The annual average temperature ranges between 25 and 29°C and the relative humidity between 69 and 97%. The soils are either deep ferrallitic or rich in clay, humus and minerals (Adomou, 2005).

Sampling

Trees were only identified in two basic land-use: homegardens and farmlands as already reported by Dah-Nouvlessounon et al. (2015). Morphological data were collected between June and July 2017 during fruit production period of the species. Communes where the species is present were identified by consulting databases then trees were accessed using a snow-balling method. In each commune, fruiting trees were purposively selected by using a minimum distance of 50 m to avoid closely related individuals. A total of 79 tree accessions were sampled of which 60

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Figure 1. *G. kola* a) tree standing in a homegarden; b unripe and ripe fruits; c) seeds

in homegardens, and 19 in farmlands. The nineteen individuals in farmlands are statistical sufficient for comparison of species-specific trait values (Perez-Harguindeguy et al., 2013). On each sampled tree, ten leaves collected from the first lateral branch and five randomly harvested fruits were considered as in Dah-Nouvlessounon et al. (2016).

Data collection and processing

Characterization of *G. kola* was based on 17 morphological variables related to tree trunk and canopy (tree growth), fruits, leaves and seeds characteristics. Tree growth variables are stem diameter at 1.30 m above the ground (dbh), total height, first ramification height, crown height, and crown diameter. Variables related to leaves are leaf blade length, leaf width, petiole length, and petiole diameter. Fruits' variables are fruit length, fruit thickness, fruit weight, fruit husk weight, and number of seeds per fruit while variables measured on seeds was seed length, seed thickness, and seed wet weight. The tree growth characteristics were accessed using the formula in Table 1. The leaf blade length and width, the petiole length were measured using a decimeter while stem diameter were measured using a pentadecameter. The length and the width of the fruits and the nuts were taken using a slide foot. Fruit weight, fruit husk weight and seed wet weight were measured using a balance of precision 0.01 with a maximum range of 500 g.

Statistical analyses

Mean values, and standard error of mean and coefficient of variation of each morphological traits were calculated for all the trees and trees within each land-use type. A two-independent samples t-test was performed to test for differences in morphological traits between land-use types. To identify the most important traits that discriminated trees regarding land-use types, a canonical discriminant analysis was applied to all morphological traits. The most discriminant traits were then used to plot trees according to their land use types in the canonical axes. All analyses were run using R software version 3.4.3 (R Core Team, 2018).

RESULTS

Impact of land-use on morphological characteristics of bitter kola

Impact of land-use tree growth characteristics of bitter kola

Tree growth traits were relatively dispersed in both land-use types (CV >25%) except for total height and crown height which were less dispersed. The highest variation was found in first ramification height followed by stem diameter (dbh), and crown diameter (Table 2). There was no significant difference between land-use types for total height, first ramification height, and crown height. However, stem diameter was significantly different between land-use types. The largest trees were encountered in farmlands with a mean dbh of 51.53 cm; whereas the thinnest trees were observed in home gardens with mean dbh of 41 cm (Table 2).

Impact of land-use on leaf size characteristics of bitter kola

Compared to tree growth traits, most of the morphological descriptors of leaves were relatively less dispersed (CV < 25 %) in both land-use types (Table 3). The highest variation was recorded in petiole diameter in both home gardens and farmlands. There was no significant difference between blade leaf width, petiole

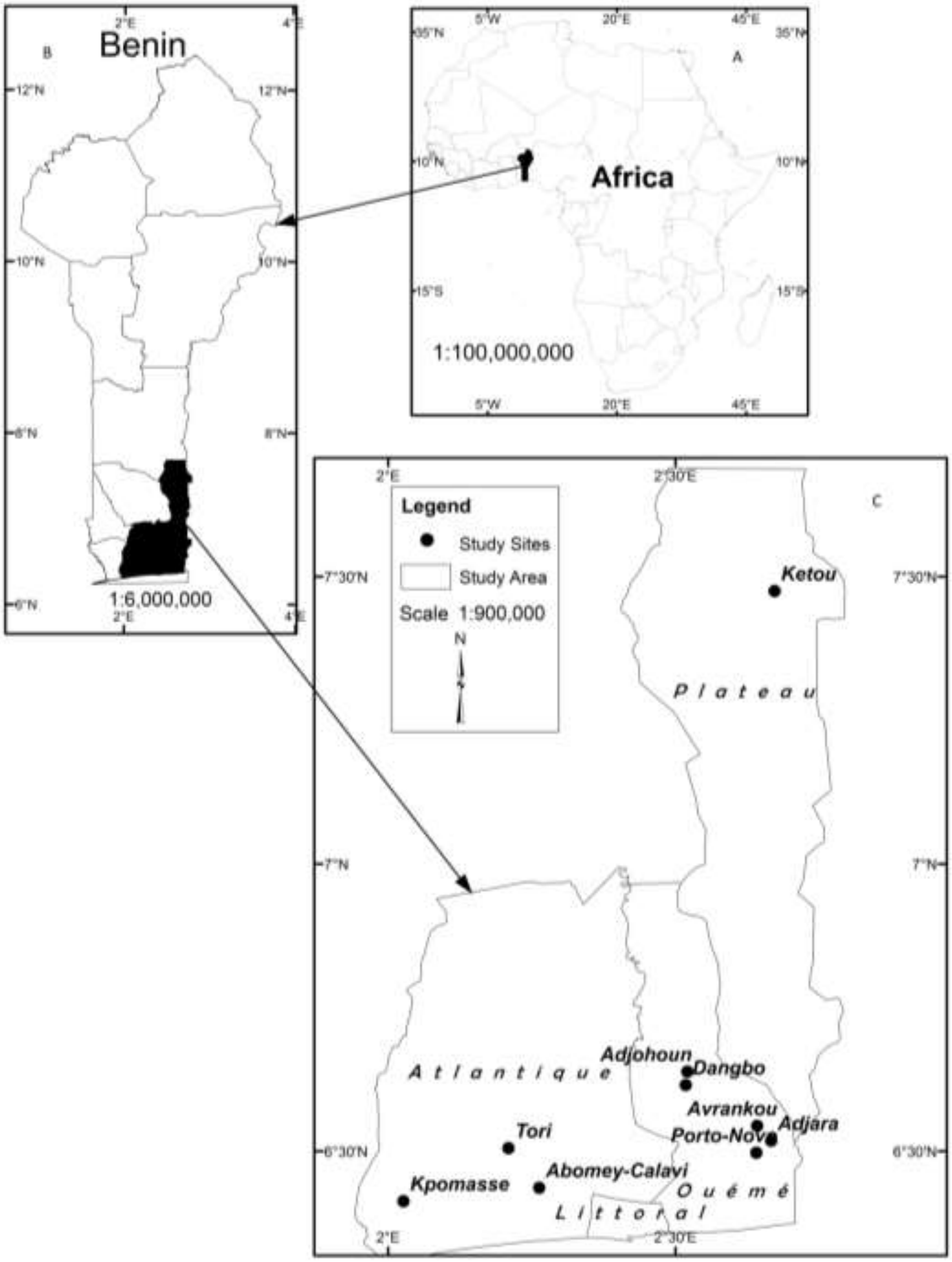

Figure 2. Study area showing (A) the location of Benin in Africa, (B) the position of the three regions studied in Benin, and (C) the Communes where the trees were located.

length and petiole diameter and land-use types. Leaf blade length in home gardens and farms differed significantly (Table 3). The leaf blade was longer in farmlands (129.52 mm) than in home gardens (115.76 mm).

Impact of land-use on fruits and seed's characteristics of bitter kola

In general, most fruit traits had relatively low variation (CV < 25%) except for husk weight and number of

Table 1. Tree growth characteristics.

Growth parameter	Formula	Explanations	References
Stem diameter (Dbh)	$Dbh = \frac{C}{\pi}$	The stem diameter of the tree (dbh) was determined by measuring the circumference (C) at 1.30 m using a pentadecameter.	-
Dbh for multi-stemmed tree	$Dbh = \sqrt{d_1^2 + d_2^2 + ... + d_n^2}$	d1…dn is the Dbh of stem 1… stem n	Saıdou et al. (2012)
Total height	$H = \frac{V_2 - V_1}{L}$	L = sightings distance of 10 m between the operator and the tree. V1 = first sighting, at the foot of the tree V_2 = second sighting, at the top of the tree	Rondeux (1999)
First ramification height (Hfr)		L = sightings distance of 10 m between the operator and the tree. V1 = first sighting, at the foot of the tree V_3 = second sighting, at the first ramification	
Crown height (Hcr)		H= total height, Hfr= first ramification height	-
Crown diameter (Dcr)		D_1 = crown North–South diameter D_2 = crown East–West diameter	-

Table 2. Tree growth variation according to land-use type.

Parameter	Overall (n=79)		Homegardens (n=60)		Farms (n=19)		P
	Mean ± SE	CV	Mean ± SE	CV	Mean ± SE	CV	
Dbh (cm)	43.79 ± 1.79	36.46	41.00 ± 1.92	36.35	51.53 ± 3.80	32.16	0.011
Total Height (m)	14.83± 0.33	19.86	14.91 ± 0.40	20.74	14.57 ± 0.57	17.05	0.665
First Ramification Height (m)	3.08 ± 0.15	42.75	3.06 ± 0.17	42.42	3.15 ± 0.32	44.81	0.803
Crown Height (m)	11.74 ± 0.31	23.75	11.85 ± 0.38	24.89	11.42 ± 0.52	19.71	0.565
Crown Diameter (m)	9.12 ± 0.28	27.48	9.00 ± 0.32	27.12	9.49 ± 0.63	28.84	0.462

Means followed by the same letter on a row are not statistically different at probability $P < 0.05$; SE, standard error of mean; CV, coefficient of variation (%).

seeds. However, the fruit traits did not vary in the same way between land-use types. In home gardens, a relatively high variation was observed only in number of seeds while it was observed in husk weight and fruit weight in farmlands (Table 4). The highest overall trait variation as well as the highest variation in home gardens was observed in number of seeds. The highest variation was recorded in husk weight in farmlands. There was a significant difference between land-use types for fruit length, fruit width, fruit weight, and husk weight. No significant difference was observed between land-use types for the number of seeds (Table 4). In farmlands, fruit length (56.06 mm), fruit width (59.53 mm), fruit weight (109.97 mm) and husk weight (103.23 mm) were higher than fruit length (52.02 mm), fruit width (55.55 mm), fruit weight (88.50 mm) and husk weight (85.43 mm) in home gardens. All seed traits had relatively low variation (CV < 25%) in both land-use

Table 3. Leave traits variation according to land-use type.

Parameter	Overall (n=79)		Homegardens (n=60)		Farms (n=19)		P
	Mean ± SE	CV	Mean ± SE	CV	Mean ± SE	CV	
Blade Length (mm)	119.06 ± 2.01	15.04	115.76 ± 2.25	15.03	129.52 ± 3.59	12.10	0.007
Blade Width (mm)	49.66 ± 0.65	11.65	49.44± 0.78	12.20	50.34 ± 1.15	9.96	0.556
Petiole Length (mm)	12.12 ± 0.21	15.13	11.93 ± 0.23	14.75	12.71 ± 0.46	15.60	0.110
Petiole Diameter (mm)	1.80 ±0.03	16.52	1.80 ± 0.04	16.69	1.80 ± 0.07	16.42	0.948

*Means followed by the same letter on a row are not statistically different at probability P< 0.05. SE, standard error of mean; CV, coefficient of variation (%).

Table 4. Fruit traits variation according to land-use type.

Parameter	Overall (n=79)		Homegardens (n=60)		Farms (n=19)		P
	Mean ± SE	CV	Mean ± SE	CV	Mean ± SE	CV	
Fruit Length (mm)	52.99 ±0.61	10.22	52.02 ± 0.54	8.07	56.06 ± 1.72	13.37	0.004
Fruit Width (mm)	56.51 ± 0.52	8.20	55.55 ± 0.50	6.91	59.53 ± 1.30	9.52	0.001
Fruit Weight (g)	93.66 ± 2.63	24.97	88.50 ± 2.13	18.63	109.97 ± 7.64	30.27	0.000
Husk Weight (g)	87.35 ± 2.58	26.24	85.43 ± 2.55	23.16	103.23 ± 7.45	31.44	0.000
Number of Seeds	2.34 ± 0.08	28.82	2.34 ± 0.09a	30.28	2.36 ± 0.13	24.42	0.921

*Means followed by the same letter on a row are not statistically different at probability P< 0.05. SE, standard error of mean; CV, coefficient of variation (%).

Table 5. Seed traits variation according to land-use type.

Parameter	Overall (n=79)		Homegardens (n=60)		Farms (n=19)		P
	Mean ± SE	CV	Mean ± SE	CV	Mean ± SE	CV	
Seed Length (mm)	28.87 ± 0.79	24.24	27.59 ± 0.89	24.85	32.92 ± 1.36	18.07	0.003
Seed Width (mm)	17.20 ± 0.28	14.67	16.76 ± 0.34	15.72	18.58± 0.34	7.9	0.004
Seed Weight (g)	6.31 ± 0.17	23.66	6.04 ± 0.19	23.98	7.15 ± 0.31	18.76	0.000

*Means followed by the same letter on a row are not statistically different at probability P< 0.05. SE, standard error of mean; CV, coefficient of variation (%).

types. The highest overall trait variation as well as the highest variation in home gardens was observed in seed length followed by seed weight. The highest variation in farmlands was observed in seed weight followed by seed length (Table 5). Seed length (32.92 mm), seed width (18.58 mm) (7.15 mm) and seed weight were significantly higher in farmlands than seed length (27.59 mm),seed width (16.76 mm) and seed weight (6.04 mm) in home gardens (Table 5).

Discriminant morphological descriptors of G. kola according to land-use types

The canonical discriminant analysis indicated that some morphological descriptors separated *G. kola* trees according to land-use types (P < 0.001). The first axis saved 100% of the information. Only 8 out of the 17 initial descriptors were identified as the most discriminant of trees according to land-use types. There were stem dbh, blade length, fruit length, fruit width, husk weight, seed length, seed width and seed weight (Figure 3). Trees in farmlands are bigger, with longer blades, longer and bigger fruits, and longer, bigger and heavier seeds.

DISCUSSION

The relatively important variation of morphological descriptors around mean values especially for tree

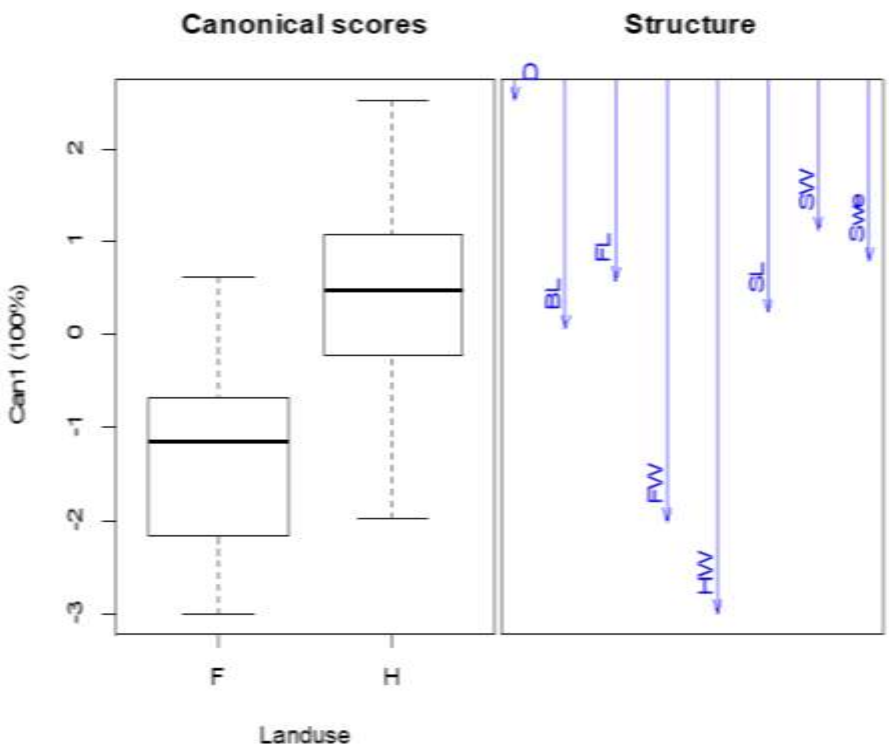

Figure 3. Morphological descriptors discriminating land-use: canonical scores and structures on the first canonical axis. D- diameter, FL= fruit length, FW- fruit width, HW- husk weight, SL- seed length, SW- seed width, SWe- seed weight.

growth and seed traits is an indicator of the potential of the species for domestication through selection of elite trees. Our results reveal that land-use type has an impact on variation of tree diameter, leaf blade length, and fruit and seed size of bitter kola. .The difference between home gardens and farmlands for those traits is possibly linked to different management practices occurring in the land-uses. Although they are both under human management, different practices are done in farmlands and home gardens. The largest *G. kola* trees were found in farmlands. Considering that farmlands are less disturbed than homesteads (Schumann et al., 2010), trees in farmlands might have less pressure such as pruning and debarking than in homesteads and heavy pruning has been shown to negatively affect tree diameter (Kumar et al., 2010; Erkan et al., 2016). Contrary to our findings, Akpona et al. (2015) found no significant difference in trees diameter of shea butter from three land-use types especially parklands, fallows and villages, possibly because trees are not subject to particular management. In comparing fruits and seeds descriptors between the land-use types, fruits and seeds from farmlands were found to be bigger and heavier than those from home gardens. This result may be explained by the fact that farmlands are more fertile than home garden soils. The soil where the trees grow is an important factor that may have affected the morphological traits of the seed and fruit (Assogbadjo et al., 2006). Farmlands are areas where annual crops are actively cultivated. Soil fertilizers originally provided to annual crops also benefit associated trees in farmlands (Aleza et al., 2018). In addition, the findings indicate that dbh, blade length, fruit length, fruit width, husk weight, seed length, seed width and seed weight are the most appropriate traits to discriminate *G. kola* trees among land-use types. Given the degree of variation reported in this study, land-use management may be an important determinant in morphological variability of the species. Selection for improvement of fruit and seed traits would be more effective among trees in farms which recorded the highest values.

Conclusion

This study assessed the variability of tree and fruit morphometry of *G. kola* and tested their differences between home garden and farmland. The observed variability in morphological traits highlights the potential for selection within the species. We also found significant difference between both land uses, with stem diameter, fruits and seeds of the trees being bigger in farmlands possibly due to difference in management practices. Experimental studies are needed to provide better understanding of the species response to different management practices. This morphological study should be completed with amolecular analysis of the intraspecific genetic variation. This would provide insights to define an effective conservation strategy for *G. kola* and would be very useful for the development of breeding programs in order to increase *G. kola* production in Benin.

CONFLICT OF INTERESTS

The authors have not declared any conflict of interests.

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