On-farm management and participatory evaluation of pigeonpea (*Cajanus cajan* [L.] Millspaugh) diversity across the agro-ecological zones of Benin Republic

Géofroy KINHOEGBE (✉ dongeofroy@gmail.com)

University of Abomey-Calavi <https://orcid.org/0000-0002-5598-708X>

Gustave Djèdatin

BIOGENOM Laboratory, Faculty of Sciences and Technology of Dassa (FAST-Dassa), National University of Sciences Technologies Engineering and Mathematics of Abomey (UNSTIM)

Laura Estelle Yêyinou Loko

Laboratory of Applied Entomology, FAST-Dassa, UNSTIM

Abraham Gnimansou Favi

University of Abomey-Calavi

Aristide Adomou

University of Abomey-Calavi

Clément Agbangla

Laboratory of molecular genetics and genomes analysis, University of Abomey-Calavi

Alexandre Dansi

Laboratory of Biotechnology, Genetic Ressources and Plant and Animal breeding (BIORAVE), FAST-Dassa

Research

Keywords: Benin, On-farm management, Participatory evaluation, Pigeonpea, Preference criteria, Production constraints

Posted Date: March 26th, 2020

DOI: <https://doi.org/10.21203/rs.2.19119/v2>

License: This work is licensed under a Creative Commons Attribution 4.0 International License.

[Read Full License](#)

Version of Record: A version of this preprint was published at Journal of Ethnobiology and Ethnomedicine on May 13th, 2020. See the published version at <https://doi.org/10.1186/s13002-020-00378-0>.

Abstract

Background: Pigeonpea is a multipurpose food legume that contributes to food security in Benin. However, its production declined and some landraces are being threatened with disappearance. For establishment of conservation and breeding programs previous ethnobotanical surveys on pigeonpea were done in Benin but restricted to south and central regions. Knowing that pigeonpea is also grown in northern Benin, and that the varieties cultivated in this region can show agronomic performances, it is therefore important to evaluate the diversity of this legume in this region. However, an exhaustive documentation of pigeonpea diversity grown in Benin Republic are necessary for effective breeding and conservation programs. Therefore, this study aimed to document genetic diversity of pigeonpea, across the agro-ecological zones of Benin Republic for its promotion and valorization. Methods: 500 producers of pigeonpea belonging to thirteen sociolinguistic groups were selected through 50 villages. Data were collected using methods and tools of participatory research appraisal. Folk nomenclatures, taxonomy of pigeonpea and seed system were investigated. The distribution and extent of pigeonpea landraces were evaluated using Four Square Analysis method. A comparative analysis of pigeonpea uses categories, production systems, pigeonpea production constraints, farmers' preference criteria and participative evaluation for existing landraces across agro-ecological zones was done. Result: Folk nomenclature and taxonomy were mainly based on seed coat colour and size. Seven pigeonpea use category were recorded including sacrifice, grain processing and fertilization. The results showed that pigeonpea seed system is informal. Based on seed characteristics, fifteen landraces were recorded with seven new landraces. The Sudano-Guinean zone contained the highest number (11) of landraces. The average number of landraces per village was 2.7. A high rate of landraces threatened with disappearance was observed across the ecological zones. Ten constraints are known affecting pigeonpea production in Benin with pests and diseases as the most important in all agro-ecological zones. This study revealed that pigeonpea cultivation is increasing in the Sudanian zone. Varieties to be produced must be selected on the basis of 11 criteria among them precocity and resistance to pests and diseases, in the three ecological zones and adaptability to any type of soil in the Sudanian zone were the most important. The participatory evaluation revealed the existence of a few performing cultivars. Conclusions: Our results show that to implement a pigeonpea genetic conservation program in Benin, it would be necessary to take into account the diversity, production constraints and criteria of varietal preference, which varied according to agro-ecological zones. In situ and ex situ conservation strategies are important to preserve pigeonpea landraces. Morphological and molecular characterizations of identified cultivars are highly recommended to help select suitable varieties for breeding programs.

Background

Pigeonpea (*Cajanus cajan* [L.] Millspaugh) is a multipurpose food legume, serving as a lifeline to resource-poor farmers in tropical and subtropical regions of Asia, Africa, and Latin America [1]. Pigeonpea is an excellent source of protein (21.7g/100g), dietary fibres (15.5g/100g), soluble vitamins, minerals and essential amino acids [2, 3]. Moreover it is also used in traditional medicines and leaves, flowers, roots;

seeds are used for the cure of bronchitis, sores, respiratory ailments and also acts as an alexeritic, anthelmintic, expectorant, sedative, and vulnerary [4, 3].

In Benin, pigeonpea is highly consumed in the South-East through the Adja cultural area and contribute to the improvement of household incomes [5]. The plant is used for soil conservation and weed management in the fields [6, 7, 5]. Despite the importance of pigeonpea [5], very few research efforts have been undertaken to improve the production of the specie. As a result, the potential yield of pigeonpea is estimated at 2,500 kg/ha, while the yields obtained on farmer's fields is estimated at 620 kg/ha in Benin [8]. This low yield could be due to the lack of improved varieties in Beninese agriculture [9]. Therefore, an exhaustive collection of pigeonpea diversity cultivated at the country level is the base for the development of any varietal improvement program and the implementation of conservation strategy.

Several studies were done on pigeonpea diversity in Benin. However, all previous investigations on pigeonpea in Benin have been restricted to South and Central Benin [9, 10, 11, 12]. These studies reported 7 [11] and 8 [9] pigeonpea landraces with significant difference of diversity across the socio-linguistic groups and decreased production of this legume in Benin. [11]. However there is no data on the state of pigeonpea diversity and production constraints in northern Benin. Whereas past years, pigeonpea landraces were introduced in this region for soil fertility management [13]. In addition, no comparative study on pigeonpea production constraints across different ecological zones in Benin has yet been documented, varietal diversity as well as farmers' varietal preference criteria and their variation throughout ecological zones and sociolinguistic groups have been very little documented. While it is known that understanding the genetic diversity, uses, and distribution of orphan crops is essential in determining what to conserve and where to conserve, for sustainable utilization [14, 15, 16], it is important to dispose a comprehensive collection of pigeonpea genetic resources of Benin and to document all associated ethnobotanical knowledge by extensive survey [9, 11].

Seeds are the lifeblood and foundation of a successful farming and a crucial element in the lives of agricultural communities [15]. The procedures, through which a cultivar is bred, produced, certified, stored, marketed and used which includes all the channels through which farmers acquire genetic materials and in interaction with the commercial seed industry is known as seed system [16]. Thus, the success of crop varieties introduction is tightly linked to the uses, biophysical conditions, the cropping systems in which the crop is integrated which vary across growing areas [10]. Folk taxonomy is a pre-scientific type of naming and classification system rooted in culture [17]. Unlike its scientific counterpart, folk taxonomy is mostly undocumented. Likewise, the Zoological Code of Nomenclature does not regulate it and the resulting names are specific to each culture. As a result, vernacular names have a very local distribution and may change with time because of incidental events and contact with other languages [18]. However, folk taxonomy or traditional classification of crop landraces is essential as these are the basic units that farmers manage, select and use diversity of their crops [11]. So the knowledge of folk nomenclature and taxonomy is very useful for communicating about pigeonpea usage in local communities. Unfortunately, pigeonpea folk taxonomy and nomenclature in Benin is restricted [9, 11]. These information are however vital, among others, for developing seed distribution and establishment of regional varietal map [19].

In developing countries where agriculture is the spearheading of the economy, improved varieties must be developed or simply searched for within the existing diversity. In both cases, a good knowledge of the existing varietal diversity and the agronomic performances of varieties are necessary [20, 21]. Thus, farmers' participation in varietal selection process is determinant of variety adoption [22]. Moreover, documentation and identification of high-performance cultivars based on farmer's varietal preference criteria will provide strategies to overcome constraints affecting pigeonpea production in Benin. Hence, it is important to evaluate the performance of pigeonpea existing landraces under participatory approach to enhance pigeonpea production and productivity contributing thereby to attain food security and reduce poverty.

This study on pigeonpea aimed to: (1) document different landraces local nomenclature and folk taxonomy of pigeonpea grown in Beninese agriculture, (2) compare seeds management and conservation systems of pigeonpea genetic resources and use categories across different ecological zones, (3) compare constraints associated with pigeonpea production and varietal preference criteria across different ecological zones and sociolinguistic groups and (4) evaluate in participatory way the performances of different landraces in relation to agronomic and culinary traits.

Methods

Study area

The study was carried out in Benin. With a population size of 10 008 749 habitants [23], Benin is located in the intertropical zone between parallels 6° 30' North and 12° 30' North latitude, and meridians 1° East and 30° 40' East longitude [24]. With an area of 114,763 km², Benin is limited in the north by the Niger River in the northwest by Burkina Faso, in the west by Togo, in the south by the Atlantic Ocean and in the east by the Nigeria (Figure 1). The Republic of Benin is divided into three ecological zones: the Guinean zone in the South (6° 25' North latitude and 7° 30' North longitude), the Sudano-Guinean zone (7° 30' North latitude and 9° 45' North longitude) in the Central and the Sudanian zone (9° 45' North latitude and 12° 25' North longitude) in the north [25]. The Guinean and Sudano-Guinean zones are both located in moist agro ecological zone characterized by a subequatorial bimodal climate with two dry seasons and two rainy seasons. The Guinean zone is characterized by an annual rainfall varying between 1200 and 1500 mm/year. The temperature ranges from 24 to 30 °C. The Sudano-Guinean zone annual rainfall varies from 1100 to 1300 mm/year (Table 1). The temperature in this zone varies between 25 and 34 °C. The Sudanian zone is located in the semi-moist agro ecological zone characterized by a unimodal climate pattern with one rainy season and one dry season. The annual rainfall varies between 900 and 1100 mm/year while the temperature ranges from 21 to 35 °C [25] (Table 1).

After an exploratory study in agricultural research institutions, visits to local and urban markets, discussion with farmers and sellers, surveyed villages were selected based on the pigeonpea production, their accessibility and the manner to cover maximum of sociolinguistic groups. A total of 50 were selected and included in the survey (Figure 1).

Data collection

Surveys were done using methods (group discussions, individual interviews and field visits) and tools (questionnaires) of participatory research appraisal following Dansi et al. [26].

Focus groups

In each village, groups of 15 to 28 farmers were identified and brought together with the help of administrative and/or local authorities (village chief, farmers' associations, etc.). Interviews were conducted with the help of local translators to facilitate discussions [27]. Prior to the meeting, farmers were requested in advance to bring samples of pigeonpea landraces they cultivate or knew about. After a brief presentation of the objectives to the farmers, they were asked to list, in vernacular names all pigeonpea' landraces in cultivation, in the village. The distribution and extent of these landraces were evaluated using the participatory method of Four Square Analysis described by Brush [28]. This method allows classifying existing landraces into four groups (produced by many households on large areas, produced by many households on small areas, produced by small households on large areas and produced by few households on small areas). In agreement with the farmers, we agreed that a given landrace cultivated by few households is that grown by no more than 20% of farmers in the context of the village; and landrace cultivated on a small area is that cultivated on not more than 0.25 ha. The participatory evaluation of identified landraces for agronomic and culinary traits was carried out according to Gbaguidi et al. [29]. The considered parameters were the productivity, vegetative cycle, cooking, sensitivity to pests and disease and sensitivity to storage insects. The two-level evaluation method described by Loko et al. [30] was used. In this approach, for a given trait, a landrace is scored 1 when it shows good performance and 0 when it shows the opposite performance. After that, local nomenclature, folk taxonomy and the vegetative cycle of landraces were documented. According to Dansi et al. [31], farmers were asked to list all the constraints associated to pigeonpea production. These constraints were prioritized in group by identifying and gradually eliminating the most severe constraint. In a first step, farmers were asked to identify, among the constraints they have listed, the most critical one. The constraint thus identified is ranked first and is eliminated from the list. The same procedure is repeated until the last constraint was ranked. Secondly, farmers were asked to list all the traits that could interest them and motivate them to continue growing pigeonpea. Using the same approach (gradual elimination of the most important criterion), the identified criteria were then prioritized. The discussions were free, open-ended and without a time limit being set.

Household surveys

After group discussion, ten households were identified for individual interviews, by village. In each household, the person interviewed was chosen based on the common agreement from the host couple according to Christinck et al. [32]. Socio-economic data (gender, educational level, ages, experience, household size), biophysical resources (cropping area, source of labour), cultural practices (Sowing period, plant types, land type, land fertilization or not, pests and diseases management, farming activities) and seed system (number of cultivated landrace, sowing time, crop type, cropping system,

perception about the evolution of pigeonpea cultivation, fertilization, sources of labour, level of intervention in the production chain, pests and diseases incidence and its management and pigeonpea cropping areas were recorded for 2015, 2016 and 2017), the reasons for pigeonpea production; the different pigeonpea use categories; pests' incidence and its management have been documented. According to their incidence pattern, pests incidence was categorized by farmers as negligible (none), low, high and very high. Incidence was categorized as negligible when pest appeared in very low number while it was categorized as low when infestation was responsible for growth retardation and high when infestation involves damage to flowers or pods and very high when infestation are responsible for death of plant.

Data analysis

Descriptive statistics were used to analyze data. To avoid overestimation of pigeonpea diversity in each ecological zone, correspondences between vernacular names were made following seed characteristics (seed color, color pattern, pigmentation color and the seed eyes color) according to Mohammed et al. [33], Ayenan et al. [9] and Zavinon et al. [11]. The frequency of disappearance of each landrace was calculated using the following formula: $FD = (z/Z) \times 100$; Where: z = Number of landraces threatened with disappearance (cultivated by few households on small areas) and Z = total number of landraces identified in the ecological specific zone. In order to facilitate comparisons and to reduce outliers, from one ecological zone to another, reasons for pigeonpea cultivation and different uses (seed or other plant parts) were categorized [34, 35]. The Fidelity Level of each category of reason and use was calculated at the scale of each ecological zone according to Akohoué et al. [14]. The Fidelity Level was calculated according to the formula described by Friedman [36]: Fidelity Level (FL) = $(F/\Sigma F) \times 100$; Where: F = number of respondents for a given modality of use or reason that motivates pigeonpea cultivation and ΣF = sum of the number of respondents for all modalities of use or reason. The constraints were prioritized at the level of each ecological zone and the overall study area on the basis of the average of the following three parameters: the total number of villages in which the constraint is cited (TNV); the number of villages where the constraint is the major one or ranked first (MAC); the number of villages in which the constraint was classified among the principal constraints (PCO) i.e. among the first five. For each of these parameters, a high value indicates an importance for the constraint. Thus, the importance of the constraint is determined by the formula described by Dansi et al. [30]: $IMC = (NTV + MAC + PCO) / 3$. The same approach was used to rank farmers' varietal preference criteria. To compare socio-economic data reported in percentage of responses or in average (gender, educational level, ages, experience, household size), biophysical resources (cropping area, source of labour), cultural practices (Sowing period, plant types, land type, land fertilization or not, pests and diseases management, farming activities) and seed system

(number of cultivated landrace, sowing time, crop type, cropping system, perception about the evolution of pigeonpea cultivation, fertilization, sources of labour, level of intervention in the production chain, pests and diseases incidence and its management and pigeonpea cropping areas recorded for 2015, 2016 and 2017) from one ecological zone to another, Analysis of Variance (ANOVA) and Tukey test was

used for quantitative variables using Minitab 16 Software while the bilateral Z test was used for qualitative variables, using Statistica 7.1 Software. For a given incidence modality of pests' incidence on pigeonpea yield (none, low, average, high and very high), percentage of responses was compared from one ecological zone to another by using bilateral Z test. In order to determine a potential significant change in the cropping area from 2015 to 2017, Analysis of Variance was conducted at the scale of the study area and within each ecological zone. Before ANOVA, data were log-transformed ($\log(x + 1)$) for variances homogeneity.

Results

Socio demographic characteristics of respondents

In total 500 pigeonpea producing households including 190 in the Guinean zone, 200 in Sudano-Guinean zone and 110 in the Sudanian zone were surveyed. Pigeonpea farmers ranged from 21 to 76 years old with an average of 45.9 ± 9.2 years old. The majority (62.4%) of farmers were men. The majority of pigeonpea farmers were found to be illiterate (43.4%), while 31.6% and 25% were found to have primary and secondary levels of education, respectively. The average household size was 6.4 ± 2.1 members (ranging from 3 to 11 members). The experience year old was 15 ± 8 years, on average (Table 2).

Significant differences in age of the surveyed pigeonpea farmers were observed across ecological zones. On average, farmers in the Guinean zone are older (48.7 years against 44 years) and more experienced than those of Sudano-Guinean zone (18.4 years of experience against 16.5). The number of farmers with none, primary and secondary level of education varied between ecological zones.

Local nomenclature

Across the thirteen sociolinguistic groups surveyed in the study area, 50 different pigeonpea local names were recorded in the local dialects. Referring to the various vernacular names identified, the generic name of pigeonpea varied according to sociolinguistic group and ecological zones (Table 3).

In the Guinean and Sudano-Guinean zones, pigeonpea is called, Hounkoun, Kloué or Klouékoun referring to Cowpea, by farmers belonging to Fon and Mahi sociolinguistic groups while in the Guinean and Sudanian zones, pigeonpea is called, Otili in reference to a pod-producing tree, by farmers belonging to Nago and Dendi sociolinguistic groups. However, Bariba and Peulh sociolinguistic groups designated pigeonpea by Wotiri in reference to a pod-producing erected tree. Moreover, in the Guinean zone, farmers belonging to Holly and Yoruba sociolinguistic groups designated pigeonpea by Otini. Pigeonpea is called Ekloui or Kloui by Adja sociolinguistic group. In Sudano-Guinean zone, pigeonpea is called, Colo (meaning is unknown to farmers) by Idaasha sociolinguistic group while pigeonpea is called Tissi Tounan and Itoun by Biali and Somba sociolinguistic groups respectively, referring to a cowpea.

Folk taxonomy

In the study area, 5 criteria were used by farmers to designate pigeonpea. The great majority of names (90.7%) given to pigeonpea have a meaning. More than half pigeonpea vernacular names correspond to morphological aspect (71%) of seeds. Such as seed coat colour (85.5%), seed coat and eyes colour (9.2%), seed size (1.3%), seed coat colour and size (4%). Plant type (3.7%), seed origin (8.4%), vegetative cycle (10.3%) and referring to cowpea (3.7%) were also among criteria used by farmers to name pigeonpea (Table 4).

The folk taxonomy of pigeonpea has a hierarchical structure with two hierarchy levels as found in several sociolinguistic groups (Adja, Bariba, Fon, Holly, Idaasha, Mahi, Nago, Peuhl and Yorouba). For example, in the Adja sociolinguistic group, the generic name of pigeonpea Ekloui or Kloui is subdivided into 5 infra-specific pigeonpea taxa (*Ekloui djou*, *Ekloui koudji*, *Ekloui ri*, *Ekloui wlanwlan*, *Ekloui wliwlito*). In the Fon sociolinguistic group, the generic name of pigeonpea Klouékoun is subdivided into 6 infra-specific pigeonpea taxa (*Klouékoun vòvò*, *Klouékoun wéwé*, *Klouékoun wéwé tété*, *Klouékoun wéwé noukoun vòvò*, *Klouékoun wéwé noukoun wiwi*, *Klouékoun wlanwlan*). While in the Bariba sociolinguistic group, the generic name of pigeonpea Wotiri is subdivided into 4 infra-specific pigeonpea taxa (*Wotiri gbika*, *Wotiri goukorou*, *Wotiri wonka*, *Wotiri souan*).

Diversity of cultivated pigeonpea landraces

Based on seed characteristics, fifteen pigeonpea landraces were identified in the study area (Figure 2). At village level, the number of pigeonpea landrace ranged from 1 to 5 with an average of 2.7 ± 1 . The highest number of landraces (5) per village was reported at Ouèssènè in the department of Alibori. At the household level, the number of pigeonpea landrace held by producers ranges from 1 to 3 with an average of 1.3 ± 0.5 . Seventy two point two (72.2%), 27.6% and 0.2% of the producers cultivated 1, 2 and 3 landraces respectively. The highest number of landraces (3) per household was reported at Ouèssènè in the department of Alibori and maintained by only one producer. The Sudano-Guinean zone contained the highest number of landraces followed by the Guinean and Sudanian zones (11, 9 and 7 landraces respectively) while the highest number of landraces (5) per village and per household (3) was recorded in the Sudanian zone.

Distribution and extent of pigeonpea landraces

Within each ecological zone, the production was limited to specific districts and departments. In the Guinean zone, the production was restricted to the districts of Adja-Ouèrè, Kétou and Pobè in the department of Plateau and the districts of Aplahoué, Klouékanmè and Lalo to the department of Couffo. In the Sudano-Guinean zone, pigeonpea is cultivated in the districts of Dassa-Zoumè, Ouèssè, Savalou and Savè in the department of Collines and the districts of Covè, Djidja, Zakpota and Zangnannado in the department of Zou. Lastly, in the Sudanian zone, pigeonpea is cultivated in the districts of Bembèrèkè and Kalalé in the department of Borgou and the district of Gogounou in the department of Alibori. The Four Squares Analysis revealed that in the Sudanian zone, among the 9 landraces presents, 1 (*Klouékoun wéwé noukoun vòvò* (Mahi and Fon sociolinguistic groups)) is cultivated by many households on a large area, 1 (*Otili founfoun kéké* (Idaasha sociolinguistic group)) by few households on large area while the

7 remaining ((*Ekloui djou* (Adja sociolinguistic group), *Wlétchivé kloui* (Adja sociolinguistic group), *Carder ekloui* (Adja sociolinguistic group), *Otili founfoun lakoun* (Idaasha sociolinguistic group), *Klouékoun wéwé tété* (Mahi sociolinguistic group), *Otili kpoukpa* (Nago sociolinguistic group) and *Klouékoun vòvò* (Fon and Mahi sociolinguistic groups)) are produced by few households on small area. In the Sudano-Guinean zone, *Klouékoun wéwé nounkoun wiwi* (Mahi and Fon sociolinguistic groups) is cultivated by many households on large area, *Klouékoun wéwé tété* (Mahi sociolinguistic group) and *Otili founfoun kékéle* (Idaasha sociolinguistic group) are cultivated by few households on large area, and *Wlétchivé kloui* (Adja sociolinguistic group) and *Klouékoun wlanwlan* (Fon sociolinguistic group) by many households on small area. *Klouékoun wéwé nounkoun wiwi* (Mahi and Fon sociolinguistic groups), *Otini kpoukpa* (Holly sociolinguistic group), *Colo kpikpa* (Idaasha sociolinguistic group), *Otili founfoun lakoun* (Idaasha sociolinguistic group), *Otili kpoukpa* (Nago sociolinguistic group) and *Klouékoun vòvò* (Fon and Mahi sociolinguistic groups) are cultivated by few households on small area. In the Sudanian zone, 2 landraces ((*Klouékoun wéwé nounkoun wiwi* (Mahi and Fon sociolinguistic groups) and *Otili founfoun kékéle* (Idaasha sociolinguistic group)) are cultivated by many households on large area while 1 landrace ((*Klouékoun wlanwlan* (Fon sociolinguistic group)) is cultivated by few households on large area, 4 landraces ((*Ekloui djou* (Adja sociolinguistic group), *Wotiri wonka* (Bariba sociolinguistic group), *Wotiri souan* (Bariba sociolinguistic group) and *Klouékoun vòvò* (Fon and Mahi sociolinguistic groups)) are cultivated by few households on small area. Thus, in the Guinean zone, 7 landraces are threatened with disappearance, 6 in the Sudano-Guinean zone against 4 in the Sudanian zone. Where landraces are threatened with disappearance, the frequency of disappearance varied between 50 and 100% (Table 5).

The distribution analysis revealed that the *Otini kpoukpa* (Holly sociolinguistic group), *Colo kpikpa* (Idaasha sociolinguistic group) and *Klouékoun wéwé nounkoun wiwi* (Mahi and Fon sociolinguistic groups) were specific to the Sudano-Guinean zone; *Wotiri souan* (Bariba sociolinguistic group) and *Wotiri wonka* (Bariba sociolinguistic group) specific to the Sudanian zone while *Carder ekloui* (Adja sociolinguistic group) was specific to the Guinean zone while *Klouékoun wéwé nounkoun wiwi* (Mahi and Fon sociolinguistic groups), *Otili founfoun kékéle* (Idaasha sociolinguistic group) and *Klouékoun vòvò* (Fon and Mahi sociolinguistic groups) were cosmopolitan for the three ecological zones. Landraces named *Wlétchivé kloui* (Adja sociolinguistic group), *Otili founfoun lakoun* (Idaasha sociolinguistic group), *Klouékoun wéwé tété* (Mahi sociolinguistic group) and *Otili kpoukpa* (Nago sociolinguistic group) were present in the Guinean and Sudano-Guinean zones, *Ekloui djou* (Adja sociolinguistic group) in the Guinean and Sudanian zones while *Klouékoun wlanwlan* (Fon sociolinguistic group) was present in the Sudano-Guinean and Sudanian zones.

Reasons for pigeonpea production and uses category

Our study revealed that pigeonpea is produced for three main reasons depending on the ecological zones (Table 6).

In the Guinean and Sudano-Guinean zones, nutritional value is the main source of motivation while in the Sudanian zone the land fertilizing power is the main source of motivation. The third reason is the market

value. The different pigeonpea uses categories were mainly concentrated on grains. Based on their fidelity level, pigeonpea is more used in medicine in the Guinean (FL = 19.5%) and Sudanian (FL = 23.9%) zones. According to farmers, boiled leaves are used in oral route to treat malaria. Also, the decoction of the leaves is used in bath to treat measles and is also used as an antibiotic to treat mouth's sores or tooth decay. The roots, when chewed, prevents the rise of snake venom, in the case of snake bite. Use of pigeonpea grains as an offering for food or symbolic purposes and in sacrifice to divinity is specific to the Sudano-Guinean zone and only restricted to Holly and Nago sociolinguistic groups. While grain processing into donuts is specific to Guinean (FL = 4.3%) and Sudano-Guinean (FL = 2%) zones and only restricted to Holly and Adja sociolinguistic groups. In these zones, pigeonpea are roasted and reduced to flour to sprinkle sauces as nutritional supplement by the first one sociolinguistic group or to make donuts by the second one. Consumption, weed control and land fertilization are common to all three ecological zones (Table 6).

Cultural practices

Pigeonpea was considered as an annual plant by most of surveyed farmers (93.2%). Only 6.2% of farmers considered this legume as a perennial plant. For the last one, plant is left in the field and is harvested the following year. The main pigeonpea farming activities included: ploughing, sowing, weed control, pod harvest, pod plugging and winnowing. Seeding and weed control were practiced by all the farmers. Pigeonpea is sown between April, May, June (73.6%) in intercropping with other seasonal crops (82.8%) or in pure stand (17.2%). Three sources of labour were observed. For farming activities, 13.2% of farmers used family labour, 73% combined family and friends labour while 13.8% used a combination of family, friends and jobber labour (Table 7).

Activities such as land fertilization was never practiced by farmers included in this study while only 14% of farmers included in this study used pesticide. The average grain yield in farmers' fields was estimated at 553.4 ± 36.3 kg/ha. According to farmers, during the three last years, Sudano-Guinean zone were the largest cropping area followed by the Guinean zone while farmers in the Sudanian zone produced pigeonpea on a small cropping area (Table 7). Sowing was more realized between April, May and June in the Guinean and Sudano-Guinean zones (97.9% and 91% respectively) whereas it was more realized between June, July and August in the Sudanian zone (68.2%). Intercropping with other seasonal crops such as maize and millet was specific to Guinean (100%) and Sudano-Guinean (98.5%) zones while pigeonpea was more cultivated in pure stand in Sudanian zone (75.4%). Family and friends were the main source of labour for various farming activities in the Guinean and Sudano-Guinean zones (87.9% and 61.5% respectively) while family members (49.3%) was the main source of labour in the Sudanian zone. Our result revealed that the average pigeonpea yield in the Sudanian zone is lower (522.3 ± 44 kg/ha) compared to the Guinean and Sudano-Guinean zones (557.5 ± 15.9 kg/ha and 566.6 ± 35.8 kg/ha respectively).

Seed system

Different sources of seed were mentioned by farmers. Previous harvest (60.2%) is the main source of seed. Other sources are: Borrowing of seeds from friends (22%) and local market (17.8%). After each harvest, 67.8% of farmers stored seeds until scarcity at market or for the following season while 32.2% of them sold seeds in local markets. Comparing seed system between ecological zones, previous harvest was the main source of seed in the Guinean and Sudano-Guinean zones (70% and 62.9% respectively). Borrowing of seeds from friends is the main source (50.4%) in Sudanian zone. After each harvest, farmers stored more grains in the Guinean and Sudano-Guinean zones (70% and 84% respectively) while they were more immediately sold in Sudanian zone (65.5%) (Table 7).

Pigeonpea production constraints

In total, 10 constraints were identified as affecting pigeonpea production. The long vegetative cycle followed by pests and diseases and rainfall irregularity were considered to be the major constraints (Table 8). According to farmer's descriptions, low productivity ranked seventh among the constraints followed by the sensitivity to storage insects. All these constraints have been reported in the three ecological zones. However, their relative importance varied from one zone to another. The most important constraint in the Guinean and Sudano-Guinean zones was the long vegetative cycle. Sensitivity to pests and diseases ranked second. In the Sudanian zone pests and diseases ranked as the most important constraint. Soil poverty ranked second (Table 8).

Incidence of pests on pigeonpea yield and control methods

The incidences of pests and diseases on farmer's field were as follows: low in Guinean and Sudano-Guinean zones (52.6% and 42.5% respectively); high in Sudanian zone (81.8%) (Table 9). As result, farmers reported growth retardation and damage to flowers or pods respectively. Control method was only reported in the Sudanian zone (63.7%). Three reasons justified the non-control of pests: high price of pesticides (49.6%), risk of intoxication (29.6%) and lack of sprayers (20.8%).

Evolution of pigeonpea production in Benin

Overall, the majority of farmers (69.4%) has reported a decrease of pigeonpea production in Benin. This downward trend was the fact to the Guinean and Sudano-Guinean zones (75.79 % and 85.5% respectively). In these zones, the decrease in cropping area is highly significant ($p \leq 0.001$). Indeed, the average of cropping area was 0.9 ± 0.2 ha in 2015, 0.8 ± 0.1 ha in 2016 and 0.5 ± 0.1 ha in 2017, in the Guinean zone (Table 7). Similarly, in the Sudano-Guinean zone, average cropping area was 1.3 ± 0.8 ha in 2015, 0.9 ± 0.4 ha in 2016, 0.7 ± 0.3 ha in 2017, in the Sudano Guinean zone (Table 7). In contrary, in the Sudanian zone, pigeonpea cultivation is increasing (70.91%). In this zone, the increasing of cropping area is highly significant ($p \leq 0.001$). The average cropping area was 0.3 ± 0.1 ha in 2015, 0.4 ± 0.1 ha in 2016 and 0.4 ± 0.1 ha in 2017 (Table 7). This increasing is due to the fertilizing power of the plant (89.1 %) and weeds control (10.9%).

Farmers' preference criteria of pigeonpea

Through the study area, 11 criteria depending on the ecological zones and different sociolinguistic groups underlined the choice of pigeonpea varieties to be cultivated by farmers. Farmers perceived precocity, resistance to pests and diseases, short cooking time, adaptability to any types of soil, good taste and high productivity as the most important preferred traits. (Table 10).

In Guinean and Sudano-Guinean zones farmers have strong tendency for early maturing (precocity) and resistant to pests and diseases pigeonpea varieties while in the Sudanian zone, farmers preferred resistant to pests and diseases and adaptable to any type of soil pigeonpea varieties (Table 10). Precocity appeared at in front of the criteria for all sociolinguistic groups except Nago sociolinguistic group for whom adaptability to any type of soil was the first criterion. Farmers belonging to Bariba sociolinguistic group preferred varieties with mature early, resistant to pests and diseases; with short cooking time; show adaptability to any type of soil and have good taste (Table 11).

In addition to Bariba sociolinguistic group's preferred traits, farmers belonging to Boo sociolinguistic group showed strong tendency to pigeonpea varieties cultivable at any time of the year and resistant to storage insects. Dendi sociolinguistic group preferred varieties with high productivity and cultivable at any time of the year and Peuhl sociolinguistic group preferred high productive and resistant to storage insects pigeonpea varieties. Precocity, resistance to pests and diseases, short cooking time and adaptability to any type of soil were farmers belonging to Yoruba sociolinguistic group preferred traits.

Participatory evaluation of pigeonpea landrace grown in Benin

According to farmers, none of the landraces identified simultaneously in the three ecological zones is performing for a given character simultaneously in the three ecological zones (Table 12). Moreover, no landrace is performing simultaneously for all 5 evaluated traits. Nevertheless, *Carder ekloui* (Adja sociolinguistic group) specific to Guinean zone combined 4 good performances (high productivity, short cooking time, resistance to pests and diseases, resistance to storage insects). *Carder ekloui* (Adja sociolinguistic group) and *Otili founfoun kékéle* (Idaasha sociolinguistic group) showed high productivity in Guinean and Sudano-Guinean zone but showed low productivity in the Sudanian zone however these two landraces, showed resistance to pests and diseases. *Klouékoun vòvò* (Fon and Mahi sociolinguistic groups) showed high productivity, short cooking time, resistance to pests and diseases, resistance to storage insects and short vegetative cycle in Guinean and Sudano-Guinean zone, but showed low productivity and susceptibility to pests and diseases in the Sudanian zone (Table 12).

Discussion

Our study showed that pigeonpea generic names varied according to sociolinguistic group and ecological zones. Our findings are similar to those of Ayenan et al. [9] and Zavinon et al. [11] in Southern Benin. However, pigeonpea is designated by the same generic name by farmers belonging to different sociolinguistic group in the same ecological zone or different ecological zones. This convergence of generic name within different sociolinguistic groups could be explained by the fact that these groups could have common origins or cohabitation could have facilitated the transfer of knowledge over time. In

addition, based on the generic names meanings, farmers across sociolinguistic groups within the three ecological zones recognized pigeonpea referring to cowpea. This suggests that farmers don't have a good knowledge of the botanical systematic of pigeonpea. There is therefore no link between folk nomenclature and the scientific classification regarding to pigeonpea. Knowing that it could have correspondence between folk nomenclature and scientific classification of the species [37], our findings are contrary to those of Akohoué et al. [14] on Kersting's groundnut in Benin. However, the hierarchical characterization of pigeonpea folk taxonomy was similar to that observed by Loko et al. [38] on common bean and reflects the high diversity level of pigeonpea in the surveyed sociolinguistic groups. Our finding in Adja sociolinguistic group infra-specific pigeonpea taxa was contrary to those of Ayenan et al. [9] and Zavinon et al. [11] who distinguished respectively 2 and 3 infra-specific pigeonpea taxa. However, local names do not necessarily reflect the genetic history of landraces because different names may be given to identical seeds of landraces or a single name may apply to heterogeneous crops [39]. Such a situation may contribute to under or over-estimate the diversity within species [40, 25, 41, 9]. So to avoid redundancies and optimizing the efficient conservation and sustainable use of pigeonpea, it is important to conduct morphological and molecular characterizations to avoid redundancies and establish equivalence between the local names [28, 42, 43].

Farmers used morphological aspect of seeds (coat colour, seed eyes colour, and seed size), plant type, seed origin and vegetative cycle for folk varieties' identification. These criteria of pigeonpea classification and identification are among the descriptors of *C. cajan* recommended by IBPGR and ICRISAT [44] and used by many authors in morphological characterization of this legume. Our study revealed that morphological aspect of seeds (in particular the seed coat colour) was the predominant criterion used by farmers to classify and to identify pigeonpea landraces. The main reason is that seed coat colour is unique to each landrace while other traits may be commonly shared [14]. However our finding was contrary to those of Manyasa et al. [45] who reported pigeonpea seed size and maturity as the most important criteria used by farmers in Ugandan. However, similar observations were reported by Esan and Ojemola [46] in Nigeria, Ayenan et al. [9] and Zavinon et al. [11] in Southern and Central Benin and suggested that selection based on morphological aspect of seeds will have a definite role in the framework of on-farm conservation of this legume in Benin.

According to Ayenan et al. [9] and Zavinon et al. [11] respectively eight and seven pigeonpea landraces were recorded in Benin. In our study, we recorded fifteen pigeonpea landraces based on seed characteristics difference. The seven new landraces are the *blackish seeded landrace* called *Otini kpoukpa* (Holly sociolinguistic group), the *brown seeded landrace* called *Colo kpikpa* (Idaasha sociolinguistic group), the *cream with black eye seeded landrace* called *Klouékoun wéwé nounkoun wiwi* (Mahi and Fon sociolinguistic groups), the *cream seeded landrace* called *Klouékoun wéwé tété* (Mahi sociolinguistic group), the *light red seeded landrace* called *Otili kpoukpa* (Nago sociolinguistic group), the *purple and mottled seeded landrace* called *Wotiri wonka* (Bariba sociolinguistic group) and the *red and mottled seeded landrace* called *Wotiri souan* (Bariba sociolinguistic group). Given that, previous studies did not take into account the entire production area as insignificant as it may seem, a part of the existing pigeonpea landraces in Benin was left out. This finding suggests that extent of the study area affects

species richness [47, 14]. Thus a study which has as one's ambition to better reflect existing diversity of cultivated species should not be restricted to only the major production areas of the species.

Our results revealed that pigeonpea diversity at on-farm level was specific to ecological zones. In fact, the same landrace didn't have the same distribution and extent across ecological zones. For instance, *Otili founfoun kékélé* (Idaasha sociolinguistic group) was cultivated by few households on large area in the Guinean and Sudanian-Guinean zones while it was cultivated by many households on large area in the Sudanian Zone. This practice involves an indirect selection of some of landraces in certain ecological zones while it promotes a gradual disappearance of another one. Hence, conservation strategy should be defined for landraces threatened with disappearance according to their ecological zones. Thus, each ecological zone could be favorable candidate for in-situ conservation of pigeonpea genetic resources in Benin. The highest number of landraces per village and per household was recorded at Ouèssèné in the department of Alibori in the Sudanian zone. Therefore, Sudanian zone becomes important for the conservation of pigeonpea genetic resources in Benin and confirmed the fact that each ecological zone could be favorable candidate for in-situ conservation of pigeonpea genetic resources as suggested previously.

The fertilizing power of pigeonpea as main reasons for producing this legume reported in present study is not surprising because pigeonpea has a significant position in dry land farming systems especially adopted by small and marginal farmers in many parts of the world by fixing nitrogen, flexibility for mixed cropping or inter crop [48, 49]. The use of pigeonpea leaves to treat various diseases such as malaria corroborates the observations made by Ayenon et al. [9] and Zavinon et al. [11] in Benin and those of Aiyeloja and Bello [50] and Oladunmoye et al. [51] in Nigeria. Also, the use of pigeonpea as weeds control has been reported by several authors in Benin [52, 53, 5]. However, pigeonpea roots utilization in prevention of snake venom rising has not been reported elsewhere. Also, grain processing into donuts has not yet been reported by previous studies. Unfortunately, this technological ability of pigeonpea is weakened by its oil retention. Thus, this technological ability of pigeonpea must be explored and improved, like the soybean's transformation into cheese, in Benin. This will help in malnutrition reduction in rural populations and could contribute to the in situ conservation of the existing pigeonpea diversity. Moreover, the use of pigeonpea grains as an offering for food or as symbolic purposes and in sacrifice to divinity has not yet been reported by previous work. All these findings are found to be sociolinguistic groups and ecological zones-dependent and suggest that pigeonpea farmers, in Benin do not have the same knowledge on the use of pigeonpea. However, specific knowledge relative to the plant part uses might be kept and transmitted within communities in some areas as a result of vertical knowledge transmission [54, 14]. Knowing that integrating cultural practices of local communities permit an efficient on farm conservation [55, 38], this specific use category of pigeonpea genetic resource show the potentiality of cultural approach for the conservation of this legume in Benin.

Our study revealed that in the Sudanian zone, pigeonpea cultivation is increasing while it is decreasing in the Guinean and Sudano-Guinean zone. Our findings in the Guinean and Sudano-Guinean zone corroborate those made by Zavinon et al. [11]. In fact, the productivity of the smallholder farming system

in the Sudanian zone is under threat due to soil fertility decline [56]. Research in many parts of Africa including Benin have showed that legumes have the potential to sustain soil fertility in smallholder farming systems [57, 58, 49]. Thus, thanks to the project "Protection and Rehabilitation of Soils to Improve Food Security (ProSOL)" of the German Federal Ministry for Economic Cooperation and Development (BMZ), an integrated soil fertility management (GIFS) through a maximization of use of different organic sources of fertilizers such as pigeonpea was initiated in 2015. This project allowed, in this area, the popularization of pigeonpea by using its fertilizing power. This finding support the fact that Sudanian zone is important for the conservation of pigeonpea genetic resources in Benin.

As reported by Ayenan et al. [10] and Zavinon et al. [12], our study showed that pigeonpea seed system in Benin is informal. Similar observations were made on pigeonpea in Tanzania [59] and in India [15]. This informal seed system has the advantage to facility seed exchanges among farmers and among villages [16]. However, marketed seeds must deserve attention while knowing that seed acquisition from market does not guarantee genetic purity [60]. It is so important to make available to farmers, good quality seeds in order to increase pigeonpea productivity [60, 10]. At on-farm level, the association of pigeonpea with other crops has yet been reported in others countries such as Uganda [45] and Kenya [61]. So, after each harvest, the great majority of farmers stored seeds until scarcity at market before selling them. However, farmers in Sudanian zone sold immediately their seeds that help resolving urgent problems such as children education. As a result, pigeonpea is an essential source of household income and contribute to poverty reduction in Benin as reported by Dansi et al. [5].

In Benin, many factors negatively affect pigeonpea production. Long vegetative cycle followed by pests and diseases were the main constraints affecting pigeonpea production. Indeed, african pigeonpea were characterized by the late maturity [62, 12]. According to farmers theses genotypes cultivation in sole crop occupies land witch could be used for other crops. Our results joined those of Ayenan et al. [10] and Zavinon et al. [12]. Authors reported the lack of improved varieties (long vegetative cycle, low productivity, Insects attack and lack of quality seed) as the main constraint affecting pigeonpea production in the Guinean and Sudano-Guinean zones of Benin. Moreover, pests and diseases referred as the first one constraint in the Sudanian zone is not surprising. In this zone, pigeonpea was more cultivated on pure land, which facilitated pests' attraction. Our findings confirmed the observations made by Sarkar et al. [49] which revealed that intercropping system minimizes pest and diseases attraction compared to the intercropping system. Farmers in this zone had limited access to pesticides and were most suffering from production loss. Although pests and diseases impact was found to be low in the study area, their presence is the key indicator of the urgent need to develop strategies against these pests. Instead of the use of pesticides, an integrated pest management is recommended, through the combination of biological control based on the use of natural enemies of these pests and genetic control based on the use of tolerant or resistant variety [63, 64, 29].

As it is the case in the majority of leguminous where the attack of storage insects is a major constraint [65], surveyed farmers reported seeds' attack by storage insects. Farmers reported the use of some toxic products to protect their seeds. A sensitization of farmers or consumers for a purely biological

conservation, as the use of small peppers, is highly recommended, as in the case of Kersting's groundnut [66]. Curiously, low productivity ranked seventh among constraints and suggests that low productivity represents only a small portion of the constraints relative to pigeonpea production. Thus, low productivity could be the direct consequence of the negative effects of other constraints [61]. Therefore, the lack of improved varieties appears as a challenge to pigeonpea production. Thus the availability of improved varieties and their distribution across the different ecological zones according to their specific needs can alleviate pigeonpea production constraints in Benin. Therefore, government should encourage small-scale enterprises to provide farmers with improved seeds.

Farmer preference criteria take an important place in breeding program and facilitate the adoption of improved varieties [40, 11]. Our study revealed that farmers perceived precocity, resistance to pests and diseases, good taste and short cooking time as the most important preferred traits. Similar observation was observed, on pigeonpea by Mergeai et al. [61] in Kenya, Shiferaw et al. [67] in Tanzania, Changaya [68] in Malawi, Ogbe and Bamidele [69] in Nigeria and Ayanan et al. [10] in Southern Benin. All these criteria were correlated with identified constraints. This suggests a veritable link between these two parameters as reported by Odjo et al. [70] on Rice. The precocity as criterion is important for farmers because short vegetative cycle varieties should certainly encourage them to produce pigeonpea. Indeed, in the global climatic context where changes are noticeable, early varieties will provide producers the guarantee that pigeonpea plants attain a significant level of vegetative development before the cuts of rain. The high productivity as criterion of varietal choice is also not surprising as it is for any breeders and farmers the most desired criteria [71, 30]. Our findings are however contrary to those of Zavinon et al. [11] for whom, high market value is the main farmers' preference criterion. In fact, the high market value cannot appear at the first rank of preference criteria because this criterion could only be the result of the adoption of an improved variety for one or the other of the criteria. Our study revealed that preference criteria varied across different sociolinguistic groups. However, convergence in preference criteria between certain sociolinguistic groups was observed. This could be explained by the cultural links and the intensive knowledge's exchange between these sociolinguistic groups or due to the common origin of these sociolinguistic groups.

For a given character, the same landrace didn't have the same performance, from one ecological zone to another. For instance, the landrace called *Otili founfoun kékélé* (Ikaasha sociolinguistic group) perceived by farmers as having high productivity in the Guinean and Sudano-Guinean zone showed low productivity in the Sudanian zone. This may be due to the variability in soil types, fertility and organic matter turn over, soil nutrient dynamics [72], water regime [73] across ecological zones. In addition, the landrace called *Klouékoun vòvò* (Fon and Mahi sociolinguistic groups) showed high productivity in the Guinean and Sudano-Guinean zone but low productivity in the Sudanian zone. Thus, as mentioned, variability in soil types, fertility and organic matter turn over, soil nutrient dynamics or water regime justifies these agronomical differences. *Carder ekloui* (Adja sociolinguistic group) only identified in the Guinean zone must deserve attention. This cultivar combined four good performances (high productivity, short cooking time, resistance to pests and diseases, resistance to storage insects), according to farmers. Thus, it appears as a promising cultivar. Unfortunately, this cultivar is threatened with disappearance.

There is urgent need to process to an ex-situ as well in situ conservation to preserve this cultivar and all those threatened with disappearance. All identified cultivars in the current study must however be tested for their referred performance according to farmers. Thus, morphological and molecular characterizations are highly recommended to select suitable cultivars for breeding programmes. Thereafter, association mapping of candidates' genes/QTLs for desirables traits can be done and used in future marker-assisted breeding programmes. Otherwise breeding of adapted pigeonpea to any type of soil and resistant to pests and disease will be of dual interest for famers in the Sudanian zone. It will enhance pigeonpea's chain value and will also help to restore the fertilizing power of impoverished lands. Waiting, taking into account farmer's preference criteria, the few performing cultivars identified can be used in a varietal exchange programmes to enhance pigeonpea production in Benin.

Conclusions

Our study showed a great varietal diversity of pigeonpea with fifteen landraces identified based on seed characteristics. Seven new landraces were found and some of them were specific to an agro-ecological zone. A highly significant decrease in cropping areas was observed in the Guinean and Sudano-Guinean zones. Several factors including pests and diseases and long vegetative cycle constrain pigeonpea production. Also the absence of performing seeds system was observed through the study area. This study revealed the existence of few performing cultivars through participatory evaluation and some of cultivars are threatened with disappearance. The establishment of an effective seeds system as well as the definition of an effective pest management strategies, breeding or introducing varieties based on farmer's preference criteria could increase pigeonpea production in Benin. Elsewhere, few performing cultivars identified, in the current study, can be used in varietal exchange programs in order to mitigate the effects of identified constraints. Morphological and molecular characterizations of identified cultivars are highly recommended to select suitable cultivars for breeding programs. *In situ* and *ex situ* conservation strategies on the one hand and on the other hand the preservation of traditional knowledge associated to pigeonpea is important to preserve landraces threatened with disappearance and to conserve pigeonpea diversity in Benin.

Abbreviations

p: p value

INSAE: Institut National de la Statistique et de l'Analyse Economique

Declarations

Funding

Not applicable.

Acknowledgments

We express our sincere gratitude to all farmers, chiefs of village, and leaders of farmer groups for their contributions to the success of this study. We would like to acknowledge the technical support of Falil BANI OROU KOUMA during the prospection and collection of cultivars.

Availability of data and materials

Raw and treated data generated during study are available from the corresponding author on reasonable request.

Authors' contributions

GK designed the study, collected and analyzed data and drafted the manuscript. AGF participated in the interview work. GD, LEYL, AD, CA and AD supervised data analysis and revised the manuscript. All authors read and approved the final manuscript.

Consent for publication

Not applicable.

Competing interests

The authors declare that they have no competing interests.

Ethics approval and consent to participate

Not applicable.

References

1. Chanda Venkata SK, Nadigatla Veera Prabha Rama GR, Saxena RK, et al. Pigeonpea improvement: An amalgam of breeding and genomic research. *Plant Breed.* 2018;00:1-10.
2. Singh L, Gupta SC and Faris DG. Pigeonpea breeding. In: Nene YL, Hall SD and Sheila VK, editors. *The pigeonpea*: CAB International, Cambridge, UK; 1990; p. 375-420.
3. Choudhary H, Singh S, Parvez N, RathoreR, Singh RP. Performance of farmers pigeon pea [*cajanus cajan* L. Millsp.] varieties: opportunities for sustained productivity and dissemination of varieties. *Int J Agric Sci.* 2016; 8(61):3471-3474.
4. Saxena RK, Saxena KB and Varshney RK. Application of SSR markers for molecular characterization of hybrid parents and purity assessment of ICPH 2438 hybrid of pigeonpea [*Cajanus cajan* (L.) Millsp.]. *Mol. Breed.* 2010; 26:371-380.
5. Dansi A, Vodouhe R, Azokpota P, Yedomonhan H, Assogba P, Adjatin A, Loko YL, Dossou-Aminon I, Akpagana K. Diversity of the neglected and underutilized crop species of importance in Benin. *Sci World J.* 2012;Article ID 932947.

6. Versteeg MN, Koudokpon V. Participative farmer testing of four low external input technologies, to address soil fertility decline in Mono province (Benin). *Agr syst.* 1993; 42(3):265-276.
7. Aihou K. Interaction between organic input by *Cajanus cajan* (L.) Millsp. and inorganic fertilization to maize in the derived savanna of the Benin Republic. PhD Thesis, Wageningen University; 2003.
8. Ministère de l'Agriculture de l'Elevage et de la Pêche (MAEP)/Direction de la Programmation et de la Prospective (DPP). Statistique de production du pois d'Angole: Annuaire statistique. Bénin; 2017.
9. Ayenan MAT, Danquah A, Ahoton EL, Ofori K. Utilization and farmers' knowledge on pigeon pea diversity in Benin, West Africa. *J Ethnobiol Ethnomed.* 2017a;13:37.
10. Ayenan MAT, Ofori K, Ahoton LE, Danquah A. Pigeonpea [*Cajanus cajan* (L.) Millsp.] production system, farmers' preferred traits and implications for variety development and introduction in Benin. *Agric. Food Secur.* 2017b;6:48.
11. Zavinson F, Adoukonou-Sagbadja H, Ahoton L, Vodouhê R, Ahanhanzo C. Quantitative Analysis, Distribution and traditional management of pigeon pea [*Cajanus cajan* (L.) Millsp.] Landraces' diversity in Southern Benin. *Eur Sci J.* 2018; 14(9):184-211.
12. Zavinson and Sagbadja. Pigeon pea [*Cajanus cajan* (L.) Millsp] cultivation, its major constraints and ethnobotanical status in Southern Benin *J Agric Crop Res.* 2019; 7(6):95-105.
13. Institute for Advanced Sustainability Studies (IASS). Gestion Durable des Terres : Analyse d'expériences de projets de développement agricole au Bénin. Assogba SCG, Akpinfa E, Gouwakinnou G, Stiem L (ed.) Potsdam, Février 2017.
14. Akohoué F, Sibiya J, Achigan-Dako EG. On-farm practices, mapping, and uses of genetic resources of Kersting's groundnut [*Macrotyloma geocarpum* (Harms) Maréchal et Baudet] across ecological zones in Benin and Togo. *Genet Resour Crop Evol.* 2019;66:195-214.
15. Mula MG, Kumar CVS, Mula RP. Seed system: the key for a sustainable pulse agriculture for smallholder farmers in the dry land tropics 1. In: 23rd PHILARM national convention. Naga City, Camarines Sur, Philippines; 2013.
16. Mula MG. Seed system institutionalization for pulses: a must in the Philippines. In: 1st Philippine Pigeonpea Congress. Batac, Ilocos Norte, Philippines: Mariano Marcos State University (MMSU). 2014; 16-18 December.
17. Mula MG. Seed system institutionalization for pulses: a must in the Philippines. In: 1st Philippine Pigeonpea Congress. Batac, Ilocos Norte, Philippines: Mariano Marcos State University (MMSU). 2014; 16-18 December.
18. Berlin B. Folk systematics in relation to biological classification and nomenclature. *Annu Rev Eco Evol Syst.* 1973;4:259–71.).
19. Zent EL, Zent S, Iturriaga T. Knowledge and use of fungi by a mycophilic society of the Venezuelan Amazon. *Econ Bot.* 2004;58:214–26.
20. Mekbib F. Infra-specific folk taxonomy in sorghum (*Sorghum bicolor* (L.) Moench) in Ethiopia: folk nomenclature, classification, and criteria. *J Ethnobiol Ethnomed.* 2007;3:38.

21. Dias GB, Gomes VM, Moraes TM, Zottich UP, Rabel GR, Carvalho AO, Moulin M, Goncalves LS, Rodrigues R, Da Cunha M. Characterization of *Capsicum* species using anatomical and molecular data. *Genet Mol Res*. 2013;12:6488-6501.
22. Orobiyi A, Dansi M, Assogba P, Loko LY, Vodouhe R, Akouegninou A, Sanni A. Chili (*Capsicum annum* L.) in southern Benin: production constraints, varietal diversity, preference criteria and participatory evaluation. *Int Res J Agr Sci Soil Sci*. 2013;3(4):107-120.
23. Ntare BR, Ndjeunga J, Waliyar F, Kodio O, Echekwu C A, Kapran I, Da Sylva A, Diallo AT, Amadou A, Bissala HY and Sako K. Farmer Participatory Evaluation and Dissemination of Improved Groundnut Varieties in West Africa. International Crops Research Institute for the Semi-Arid Tropics; 2007 p. 33.
24. INSAE. Troisième Recensement Général de la Population et de l'Habitation. Quelques résultats. Institut national de la statistique et de l'analyse économique, Cotonou; 2003. p. 9.
25. Adinci KJ, Akpo Y, Adoligbe C, Adehan SB, Yessinou RE, Sodé AI, Mensah GA, Youssao AKI, Sinsin B, Farougou S. Preliminary study on the tick population of Benin wildlife at the moment of its invasion by the *Rhipicephalus microplus* tick (Canestrini, 1888). *Vet World*. 2018;11(6):845–851.
26. Akoègninou A, van der Burg WJ, van der Maesen LJG. Flore analytique de Bénin. Leiden: Backhuys Publishers; 2006.
27. Dansi A, Adoukonou-Sagbadja H, Vodouhe R. Diversity, conservation and related wild species of Fonio millet (*Digitaria* spp.) in the northwest of Benin. *Genet Resour Crop Evol*. 2010;57:827-839.
28. Loko YL, Adjatin A, Dansi A, Vodouhé R, Sanni A. Participatory evaluation of Guinea yam (*Dioscorea cayenensis* Lam.-*D. rotundata* Poir. complex) landraces from Benin and agro-morphological characterization of cultivars tolerant to drought, high soil moisture and chips storage insects. *Genet Resour Crop Evol*. 2015;62:1181-92.
29. Brush SB. Genes in the Field: on-Farm Conservation of Crop Diversity. Lewis Publishers: Boca Raton. 2000; 3-26.
30. Gbaguidi AA, Dansi A, Loko LY, Sanni A. Diversity and agronomic performances of the cowpea (*Vigna unguiculata* Walp.) landraces in Southern Benin. *Int Res J Agric Sci Soil Sci*. 2013;3(4):121-133.
31. Loko YL, Dansi A, Linsoussi C, Tamo M, Vodouhé R, Akoegninou A, Sanni A. Current status and spatial analysis of Guinea yam (*Dioscorea cayenensis* Lam. -*D. rotundata* Poir. complex) diversity in Benin. *Int Res J Agricult Sci Soil Sci*. 2013;3(7):219-238.
32. Dansi A, Dantsey-Barry H, Agre AP, Dossou-Aminon I, Assogba P, Loko YL, N'Kpenu EK, Kombaté K, Dansi M, Vodouhé R. Production constraints and farmers' cultivar preference criteria of cultivated yams (*Dioscorea cayenensis* - *D. rotundata* complex) in Togo. *IJABPT*. 2013;4(2):191-199.
33. Christinck KVB, Kshirsagar WE, Bramel-Cox PJ. Participatory methods for collecting germplasm: experiences with farmers of Rajasthan, India. *Plant Genet Resour Newsletter*. 2000;121:1-9.
34. Mohammed M, Sowley E, Dakora F. Variations in N₂ fixation of field-grown Kersting's groundnut (*Macrotyloma geocarpum*) landraces in response to inoculation with two *Bradyrhizobium* strains in the northern region of Ghana. *S Afr J Bot*. 2016;100(103):333.

35. Gausset, Q. Ranking local tree needs and priorities through an interdisciplinary action research approach. J Transdiscipl Environ Stud. 2004;3(1):1-17.
36. Hoffman B, Gallaher T. Importance indices in ethnobotany. ERA. 2007;5:201-218.
37. Friedman J, Yaniv Z, Dafni A, Palewitch D. A preliminary classification of the healing potential of medicinal plants, based on a rational analysis of an ethno-pharmacological field survey among Bedouins in the Negev Desert, Israel. J Ethnopharmacol. 1986;16:275-287.
38. Whaanga H, Papa W, Wehi P, Roa T. The use of the Maori language in species nomenclature. JMIC. 2013;2:78-84.
39. Loko LEY, Orobiyi A, Adjatin A, Akpo J, Toffa J, Djedatin G and Dansi A (2018). Morphological characterization of common bean (*Phaseolus vulgaris* L.) landraces of Central region of Benin Republic. J Plant Breed Crop Sci. 2018;10(11):304-318.
40. Van Heerwaarden J, Hellin J, Visser RF, et al. Estimating maize genetic erosion in modernized smallholder agriculture. Theor Appl Genet. 2009;119(5):875-888.
41. Adoukonou-Sagbadja H, Dansi A, Vodouhè R, Akpagana K. Indigenous knowledge and traditional conservation of fonio millet (*Digitaria exilis*, *Digitaria iburua*) in Togo. Biodivers Conserv. 2006;15:2379-2395.
42. Kamau JI, Labeyrie V, Njoroge GN, Wanjoya AK, Wambugu PW, Muthamia ZK, Leclerc C. Dealing with farmers' Ethnolinguistic differences when collecting crop diversity on-farm. Plant Genet Resour. 2017;15(5):400-408.
43. Mudaraddi B, Saxena KB. Molecular diversity based heterotic groups in pigeonpea [*Cajanus cajan* (L.) Millsp.]. Indian J Genet Plant Breed. 2015;75:57.
44. Bareke T, Asfaw Z, Woldu Z, Beth M, Amssalu B. Diversity of common bean (*Phaseolus vulgaris* L., Fabaceae) landraces in parts of southern and eastern Ethiopia. Adv Plants Agric Res. 2018;8(6):449-457.
45. International Board For Plant Genetic Resources (IBPGR) and International Crops Research Institute for the Semi-Arid Tropics (ICRISAT). Rome, Italy and Patancheru, India. Descriptors for Pigeonpea (*Cajanus cajan* (L.) Millsp.); 1993.
46. Manyasa EO, Silim SN, Christiansen JL. Variability patterns in Ugandan pigeonpea landraces. J SAT Agric Res. 2009;7:1-9.
47. Esan and Ojemola. Evaluation of Production Systems, Traditional Knowledge of Pigeon Pea (*Cajanus cajan*) and Risks of Extinction of Pigeon Pea, Jack Bean (*Canavalia ensiformis*) and Lobia Bean (*Lablab purpureus*) in Some Parts of South West Nigeria. JEAL. 2018; 21(4):1-11.
48. Waide RB, Willig MR, Steiner CF, Mittelbach G, Gough L, Dodson SI, Juday GP, and Parmenter R. The relationship between productivity and species richness. Annu Rev Ecol Syst. 1999;30:257-300.
49. Pandit SR, Sharma A, Patil DH and Dodamani BM. Performance of pigeon pea under different sources of nutrients in rainfed conditions of Karnataka. J Food Legumes. 2015;28(2):43-45.

50. Sarkar S, Panda S, Yadav K, Kandasamy P. Pigeon pea (*Cajanus cajan*) an important food legume in Indian scenario-A review. Legume Res. 2018; 402:1-10.
51. Aiyéloja AA, Bello OA. Ethnobotanical potentials of common herbs in Nigeria: A case study of Enugu state. Educ Res Rev. 2006;1:16-22.
52. Oladunmoye MK, Kehinde FY. Ethnobotanical survey of medicinal plants used in treating viral infections among Yoruba tribe of South Western Nigeria. African J Microbiol Res. 2011;5:2991-3004.
53. Atachi P, Dannon EA and Rurema DG. Trap cropping and intercropping of pigeonpea (*Cajanus cajan* L. Millsp.) in pest management of cowpea (*Vigna unguiculata* L. Walp.) in Southern Benin: competing risk and pest status in pod attack. Ann Sci Agron. 2009a; 9(1):1-20.
54. Atachi P, Dannon EA and Rurema DG. Seed-damaging field pests in an intercropping of pigeonpea (*Cajanus cajan* L. Millsp.) and cowpea (*Vigna unguiculata* L. Walp.) in Southern Benin: dynamics of seed attack. Ann Sci Agron. 2009b; 8(2):197-218.
55. Leclerc C, Geo Coppens d'Eeckenbrugge. Social Organization of Crop Genetic Diversity. The $G \times E \times S$ Interaction Model. Divers. 2012;4(1)1-32.
56. O'Neill AR, Badola HK, Dhyani PP, Rana SK. Integrating ethnobiological knowledge into biodiversity conservation in the eastern Himalayas. J Ethnobiol Ethnomed. 2017;13(1):21.
57. Bonou-Zin RDC, Allali K, Tovignan SD, Yabi JA, Houessionon P. Drivers of Farmers' Perception of the Environmental Externalities of Cotton Production Practices in Benin: A Tobit Analysis. JAES.2019;7(2):120-130.
58. Giller KE. Nitrogen Fixation in Tropical Cropping Systems, CAB International Wallingford, UK; 2001.
59. Adjei-Nsiah S, Leeuwis C, Giller KE, Sakyi-Dawson O, Cobbina J, Kuyper TW, Abekoe M and Van Der Werf W. Land tenure and differential soil fertility management practices among native and migrant farmers in Wenchi, Ghana: implications for interdisciplinary action research. NJAS-Wagen J Life Sc. 2004;52(3-4):331–348.
60. Silim NS, Bramel JP, Akonaay HB, Mligo JK, Christiansen JL (2005) Cropping systems, Uses and primary in situ characterization of Tanzania pigeonpea [*Cajanus cajan* (L.) Millsp.] landraces. Genet Resour Crop Evol. 2005; 52:645-654.
61. Saxena KB. Seed production systems in pigeonpea. Patancheru 502 324. Andhra Pradesh, India: Tropics, International Crops Research Institute for the Semi-Arid; 2006.
62. Mergeai G, Kimani P, Mwang A, Olubayo F, Smith C, Audi P, Baudoin JP, Le Roi A. Survey of pigeonpea production systems, utilization and marketing in semi-arid lands of Kenya. Biotechnol Agron Soc Environ. 2001;5:145-53.
63. Kaoneka SR, Saxena RK, Silim SN, Odeny DA, Rao NVPRG, Shemelis HA, Siambi M, Varshney RK. Pigeon pea breeding in eastern and southern Africa: challenges and opportunities. Plant Breed. 2016;135:148-154.
64. Norton GW, Rajotte EG, Gapud V. Participatory research in integrated pest management: Lessons from the IPM CRSP. Agr Human Values. 1999;16:431-439.

65. Eneh OC. Enhancing Africa's environmental management: Integrated Pest Management for minimizing of agricultural pesticides pollution. *Res J Environ Sci*. 2011;5:521-529.
66. Baco MN, Ahanchédé A, Bello S, Dansi A, Vodouhé R, Biaou G, Lescure JP. Evaluation des pratiques de gestion de la diversité du niébé (*Vigna unguiculata*): une tentative méthodologique expérimentale au Bénin. *Cah Agric*. 2008;17:183-188.
67. Assogba P, Dansi A, Dansi M, Ewèdjè E-EBK, Loko YL, Sanni A (2015) Indigenous knowledge and agro-morphological evaluation of the minor crop Kersting's groundnut (*Macrotyloma geocarpum* (Harms) Marechal et Baudet) cultivars of Benin. *Genet Resour Crop Evol*. 635:513-529.
68. Shiferaw B, Silim S, Muricho G, Audi P, Mligo J, Lyimo S, You L and Christiansen JL. Assessment of the adoption and impact of improved pigeonpea varieties in Tanzania. *J SAT Agric Res*. 2005;3:1-7.
69. Changaya AG. Developing of high yielding pigeonpea [*Cajanus cajan*] germplasm with resistance to Fusarium wilt [*Fusarium udum*] in Malawi. PhD Thesis, University of KwaZulu-Natal; 2007.
70. Ogbe FMD and Bamidele JF. Potential of pigeonpea [*Cajanus cajan*] for planted fallow in Edo State, Nigeria. *Asian J. Plant Sci*. 2007;6:490-495.
71. Odjo TC, Dossou-Aminon I, Dansi A and Djengue HW. Diversity, Genetic Erosion and Participatory Evaluation of Rice (*Oryza sativa* L. and *Oryza glaberrima* Steud) Varieties in Benin, *Int. j. curr. res. biosci. plant biol*. 2017;4(4):147-164.
72. Kombo GR, Dansi A, Loko LY, Orkwor GC, Vodouhé R, Assogba P, Magema JM. Diversity of cassava (*Manihot esculenta* Crantz) cultivars and its management in the department of Bouenza in the Republic of Congo. *Genet Resour Crop Evol*. 2012; 59(8):1789-1803.
73. Gao XP, Zou CQ, Fan XY, Zhang FS, Hoffland E. From flooded to aerobic conditions in rice cultivation: consequences for zinc uptake. *Plant Soil*. 2006; 280:41-47.
74. Kreye C, Bouman BAM, Castañeda AR, Lampayan RM, Faronilo JE, Lactaoen A, Fernandez L. Possible causes of yield failure in tropical aerobic rice. *Field Crops Res*. 2009;111:197–206.

Tables

Table 1 Basic information regarding the biophysical characteristics of the surveyed zones

Variables	Guinean zone	Sudano- Guinean zone	Sudanian zone
Altitude (in m)	56- 223	153- 308	214- 609
Annual rainfall (mm)	1200- 1500	1100- 1300	900- 1100
Temperature (°C)	24- 30	25- 34	21- 35
Seasons	Bimodal rainfall regime : 2 dry seasons and 2 rainy seasons	Bimodal rainfall regime : 2 dry seasons and 2 rainy seasons	Unimodal rainfall regime: 1 dry season and 1 rainy season
Dominant soils	Ferrallitic soils	Ferruginous and ferrallitic soils	Concreted or hardened ferruginous soils with small deep
Number of surveyed villages	20	19	11
Surveyed sociolinguistic groups	Biali (Exotic), Somba (Exotic), Fon, Holly, Mahi, Nago, Idaasha	Adja, Fon, Holly, Mahi, Nago, Yoruba	Bariba, Dendi, Peuhl, Yoruba (Exotic), Boo

Table 2 Socio-demographic characteristics of the surveyed pigeonpea producers across agro-ecological zones of Benin

Variables	ZG (n=190)	ZSG (n=200)	ZS (n=110)	Overall (n=500)	Diff
Gender (%)					
Male	56.9 ^a	66 ^a	65.5 ^a	62.4	ns
Female	41.2 ^a	44 ^a	34.6 ^a	37.6	
Education level (%)					
None	56.9 ^a	39 ^b	28.2 ^b	43.4	***
Primary	27.9 ^a	34 ^a	33.6 ^a	31.6	ns
Secondary	15.3 ^c	27 ^b	38.2 ^a	25	***
Age (years)					
Average	48.7 ^a	44 ^b	44.5 ^b	45.9	***
Range	30-69	21-76	26-65	21-76	
Experience (years)					
Average	18.4 ^a	16.5 ^b	6 ^c	15	***
Range	10-45	10-50	3-7	3-50	
Household size (units)					
Average	6.6 ^a	6.1 ^a	6.4 ^a	6.4	ns
Range	3-11	3-11	4-10	3-11	

GZ: Guinean zone; SGZ: Sudano-Guinean Zone; SZ: Sudanean Zone; For the same variable, average that have no common letters are statistically different ($p<0.05$); *** $p\leq 0.001$; ns : non-significant difference at the 5% level.

Table 3 Pigeonpea generic names variation across sociolinguistic groups

Sociolinguistic groups	Designations	Meanings
Adja	Ekloui, Kloui	Common name
Bariba, Peulh	Wotiri	Pod-producing erected tree
Biali	Tissi Tounan	Referring to cowpea
Boo	Blacia	Referring to cowpea
Fon, Mahi	Hounkoun, Kloué, Klouékoun	Referring to cowpea
Holly, Yoruba	Otini	Common name
Idaasha	Colo	Common name
Nago, Dendi	Otili	Pod-producing tree
Somba	Itoun	Referring to cowpea

Table 4 Meaning of pigeonpea vernacular names across study area

Criteria of denomination	% of vernacular names	Vernacular names	Meaning of the vernacular name
Morphological aspect (seed coat colour and size, eyes colour)	71	Colo founfoun, Ekloui koudji, Ekloui ri, Hounkoun wéwé, Klouékoun wéwé, Klouékoun wéwé tété	Cream pigeonpea
		Otili founfoun, Otini founfoun, Wotiri gbika, Wotiri goukorou	
		Ekloui djou, Otini dudu	
		Colo kpikpa, Hounkoun vòvò, Klouékoun vòvò, Otili kpoukpa, Otini kpoukpa, Wotiri souan	Red pigeonpea
		Egblèjin, Ekloui wlanwlan, Klouékoun wlanwlan, Otini tchofiti, Wotiri wonka	Mottled pigeonpea
		Klouékoun wéwé noukoun vòvò,	Cream pigeonpea having red eyes
		Klouékoun wéwé noukoun wiwi	Cream pigeonpea having black eyes
		Otili founfoun lakoun,	Cream pigeonpea having high size
		Otili founfoun kékélé	Cream pigeonpea having small size
		Ekloui wliwlito	Pigeonpea having small size
Seed origin	8.4	Adja klouékoun, Adja kloui	Pigeonpea from Adja
		CA monlikoun	Pigeonpea introduced by CA
		Carder kloui, Carder kloui	Pigeonpea introduced by Carder
		Djidja kloui	Pigeonpea from Djidja
Vegetative cycle	10.3	Yovo loui	Pigeonpea introduced by European
		Bogan	Long vegetative cycle pigeonpea
		Kpédovinon ovo, Kpèkloué	Short vegetative cycle pigeonpea
		Nontchiovi ekloui, Nontchiovi kloui	Orphan pigeonpea
Plant type	3.7	Wlétchivé kloui	Pigeonpea producing twice a year
		Gbomandoui, Ladja kloui	Tall pigeonpea
Belonging to Cowpea	6.5	Wotiri	Pod-producing erected tree
		Itoun, Tissi tounan, Blacia	Referring to cowpea

Table 5 Distribution and extent of cultivated pigeonpea landraces across the ecological zones of Benin

Local names	Seeds characteristics	Distribution and extent			FD
		GZ	SGZ	SZ	
<i>Klouékoun wéwé nounkoun wiwi</i> (Mahi and Fon sociolinguistic groups)	Cream seed coat with black eye	NA	M-S- ^m	NA	100
<i>Klouékoun wéwé noukoun vòvò</i> (Mahi and Fon sociolinguistic groups)	Cream seed coat with red eye and intermediate size	M+S+	M+S+	M+S+	0
<i>Klouékoun wéwé tété</i> (Mahi sociolinguistic group)	Cream seed coat	M-S- ^m	M-S+	NA	50
<i>Wlétchivé kloui</i> (Adja sociolinguistic group)	Cream seed coat and highly mottled	M-S- ^m	M+S-	NA	50
<i>Klouékoun wlanwlan</i> (Fon sociolinguistic group)	Cream seed coat and mottled	NA	M+S-	M-S+	0
<i>Colo kpikpa</i> (Idaasha sociolinguistic group)	Brown seed coat	NA	M-S- ^m	NA	100
<i>Klouékoun vòvò</i> (Fon and Mahi sociolinguistic groups)	Red seed coat	M-S- ^m	M-S- ^m	M-S- ^m	100
<i>Otili kpoukpa</i> (Nago sociolinguistic group)	Light seed coat red	M-S- ^m	M-S- ^m	NA	100
<i>Otini kpoukpa</i> (Holly sociolinguistic group)	Blackish seed coat	NA	M-S- ^m	NA	100
<i>Otili founfoun kékélé</i> (Idaasha sociolinguistic group)	Cream seed coat with red eye and small size	M-S+	M-S+	M+S+	0
<i>Otili founfoun lakoun</i> (Idaasha sociolinguistic group)	Cream seed coat with red eye and high size	M-S- ^m	M-S- ^m	NA	100
<i>Carder ekloui</i> (Adja sociolinguistic group)	Cream seed coat and mottled with high size	M-S- ^m	NA	NA	100
<i>Ekloui djou</i> (Adja sociolinguistic group)	Black seed coat and mottled	M-S- ^m	NA	M-S- ^m	100
<i>Wotiri souan</i> (Bariba sociolinguistic group)	Red seed coat and mottled	NA	NA	M-S- ^m	100
<i>Wotiri wonka</i> (Bariba sociolinguistic group)	Purple seed coat and mottled	NA	NA	M-S- ^m	100
Total		9/15	11/15	7/15	-

M+S+: many households on large areas; M+S: many households on small areas; M-S +: few households on large areas; MS-: few households on small area; GZ: Guinean Zone; SGZ: Sudano-Guinean Zone; SZ: Sudanian Zone; FD: Frequency

of Disappearance; m: landrace threatened with disappearance. $FD = (z/Z)*100$ Where: z = Number of landraces threatened with disappearance (cultivated by few households in small areas) and Z = total landrace identified in the ecological zone; NA: Not Available.

Table 6 Importance of reasons for pigeonpea production and uses category in Benin

Criteria	Variables	GZ		SGZ		SZ	
		n = 190		n = 200		n = 110	
		F	FL	I p	FL	I p	FL
Reasons	Market value	107	37.8	80	29.6	66	24.1
	Nutritional value	176	62.2	190	70.4	98	35.8
	Land fertilizing power	-	-	-	-	110	40.2
	ΣF	283	-	270	-	274	-
Uses category	Consumption	164	34.8	188	38	96	31.9
	Medicine	92	19.5	75	15.2	72	23.9
	Offering	-	-	7	1.4	-	-
	Sacrifice	-	-	5	1	-	-
	Weed control	15	3.2	19	3.8	23	7.6
	Grain processing	20	4.2	10	2	-	-
	Fertilization	181	38.4	191	38.6	110	36.5
	ΣF	472	-	495	-	301	-

GZ: Guinean zone; SGZ: Sudano-Guinean Zone; SZ: Sudanian Zone; n: Number of respondents; FL = Fidelity Level, F = number of respondents for a modality of use or reason that motivates the culture and ΣF = sum of the number of respondents for all modalities of use or reason; FL = Fidelity Level

Table 7 Biophysical resources, cultural practices and seed system across ecological zones

Variables	ZG (n=190)	ZSG (n=200)	ZS (n=110)	Overall (n=500)	diff
Cropping area in 2015 (ha)					
Average	0.9±0.2 ^b	1.3±0.8 ^a	0.3±0.1 ^c	0.9±0.6	***
Range	0.5-1.3	0.5-2.5	0.3-0.5	0.3-2.5	
Cropping area in 2016 (ha)					
Average	0.8±0.1 ^b	0.9±0.4 ^a	0.4±0.1 ^c	0.7±0.3	***
Range	0.5-1	0.5-1.5	0.3-1	0.3-1.5	
Cropping area in 2017 (ha)					
Average	0.5±0.1 ^b	0.7±0.3 ^a	0.4±0.1 ^c	0.6±0.3	***
Range	0.6-0.8	0.5-1.25	0.3-0.8	0.3-1.3	
Source of labour (% of yes)					
Family labour	12.1 ^b	13.5 ^b	49.3 ^a	13.2	***
Family and friends labour	87.9 ^a	61.5 ^b	42.2 ^c	73	***
Family friends and jobber labour	-	25 ^a	8.5 ^b	13.8	***
Seed system (% of yes)					
Seeds of previous harvests	70 ^a	62.9 ^a	46.2 ^b	60.2	***
Seeds of friends	9.2 ^b	10.5 ^b	50.4 ^a	22	***
Market Seeds	20.8 ^a	26.7 ^a	3.4 ^b	17.8	***
Conservation method	3.7 ^a	4.5 ^a	-	3.2	ns
Seed storage	70 ^b	84 ^a	34.6 ^c	67.8	***
Seed purchase	30 ^b	16 ^c	65.5 ^a	32.2	***
Plant type (% of yes)					
Annual plant	92.1 ^b	90.5 ^b	100 ^a	93.2	***
Perennial plant	7.9 ^a	9.5 ^a	-	6.8	ns
Land type (%)					
Intercropping system	100 ^a	98.5 ^b	24.6 ^c	82.8	***
Pure stand	-	1.5 ^b	75.4 ^a	17.2	***
Land, pests and diseases management (% of yes)					
Fertilization	-	-	-	-	ns
Use of pesticides	-	-	63.7	14	***
Sowing period (% of yes)					
April - June	97.9 ^a	91 ^b	-	73.6	***
April - May	2.1 ^a	9 ^b	-	4.4	***
June - August	-	-	68.2	15	***
July - August	-	-	31.8	7	***
Farming activities (% of yes)					
Ploughing	65.8 ^b	83 ^a	72.7 ^b	74.2	***
Sowing	100 ^a	100 ^a	100 ^a	100	ns
Weed control	100 ^a	100 ^a	100 ^a	100	ns
Pod harvest	92.6 ^b	97.5 ^a	87.3 ^b	93.4	***
Pod plugging	84.7 ^b	96 ^a	80.9 ^b	88.4	***

Winnowing	52.1 ^b	17 ^c	74.5 ^a	43	***
Yield (kg/ha)					
Average	557.5±15.9 ^a	566.6±35.8 ^b	522.3±44 ^c	553.4±36.3	***
Range	450-560	550-650	450-560	450-650	

GZ: Guinean zone; SGZ: Sudano-Guinean Zone; SZ: Sudanean Zone; n: Number of respondents; diff: difference; for the same variable, means or percentages that have no common letters are statistically different ($p < 0.05$); *** $p \leq 0.001$; ns : non-significant difference at the 5% level

Table 8 Comparative table of pigeonpea production constraints across ecological zones

Constraints	Overall					Rank per zone			
	NTV	MAC	PCO	Imp	Rank	ZG	ZSG	ZS	
Long vegetative cycle	50	28	48	42	1	1	1	3	
Pests and diseases	48	14	48	36.7	2	2	2	1	
Rainfall irregularity	30	3	25	19.3	3	3	4	4	
Weeding	25	1	23	16.3	5	4	5	6	
Lack of improved varieties	26	-	24	16.7	4	5	3	5	
Storage insects	10	-	7	5.7	8	6	9	8	
Sol poverty	15	3	13	10.3	6	7	8	2	
Harvest and post-harvest work	10	1	4	5	9	8	9	7	
Low productivity	11	-	10	7	7	9	6	6	
Lack of cultivable land	5	-	3	2.7	10	10	7	9	

ZG: Guinean zone; ZSG: Sudano-Guinean Zone; ZS: Sudanian zone; TNV: Total Number of Villages in which the constraint is cited; MAC: Number of villages where the constraint is the major one or ranked first; PCO: number of villages in which the constraint was classified among the principal constraints i.e. among the first five; Imp: Importance

Table 9 Evaluation of pests and diseases impact in pigeonpea production

Evaluation (% of responses)	Variables	Overall (n = 500)	ZG (n = 190)	ZSG (n = 200)	ZS (n = 110)	Diff
Impact on pigeonpea yield	None	12.8	18.4 ^b	28.5 ^a	2.7 ^c	***
	Low	51.3	52.6 ^a	42.5 ^b	1.8 ^c	***
	Average	32.1	29 ^a	29 ^a	9.1 ^b	***
	High	2.6	-	-	81.8	***
	Very high	1.3	-	-	4.6	***
Control of pests and diseases	Absence of control		-	-	36.3	***
	Use of cotton pesticides		-	-	63.7	***

GZ: Guinean zone; SGZ: Sudano-Guinean Zone; SZ: Sudanian Zone; n: Number of respondents; diff: difference; for the same variable, means or percentages that have no common letters are statistically different ($p < 0.05$); *** $p \leq 0.001$; ns: non-significant difference at the 5% level.

Table 10 Farmers' preference criteria of pigeonpea across ecological zones

Preference criteria	Overall					Rank per zone		
	NTV	MCR	PCr	Imp	Rank	ZG	ZSG	ZS
Precocity	50	23	49	40.7	1	1	1	3
Resistance to pests and diseases	45	16	45	35.3	2	2	2	1
Short cooking time	39	0	30	23	4	3	5	5
Adaptability to any type of soil	28	5	25	19.3	6	4	8	2
Good taste	38	0	35	24.3	3	5	4	4
High productivity	35	3	23	20.3	5	6	3	7
Cultivable at any time of the year	22	1	10	11	7	7	7	8
High market value	11	2	10	7.7	8	8	6	-
Resistance to storage insects	10	0	5	5	9	9	10	6
Easy for ginning	6	0	1	2.3	11	10	-	10
Drought resistance	11	0	3	4.7	10	10	9	9

GZ: Guinean zone; SGZ: Sudano-Guinean Zone; SZ: Sudanian Zone; TNV: Total Number of Villages in which the criterion is cited; MCR: Number of villages where the criterion is the major one or ranked first; PCr: number of villages in which the criterion was classified among the principal criterion i.e. among the first five; Imp: Importance

Table 11 Importance (in rank) of varietal preference criteria across different sociolinguistic groups

Preference criteria	Adja	Bariba	Biali	Boo	Dendi	Fon	Holly	Idaasha	Mahi	Nago	Peuhl	Somba	Yorouba
Precocity	1	1	1	1	1	1	1	1	1	3	1	1	1
Resistance to pests and diseases	2	1	-	1	1	2	1	1	2	3	1	1	1
Short cooking time	2	1	-	1	1	3	1	2	2	2	1	-	1
Adaptability to any type of soil	5	1	1	1	1	5	2	-	5	1	1	-	1
Good taste	4	1	1	1	1	2	1		3	2	1	1	2
High productivity	3	2	1	2	1	2	3	2	2	2	1	-	3
Cultivable at any time of the year	5	3	-	1	1	6	3	2	4	1	2	-	1
High market value	6	-	1	-	-	6	2	1	5	-	-	1	-
Resistance to storage insects	-	3	-	1	-	7	-	-	5	-	1	-	4
Easy for ginning	7	4	-	2	-	-	-	-	5	-	2	-	4
Drought resistance	-	2	-	2	-	4	-	-	-	-	-	-	3

Table 12 Agronomic and culinary characteristics of pigeonpea landraces grown accros Benin's ecological zone

Landraces/Local names	ZG	ZSG	ZS
CBSL <i>Klouékoun wéwé noukoun wiwi</i> (Mahi and Fon sociolinguistic groups)	NA	High productivity; Long cooking time; Long vegetative cycle; Resistant to diseases and pests; Susceptible to storage insects	NA
CRISL <i>Klouékoun wéwé noukoun vòvò</i> (Mahi and Fon sociolinguistic groups)	High productivity; Long cooking time; Long vegetative cycle; Resistant to diseases and pests; Susceptible to storage insects	High productivity; Long cooking time; Long vegetative cycle; Resistant to diseases and pests; Susceptible to storage insects	Low productivity; Long cooking time; Long vegetative cycle; Resistant to diseases and pests; Susceptible to storage insects
CSL <i>Klouékoun wéwé tété</i> (Mahi sociolinguistic group)	High productivity; Long cooking time; Long vegetative cycle; Resistant to diseases and pests; Resistant to storage insects	High productivity; Long cooking time; Long vegetative cycle; Resistant to diseases and pests; Resistant to storage insects	NA
CHMSL <i>Wlétchivé kloui</i> (Adja sociolinguistic group)	Low productivity; Long cooking time; Long vegetative cycle; Resistant to diseases and pests; Resistant to storage insects	Low productivity; Long cooking time; Long vegetative cycle; Resistant to diseases and pests; Resistant to storage insects	NA
CMSL <i>Klouékoun wlanwlan</i> (Fon sociolinguistic group)	NA	Low productivity; Long cooking time; Long vegetative cycle; Resistant to diseases and pests; Resistant to storage insects	Low productivity; Long cooking time; Long vegetative cycle; Susceptible to diseases and pests; Resistant to storage insects
BWSL <i>Colo kpikpa</i> (Idaasha sociolinguistic group)	NA	Low productivity; Long cooking time; Long vegetative cycle; Resistant to diseases and pests; Resistant to storage insects	NA
RSL <i>Klouékoun vòvò</i> (Fon and Mahi sociolinguistic groups)	High productivity; Short cooking time; Short vegetative cycle; Resistant to diseases and pests; Resistant to storage insects	High productivity; Short cooking time; Short vegetative cycle; Resistant to diseases and pests; Resistant to storage insects	Low productivity; Short cooking time; Short vegetative cycle; Susceptible to diseases and pests; Resistant to storage insects
LRLS	High productivity; Short	High productivity; Short	NA

<i>Otili kpoukpa</i> (Nago sociolinguistic group) BKSL	cooking time; Short vegetative cycle; Resistant to diseases and pests; Resistant to storage insects NA	cooking time; Short vegetative cycle; Resistant to diseases and pests; Resistant to storage insects Low productivity; Long	NA
<i>Otini kpoukpa</i> (Holly sociolinguistic group) CRSSL	High productivity; Long	cooking time; Long vegetative cycle; Resistant to diseases and pests; Resistant to storage insects High productivity; Long	Low productivity; Long
<i>Otili founfoun kékéle</i> (Idaasha sociolinguistic group) CRHSL	cooking time; Long vegetative cycle; Resistant to diseases and pests; Susceptible to storage insects High productivity; Long	cooking time; Long vegetative cycle; Resistant to diseases and pests; Susceptible to storage insects High productivity; Long	cooking time; Long vegetative cycle; Resistant to diseases and pests; Susceptible to storage insects NA
<i>Otili founfoun lakoun</i> (Idaasha sociolinguistic group) CMHSL	cooking time; Long vegetative cycle; Resistant to diseases and pests; Susceptible to storage insects High productivity; Short	cooking time; Long vegetative cycle; Resistant to diseases and pests; Susceptible to storage insects NA	NA
<i>Carder ekloui</i> (Adja sociolinguistic group) BMSL	cooking time; Long vegetative cycle; Resistant to diseases and pests; Resistant to storage insects High productivity; Long	NA	Low productivity; Long
<i>Ekloui djou</i> (Adja sociolinguistic group) RMSL	cooking time; Long vegetative cycle; Resistant to diseases and pests; Resistant to storage insects NA	NA	cooking time; Long vegetative cycle; Susceptible to diseases and pests; Resistant to storage insects Low productivity; Long
<i>Wotiri souan</i> (Bariba sociolinguistic group) PMSL	NA	NA	cooking time; Long vegetative cycle; Susceptible to diseases and pests; Resistant to storage insects Low productivity; Long
<i>Wotiri wonka</i> (Bariba sociolinguistic group)			cooking time; Long vegetative cycle; Susceptible to diseases and pests; Resistant to storage insects

BKSL: Blackish seeded landrace; BMSL: Black and mottled seeded landrace; BWSL: Brown seeded landrace; CBSL: Cream with black eye seeded landrace; CHMSL: Cream and highly mottled seeded landrace; CMHSL: Cream and

mottled with high size seeded landrace; CMSL: Cream and mottled seeded landrace; CRHSL: Cream with red eye and high size seeded landrace; CRISL: Cream with red eye and intermediate size seeded landrace; CRSSL: Cream with red eye and small size seeded landrace; CSL: Cream seeded landrace; LRSL: Light red seeded landrace; PMSL: Purple and mottled seeded landrace; RMSL: Red and mottled seeded landrace; RSL : Red seeded landrace; ZG: Guinean zone; ZSG: Sudano-Guinean Zone; ZS: Sudanian zone ; NA : Landrace Absent

Figures

Figure 1

Map of Benin showing the geographical locations of the surveyed villages.

Figure 2

Different pigeonpea landraces cultivated across ecological zones of Benin.