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Ethnobotanical characterization of scarlet eggplant (*Solanum aethiopicum* L.) varieties cultivated in Benin (West Africa)

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ABSTRACT

The African eggplant (*Solanum aethiopicum* L.) is an important traditional vegetable cultivated in tropical regions for its edible fruits. In the Benin Republic, *S. aethiopicum* is mainly cultivated by rural farmers for food and for its use in traditional medicine. Assessing varietal diversity, endogenous knowledge, production constraints and farmers' preference criteria are of great importance for promotion and conservation purposes. Using rural appraisal tools and methods, an ethnobotanical study was conducted in 680 households across 92 villages. A total of 60 local cultivars were collected and documented in the surveyed sites. We documented 15 farmers' criteria for agronomic (57.88% of responses), culinary (28.51%) preference, and for economic (13.61%) aspects. Several constraints related to eggplant production in Benin were also recorded. The low market demand (27% of responses), lack of high-yielding cultivars (11.08% of responses), low fruit storability (10.67%), low productivity (9.84%), soil poverty (8.43%), susceptibility to high soil moisture (8.02%), pests (9.56%), diseases (8.45%), and drought (6.38%) appeared to be the most important constraints of the eggplant production system in Benin. In addition to synthetic pesticides, the eggplant farmers use botanical plant extracts such as extracts from *Azadirachta indica* (Meliaceae) and *Hyptis suaveolens* (Lamiaceae). It appears that eggplant production is still traditional and is of limited use in Benin. Finally, the currently collected germplasm was proposed for further evaluation using morphological and molecular markers to provide breeders with traits of interest for developing better eggplant varieties and hybrids that are suitable for local environmental conditions and production systems.

1. Introduction

The scarlet eggplant (*Solanum aethiopicum* L.; family: *Solanaceae*) is an indigenous vegetable species grown in African countries. *Solanum aethiopicum* is the second most widely cultivated eggplant, occurring in Africa, and in some parts of the Caribbean, Brazil and southern Italy [1,2]. Its production in Africa has significantly increased from 606,672 tons in 1994 to 2,079,920 tons in 2018 [3]. *Solanum aethiopicum* contains essential nutrients such as carbohydrates, proteins, fat, fibers and vitamins (A; B1, B2, B6, B12; C, D) that are crucial for human health [4,5]. *Solanum aethiopicum* is also known to have several medicinal properties and is sometimes listed as a nutraceutical [6,7]. The Igbo people in the Nigerian community can hardly do without eating eggplant because it is good for the sight. In a study to assess the effects of eggplant on some visual functions of visually active Igbos of Nigeria, the experts found that the consumption of eggplant fruits may be of great benefit to glaucoma patients [8]. According to Refs. [9,10], frequent consumption of this vegetable can reduce blood pressure and prevent heart disease. *Solanum aethiopicum* has been reported to be an important source of resistance to several pests [11] and diseases [12]. Four cultivars have been

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recognized in *S. aethiopicum* including Gilo, Shum, Kumba and Aculeatum [13,14].

In the Benin Republic, *S. aethiopicum* occurs across the whole country and on small scale cultivation in home gardens [15]. It's one of the neglected and under-utilized crops and there is no national research program deeply conducted for its promotion. It relates to so-called neglected and under-utilized crops because they are locally abundant in developing countries, rare on a scale [14,16] and there is a low level of research investments in their favor compared to those made for dominant crops. Their potential is also untapped as a means of subsistence [17].

With the notable exception of the study by Ref. [18] on mite pests, there is no single article presenting not only an exhaustive list of cultivated eggplant of Benin but also their local name, production constraints (including pests and diseases), cultural characteristics, extent and distribution, and farmers' preference criteria. This paper presents the results of a survey on the ethnobotany of cultivated scarlet eggplant in Benin. Ethnobotanical knowledge of Benin eggplant genetic resources will facilitate their conservation and use in further studies and breeding programs [19,20]. Ethnobotanical research will help to address the characteristics of traditional knowledge to establish priorities together with the local communities to ensure that local values are translated into rational uses of resources and effective conservation of eggplant diversity and cultural knowledge [21]. Our expedition will thus be spent building a relationship between the communities to make an effort to understand their needs so that the research conducted will be mutually beneficial. This study aimed at document endogenous knowledge of local scarlet eggplant cultivated in the Benin Republic. Specifically, it involves mapping the eggplant production zones in the country (i), assessing the diversity, distribution and extent of the existing scarlet eggplant cultivars (ii), prioritizing the production constraints and factors that affect cultivars diversity and (iii) identifying farmers' varietal preference criteria across agroecological and ethnic zones for breeding programs and development actions (iv).

2. Material and methods

2.1. The study area

Ninety-two (92) villages (Table 1; Fig. 1) located in diverse agro-ecological (humid, semi-arid and arid) and ethnic zones across 10 administrative departments (Alibori, Atacora, Borgou, Donga in the north, Collines, Zou in the center and Couffo, Mono, Ouémé, Plateau in the south) were surveyed in this study, which were estimated to cover the whole country in order to establish an exhaustive collection. The selected villages within departments were randomly indicated by the officers of the national extension services of the ministry of agriculture operating in the departments, following their cultural habits and confirmed using the Benin agricultural database. In addition, prior to the survey, the major markets within departments were also visited to collect from the scarlet eggplant sellers some indications about the potential villages to consider. Fifteen to 39 villages were considered per department.

2.2. Ethnobotanical investigation

Data were collected during expeditions from appropriate locations using the Participatory Research Appraisal tools and methods such as direct observation, group discussions, individual interviews and field visits through a questionnaire [27–29]. Interviews were conducted with the assistance of local translators from each area. As vegetables is mainly women's affair, they were the principal respondents in this study although men were not excluded. At each site, local women's organizations were directly involved in the study to facilitate meetings organization and data collection. The characteristics of the surveyed areas (agro-ecological zone, name of location, name of sub-location, name of village, ethnic group) were first collected after providing a detailed presentation of our research objectives to the local farmers. Then, farmers were asked to list (vernacular name) and display the different types of varieties produced and/or consumed in their village. Group discussions allowed us to gather key information about the characteristics of the inventoried eggplant varieties. These include the local names, distribution and extent, cultural practices and seed management, agronomic and culinary preference traits, production constraints, major pests and diseases, degree of consumption, perceived nutritional value, cultural importance and medicinal properties. Pictures were taken for catalogs and report writing. Field visits (home gardens, cultivated fields) were conducted to investigate farmers' varieties under cultivation in their natural habitat. The eggplant varieties were classified by local farmers according to their morphological traits.

Using the matrix scoring technique [30] and on an individual basis, varieties were ranked and the preference criteria were identified and prioritized. Individual interviews were conducted at each site together with 20 producers (men and women) of different ages randomly selected from different households with the help of village leaders. Their socio-demographic data (gender, age, education level, and experience in scarlet eggplant production) were taken into account as a starting point of the discussions kept open-ended and unlimited to allow farmers to easily express their knowledge by following [31].

Table 1
Socio-demographic characteristics of the African eggplant farmers.

Parameters	Levels	Percentage of responses (%)			
		South	Center	North	Study area (%)
Genders	Men	9.54	7.67	10.95	28.16
	Women	24.65	20.44	26.75	71.84
Education	Non educated	26.54	18.85	21.34	66.73
	Primary level	6.35	6.85	7.64	20.84
	Secondary	2.25	4.75	3.56	10.56
	University	1.02	0.35	0.5	1.87
Religions	Islamic	26.45	35.17	53.51	38.38
	Christians	46.45	39.59	24.78	36.94
	Tradition	21.55	20.56	19.44	20.52
	Others/ None	5.55	4.68	2.27	4.16
Age	<30 years	8.33	8.87	10.56	9.25
	30–50 years	36.71	38.87	38.76	38.11
	51–70 years	49.55	47.59	43.15	46.76
	>70 years	5.41	4.67	7.53	5.88
Experiences	<5 years	12.33	11.76	10.65	11.58
	6–10 years	33.65	28.77	31.96	31.46
	11–20 years	42.32	47.88	43.33	44.51
	>20 years	11.7	11.59	14.06	12.45
Activities	**Levels**	**Percentage of responses (%)**			
		Principal	**Secondary**	**Tertiary**	**Study area**
	Agriculture	68.65	39.44	31.76	46.62
	Artisans	40.25	27.11	1.21	22.86
	Traders	38.96	27.87	24.75	30.52

2.3. Inventory, geographic distribution, and extent of eggplant cultivars

During the varietal inventory process, farmers were asked to list all the scarlet eggplant cultivars that occurred in their village (supporting sample). Prior to this, farmers were informed to kindly bring with them a few samples of eggplant cultivars when attending the meeting. Geographic distribution and extent of cultivated eggplant cultivars were assessed using the participatory four-square analysis method according to Ref. [32]. Discussions were held to identify the traits of interest of each cultivar and to understand the contribution of farmers to the eggplant value chain of Benin. The main reasons why few or many households tended to grow certain cultivars on small or large surfaces

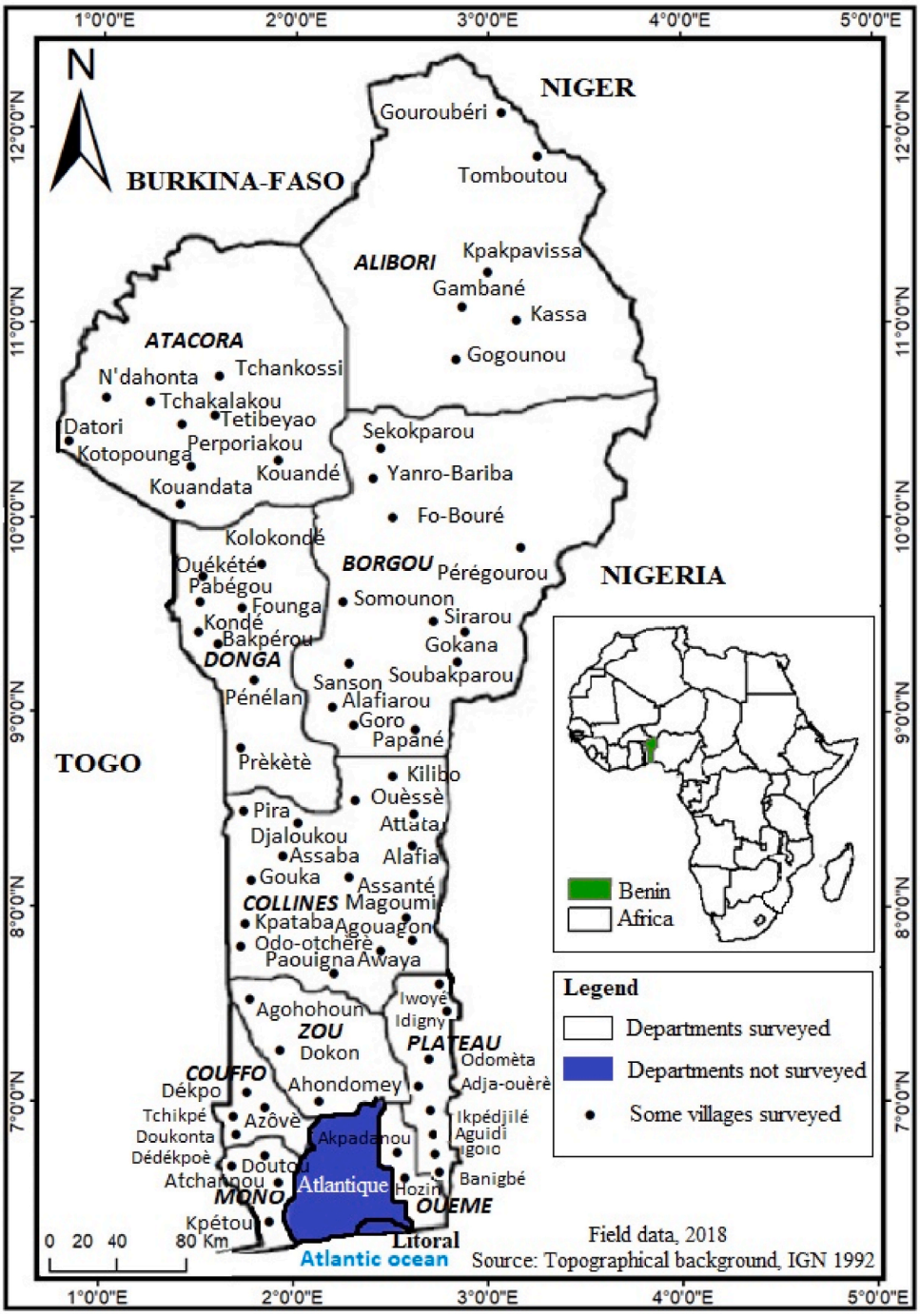

Fig. 1. Map of the study area and geographical position of the surveyed villages.

were noted. This method of four-square analysis method would lead to the identification of potential high-performing cultivars (++). It would also allow us to evaluate the rate of varietal diversity threatened by the disappearance of eggplant accessions cultivated by few households in small areas (- -).

2.4. Production constraints and farmer preference criteria

Group surveys were conducted to identify and prioritize farmer's preferences according to Ref. [33]. Farmers were asked to enumerate a number of good scarlet eggplant characteristics that should be widely adopted for farming in their villages. The different criteria were then ranked using the progressive elimination method described in Ref. [34]. Farmers were requested to list in their local language all the constraints that limit eggplant cultivation in their environment. The cited constraints were then prioritized according to their importance.

2.5. Scarlet eggplant pests and diseases investigation methods

Pests and disease damage to scarlet eggplants and farmers' perceptions of these constraints were documented using group surveys in each village. Prior to the survey, literature documentation was used to print photos of the pest and disease symptoms for demonstration in farmers' fields. Visits were then organized in four farmers' fields randomly chosen from the villages where pests and diseases were reported. These visits allowed us to evaluate the occurrence and damage of pests and

diseases in the field with help from farmers and the IPGRI official descriptor for eggplants [35]. Then, the pest and disease incidence was assessed with regard to the extent of the damage following [36] using the 0–5 scale of IPGRI where:0 = no symptom was observed; 1 = 1–10% of plants in the field are lowly infested; 2 = 10–25% of the scored plant are infested; 3 = 26–50% of the scored plants are infested; 4 = 51–75% of the scored plants are infested; 5 = more than 75% of the scored plants are infested.

2.6. Data analysis

Socio-demographical data and farmers' perception on different attributes of scarlet eggplant production (preference traits, constraint of production, seeds management) were analyzed by using descriptive statistics (mean, percentage of responses or frequency, etc.).

The cultivar diversity lost index (TPDV) was determined according to Ref. [37] using the formula: **TPDV = (n–k)/Nx100** where

n number of accessions cultivated by few households on small areas

k = number of newly introduced cultivars;

N = total number of varieties recorded in the village.

In order to estimate the eggplant varietal diversity across the studied three agro-ecological zones of Benin, Shannon-Weaver diversity index (H) was calculated according to the following formula:

$$H = -\sum PiLogPi$$

With $Pi = ni/N$; ni = number of cultivars in each village; N =Sum of ni across the survey area.

Analysis of variance (ANOVA) was used to reveal significant differences between surveyed locations (villages) and among ethnic groups studied for the number of total cultivars collected, the farmers' varietal preference, and production constraints. Socio-demographic parameters were summarized in descriptive tables and graphics. In order to classify the collected accessions according to farmers' criteria, a Multiple Correspondence Analysis (MCA) was performed. The principal factors from the MCA were used to perform the Hierarchical Cluster Analysis (HCA) using cluster analysis [38] packages within R software [39].

Pests and diseases data were statistically analyzed by calculating the incidence (*Inc*) and mean severity (*MS*). The following formulas were used in Ref. [40]:

$$Inc = \frac{\sum_{i=1}^{n} IP}{\sum_{i=1}^{n} PS} \text{X } 100$$

with IP number of infested plant and PS disease scored.

$$MS = \frac{\sum_{i=1}^{n} S}{\sum_{i=1}^{n} IP}$$

with S score of infested plants and IP Infested Plants.

3. Results

3.1. Socio-demographic characteristics of the respondents

Results of this survey showed that the majority of the 680 respondents were females and mostly with no school education (Table 1). However, some of the respondents were found to have primary, secondary and higher education level. The surveyed population was dominated by elder farmers (50–70 years old) with a work experience of 11–20 years in scarlet eggplant production. The surveyed farmers were reported to practice different activities among which crop production/agriculture was found to be the first activity in the villages. Most eggplant farmers in this study were found to be Christians, Muslims and Animists (Table 1).

3.2. Scarlet eggplant production across ethnic groups

Eggplant was not widely produced across all surveyed villages due to the limited adoption by farmers (Table 2). The extent of eggplant distribution varied across the production areas. Certain villages, especially in northern Benin appeared with greater diversity in eggplant cultivars when compared to those in the southern and central part of the country. The surveys revealed a high ethnic diversity within communities. Adja ethnic group occurring in departments of Mono and Couffo (southern Benin) was found to be the first scarlet eggplant producer in term of land allocated (Table 2).

3.3. Diversity of cultivated scarlet eggplants and their distribution

In the study area, the scarlet eggplant showed a low varietal diversity ranging from 1 to 3 cultivars per village (Table 3). An average of two scarlet eggplant cultivars was recorded in each surveyed village. It appeared that no variety was produced by many households and on large scale cultivation (Table 3) except *Gboyigouroto* who truly spread

Table 2
Distribution of scarlet cultivars collected in study areas.

N°	Local name and Languages	Distribution through villages
1	Gboyi (Adja)	Azovè (+-); Dékpo (–); Kissamey (+-), Banigbé (+-), Yovogahoué (+-), Edaguizohoué(+-), Zaffi (–), Tchikpé (+-), Lokogba (+-)
2	Gbitchan (Kotafon, Tala)	Monoto (++), Atchannou (+-)
3	Agbissan (Kotafon, Fon, Mahi, Goun)	Monoto (++); Doukonta (++), Ahondomey (–); Bamè (–)
4	Egboyi (Adja)	Dékpo (–); Kissamey (+-), Banigbé(+-), Yovogahoué (+-), Edaguizohoué(+-), Zaffi (–), Tchikpé (+-), Lokogba (+-)
5	Gbitchan lobo (Tala)	Atchannou (–)
6	Gbitchangodo (Tala)	Atchannou (–)
7	Gboyigouroto (Adja)	Azovè (+-); Dékpo (–); Kissamey (+-), Banigbé (+-), Yovogahoué (+-), Edaguizohoué(+-), Zaffi (–), Tchikpé (+-), Lokogba (+-), Kpétou (–)
8	Gboyilogboto (Adja)	Tchikpé (+-), Doutou (–)
9	Agbitchan (Watchi, Mahi)	Dédékpoè (–)
10	Ikan (Yorouba, Nagot, Holli, Idaatcha, Ifè, Tchabè)	Oko-Akaré (–), Sodji (+-), Ogando (–), Adja-ouèrè (+-), Itchagba-holi (–), Idigny (+-), Iwoyé (++), Illara (++), Ayékou (–), Odomèta (–), Oko-owo (–), Ouihi (–), Magoumi (–), Gouka (+-), Awaya (+-), Odo-ôtchèrè (+-)
11	Ikanrodo (Yorouba, Nagot, Holli)	Aguidi (+-), Igolo (–), Oko-Akaré (–), Sodji (+-), Ogando (–), Adja-ouèrè (+-), Iwoyé (++), Illara (++)
12	Ikangougou (Nagot, Holi, Yorouba)	Iwoyé (++), Illara (++), Ayékou (–), Odomèta (–), Oko-owo (–)
13	Kélé (Lokpa)	Pénélan (–), Kandi (–); Gouroubéri (+-); Yanro-Bariba (–); Djagbalo (–); Sanson (–); Perporiakou (–); Pérégourou (+-), N'dahonta (–)
14	Kpaanoulaka (Lokpa)	M'bayakou (–); Pénélan (–), Kandi (–); Gouroubéri (+-); Yanro-Bariba (–); Founga (–); Djagbalo (–); Sanson (–); Perporiakou (–)
15	Koklozingbo	Doukonta (++), Monoto (–)
16	Sambini (Bariba)	Djougou (++), Gambané (+-), Ouéké (–), Pabégou (–), Allédjo (–), Tomboutou (–), Yanro-Bariba (–), Yarra (–), Sombékourou (–), Bariénou (–), Perporiakou (+-), Kawado (–), Kassa (+-), Kolokondé(–), Malanville (+-)
17	Yètchanmiyé (Ditamari)	N'dali (–)
18	Yèkan (Lokpa, Ditamari)	N'dali (–), Tokotoko (–), Mallanville (–), Kpakpavissa (–), Kondé (+-)
19	Yèkan'tchantchayè (Ditamari)	Founga (–), N'dali (–), Tchanhounkossi (–)
20	Gabta (Dendi)	Gouroubéri (–); Akpadanou (–)
21	Kaanan (Gourmanché)	Datori (–), Tanguiéta (+-), Dipoko (–), Cobly (+-)

Table 3
Production and loss of the scarlet cultivar diversity in surveyed villages.

Variables	Minimum	Maximum	Mean ± SE	StDev	CV (%)
NTV	1	3	2.02 ± 0.05	0.5131	25.38
M + S+	0	0	–	–	–
M + S-	0	2	0.93 ± 0.05	0.44	47.06
M-S+	0	2	0.96 ± 0.05	0.47	48.80
M-S-	0	2	0.96 ± 0.05	0.47	48.80
NVI	0	1	0.04 ± 0.02	0.21	71.61
NVD	0	2	0.52 ± 0.06	0.54	74.32
TPDV (%)	0	66.67	23.55 ± 2.54	24.35	73.41

NTV: Total number of accessions per village; M + S+: Number of accessions cultivated by many household on large area; M + S-: Many household and small area; M-S+: Few household and large area; M-S-: Few household small area; NVI: Number of new introduced accessions; NVD: Number of accessions lost; TPDV: Diversity lost index, SE: Standard error, StDev: Standard deviation, CV: Coefficient of variation.

the eggplant production in Yovogahoué village located in southern Benin. The cultivar diversity lost index (TPDV) was high in some villages with a maximum value of 66.67% but the average value was 23.55% for the study area. The Shannon-Weaver diversity index calculated (H) varied from low to medium varietal diversity ranging from 1.22 to 3.88 scores across Benin villages. The scarlet eggplant diversity was found to be very low in Zou and Ouémé departments, low in Borgou and Donga and medium in certain regions of Atacora, Couffo, Mono, Plateau and Collines (Table 4). Four morphotypes were identified based on the different morphological characteristics of eggplants cultivars listed by farmers (color, shape, size, taste of the fruit, and number of lobes) (Figs. 2 and 3). All these four morphotypes were found in northern Benin, whereas only two morphotypes occur in the central and southern part of the country.

3.4. Agricultural practices of scarlet eggplant

The results of this study showed that the scarlet eggplant is mainly produced during the rainy seasons which extend in south from mid-September to October and, in both north and center, from June to September. Off-season cultivation is practiced during the dry seasons precisely from November to April and from mid-July to mid-September in the southern part and from November to April in the central and northern parts of the country.

Few interviewed farmers practiced direct sowing of eggplant seeds, whereas the majority adopted the pre-nursery culture methods. Most of farmers admitted to use Nitrogen–Phosphorus–Potassium (NPK) and Urea fertilizers a few days before transplanting in order to compensate soil deficiency conditions in some regions (center and north). Organic manures were also applied in the North.

Table 4
Scarlet diversity through departments surveyed.

N°	Departments	NV	H (bits)	NMiC	NMaC	Mean
1	Couffo	12	3.65	1	3	2.02 ± 0.85[a]
2	Collines	11	3.47	1	2	2.05 ± 0.23[a]
3	Borgou	10	2.61	1	2	2.01 ± 0.43[b]
4	Alibori	9	3.21	1	3	2.00 ± 0.84[a]
5	Atacora	9	3.88	1	4	3.01 ± 0.95[a]
6	Donga	9	2.50	1	2	2.00 ± 0.45[b]
7	Mono	10	3.50	1	3	2.26 ± 0.93[a]
8	Ouémé	5	1.22	1	2	1.01 ± 0.41[c]
9	Plateau	10	3.35	1	2	2.03 ± 0.88[a]
10	Zou	7	1.33	1	1	1.02 ± 0.63[c]
Study area		**92**	**2.69**	**1**	**2**	**2.02 ± 0.36**

Legends: NV: number of villages surveyed, H: Diversity index, NMic: Minimum number of accession per village, NMaC: Maximum number of accessions per village.

3.5. Scarlet eggplant production systems

The traditional farming systems as practiced by the surveyed farmers can be classified into three categories. The first category included more than 50% of farmers who cultivated *S. aethiopicum* in home gardens in association with other vegetables such as *Solanum lycopersicum* (L.), *Capsicum annuum* (L.), *Corchorus olitorius* (L.), *Abelmoschus esculentus* (L.), *Amaranthus* spp. In the departments of Ouémé, Plateau and Collines, the cultivation of eggplant in a home garden was much more observed. In the latter regions, the eggplant crop production was used for food consumption due to the low and poor demand at the market level. The second category included farmers who practice mixed cultures on farm. In this system, *S. aethiopicum* was found to be the main crop, whereas *Zea mays* (L.) (sown in a band) and *Manihot esculenta* (C.) (cultivated on the edge) were grown as secondary crops. The third category included farmers who practice monoculture in optimal density on farm.

3.6. Scarlet eggplant pests and diseases and management methods

Three major diseases and pests were reported in this study (Table 5). The eggplant diseases included bacterial wilt, dry crown rot and gall nematodes. Among the eggplant pests, we found stinking locusts, fruit and flower borers and caterpillars. The most significant diseases damages were fruits cracking followed by fruits gallery. Leaf perforation and inflorescence falling were found to be the most significant pest damages. The incidence and severity scores varied according to the regions. The highest incidence score was recorded in southern region, followed by northern and central part of Benin. The mean severity indexes were found to be greater than 1 (1 for No disease; 2 = 1–25% diseased, 26–50% diseased, 4 = 51–75% infested, 5 for upper than 75%) in all regions where those pests and diseases were recorded. In the fields, farmers use synthetic pesticides against pests. On the other hand, in home gardens, these are generally traditional methods such as the application of extracts from leaves (the most adopted), wood ash and local metal fences which are practiced to control pests and diseases. Most farmers use extracts from leaves of *Azadirachta indica* (Méliaceae) and *Hyptis suaveolens* (Lamiaceae) in the south and north Benin for field pests and diseases control. Only *H. suaveolens* is used by few farmers in the center. Wood ashes are highly used in the center as compared to the south and the north. Leaves extracts and wood ashes are used by spraying the eggplant leaves and flowers. Wire fences are exclusively used in home gardens against animals.

3.7. Seed acquisition and conservation strategies

Self-production (crop retention) of eggplant seeds was the main mode of seed supply adopted by majority of Benin farmers. The choice of seed retained for the next production season was mainly based on the size and shape of eggplant fruits. Farmers also make selection of good quality first fruits. After physiological maturity of these fruits they dedicate them to sowing the next eggplant generations. There was no relevant information on the acquisition of seeds by inheritance, donation, purchase and exchange in the surveyed villages. The most important and popular method used for eggplant seed conservation was found to be ex-situ conservation without any chemical treatment. The seeds were often kept in loin cloths, bottles or gourds and bags (Fig. 4).

3.8. Varietal preference criteria

Fifteen preference criteria were identified in this study and classified as of agronomic, culinary (28.51%) and economic (13.61%) importance (Table 6). Farmers' preference criteria such as high productivity (14.96%), earliness of cultivars (12.18%), resistance to the early falling of organs and good conservation of fruit were seen to be the most important agronomic traits. Eggplant farmers reported the indigenous

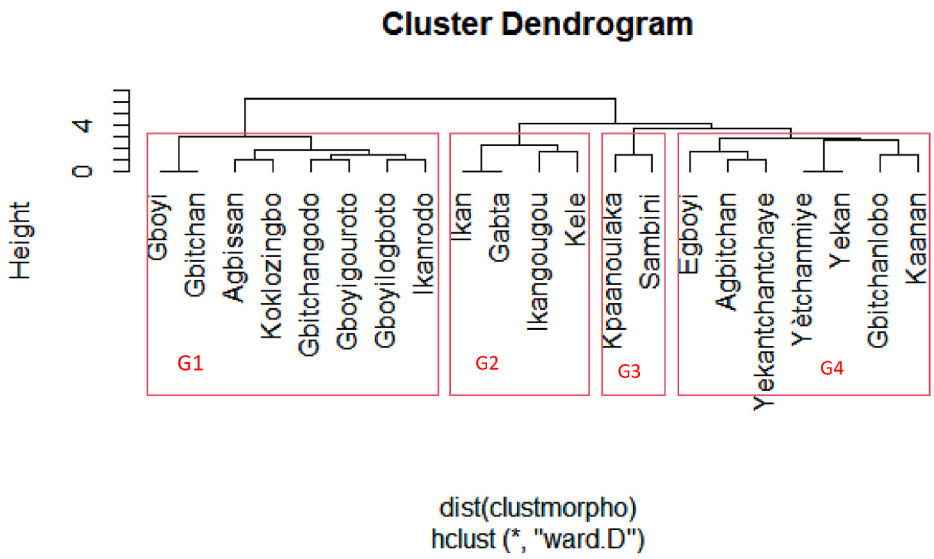

Fig. 2. Dedrogram showing the 4 morphotypes according to morphological characteristics of eggplants cultivars.

Fig. 3. Different groups of eggplants accessions according to the production areas.

knowledge of healers in Mono, Couffo and Atacora who use the fruits and leaves for medicinal purposes. Certain eggplant cultivars thus appear to have medicinal proprieties of great importance for the treatment of healthcare problems. The high economic value of the fruits was found to be a common preference criterion to all the farmers in the study area.

3.9. Constraints related to eggplant production in the study area

Eggplant production is hindered by several constraints across the study area. Ten constraints were identified and prioritized (Table 7). These include the low commercial level of the fruits, susceptibility to pests and diseases, lack of improved variety, low fruit storability. Soil poverty was found to be the main constraint in the center, whereas high susceptibility to soil moisture was seen to be major abiotic constraint to

Table 5
Farmers perception and assessment of different pests and diseases reported in study areas.

Pest and Diseases		SOUTH		CENTER		NORTH		Study area (%)	
Categories	Percentage (%)/Modalities	Inc	MS	Inc	MS	Inc	MS	Inc	MS
Gall nematodes	10	50	1.4	10	0.7	50	1.3	36.67	1.13
Dry crown rot	40	30	1.2	10	1	50	1.3	30.00	1.17
Bacterial wilt	50	30	1	20	1	40	1	30.00	1.00
Mean	**55.00**	**36.67**	**1.20**	**13.33**	**0.90**	**46.67**	**1.2**	**32.22**	**1.10**
Caterpillars*	28	50	1.2	10	1	30	1.3	30.00	1.17
Flower and fruit borers*	32	40	1.3	30	1.1	40	1.3	36.67	1.23
Stinking locusts*	40	30	1.1	20	1	30	1.2	26.67	1.10
Mean	**45.00**	**40.00**	**1.20**	**20.00**	**1.03**	**33.33**	**1.27**	**31.11**	**1.17**
Local means of treatment		25.05		0		21.16		46.21	
Leaves extracts	Leaves extracts of *A. Indica*								
	Leaves extracts of*H.suaveolens*	22.16		13.8		22.25		58.21	
	Mean	**23.605**		**6.9**		**21.70**		**52.21**	
Wood ashes	Wood ashes	11.16		16.23		6.04		33.43	
Local fences	Local fences	5.34		4.26		4.76		14.36	

Legends: Inc: Incidence in percentage (%), MS: Mean severity, *Pest.

Fig. 4. Photos showing different systems of seeds storage.

Table 6
Farmers preference criteria of African eggplant cultivars.

Categories	Criteria for preference	Study area (%)	Percentage per regions (%)		
			South	Center	North
Agronomic (58.17%)	High productivity	14.96	15.28	16.16	13.43
	Earliness of accession	12.18	11.17	13.12	12.25
	Resistance to flowers and fruits bores	7.14	2.92	4.22	14.28
	Good fruits storability	7.45	8.21	11.67	2.46
	Adaptability to several types of soils	4.87	3.37	5.01	6.24
	Resistance to diseases	3.66	3.49	4.34	3.15
	Tolerance to drought	2.66	2.89	2.43	–
	Tolerance to weeds	2.38	1.37	2.33	3.25
	Tolerance to poor soils	2.58	3.98	1.32	2.45
	Easiness of fruit harvest	1.96	2.5	1.21	–
	Total	**57.88**	**55.18**	**61.81**	**57.51**
Culinary (28.22%)	Good taste	11.97	12.23	11.43	12.25
	Good bitterness rate	6.73	5.65	4.34	10.21
	Leafy vegetable ability	5.43	2.37	8	5.31
	Good culinary quality	4.38	6.54	2.08	4.25
	Total	**28.51**	**26.79**	**25.85**	**32.02**
Economic (10.47)	High market value	**13.61**	18.03	12.34	10.47

Table 7
Production constraints of African eggplant through the production zones.

N°	Constraints of production	Percentage of responses (%)			
		Regions			Study area
		South	Center	North	
1	Low commercial level	28.55	37.06	22.26	29.29
6	Susceptibility to pests and diseases	18.49	17.02	18.53	18.01
4	Soil poverty	8.17	14.05	13.42	11.88
2	Lack of improved variety	12.01	11.02	12.51	11.85
3	Low fruit storability	10.61	11.23	11.78	11.21
5	Susceptibility to high soil moisture	14.66	–	13.39	9.35
7	Drought	7.51	9.62	8.11	8.41

the south Benin eggplant production.

4. Discussion

The discovery that all the four identified morphotypes occur in northern Benin suggests regions of great importance for scarlet eggplant diversity conservation. The higher levels of varietal diversity found in the north compared to the south and center Benin could have been correlated with human cultural diversity. Many territories exist at the periphery of northern Benin that borders Niger, Nigeria and Burkina-Faso with their ethnic diversity. Human population structure occurring in this north part of Benin suggests a mosaic zone. As demonstrated by other studies, there is an imperative interrelationship between cultural diversity and biodiversity [20,41,42]. Possible interactions may exist among southern Benin eggplant cultivars because of linguistic and geographic proximity of farmers in this part and with Togo as well.

Scarlet eggplant is broadly cultivated in Togo and there would be plant material exchanges with some mostly closed regions of Benin through informal seed system. Scarlet eggplant occurring in the south could have probably descended from a remote common ancestor. This may have caused much diversity loss.

The method of consuming *S. aethiopicum* fruits (cooked or raw) does not require their prior blanching unlike that of traditional leafy vegetables. Blanching vegetables causes a significant loss of their soluble nutrients [43] but, it preserves their macronutrients better [44]. When fresh and eaten raw, their nutritional value is greater, but it is not always possible to consume them immediately. The high consumption of eggplant in the different recorded forms may be due to cultural preferences of the local communities [45].

This study revealed that none of the surveyed eggplant cultivars was cultivated by several farmers and grown on large scale in Benin. The local farmers may have experienced a lot of difficulties of selling their products in the local markets at the highest rates as compared to other commercialized food products. Scarlet eggplant food products were not truly marketable throughout Benin. Several scarlet eggplant fields were abandoned, especially in south and center regions and cultivars remain as relict in these areas. It is thus evident that eggplant cultivars adopted by few farmers on small areas are in greater danger of extinction. These accessions deserve special attention and their discovery is crucial for preservation purposes. There is an urgent need for promoting their conservation and use in Benin [46]. Certain eggplant cultivars were grown either by few farmers on large scale areas or by many farmers but on small scale [37]. pointed out that the lack of proper conservation strategies (*in situ* and *ex situ*) would expose them to possible genetic erosion or extinction. There are examples in which such conservation approaches have been applied to crops such as eggplant in Burkina Faso [20], yam in Benin [29] and cassava in Congo [37].

Differences observed in the local names were the result of cultural differences between ethnic groups in the study area. Our finding is similar to that of [47] working on traditional leafy vegetables consumed in Benin. These authors found significant variation in the local leafy vegetables names across regions depending on ethnic groups. However, the current differences in the eggplant local names could not be only the fact of cultural but also genetic differences, related to farmers' preference criteria in function of types of morphotypes selected for cultivation. It seems likely that certain eggplant cultivars, in particular those from the same region, although having different local names, are genetically very similar, giving way to nomenclature mistakes [20,48]. It is not obvious the total of 21 local names considered by farmers is truly 21 individual genotypes at genetic level due to the synonymy problems. Gene banks must therefore use the traditional plant nomenclature with caution by trying first to confirm with genetic data in order for conservation to be properly achieved given that the same cultivar may have more than one local name differing in the complexity of languages used [20,31,48]. For example, there are many synonymies in the traditional nomenclature of cultivated plants in Benin. This is the case of *Solanaceae* family [49], cowpea [50] and traditional leafy vegetables [51]. But it is important to mention that this local nomenclature, although not very confident, allowed farmers to recognize and choose their cultivars to grow [52].

Despite the significance of the local names of eggplant accessions, some practical aspects still remain to be clarified, namely the unexplained names and synonymy, mostly depending on the ethnicity of the study country [51–53]. As assessment of genetic diversity was not an objective of this study we suggest to further characterizing these Benin scarlet eggplant cultivars by using morphological and molecular markers. This would help to estimate more accurately the eggplant genetic diversity for its better conservation and use [54,55].

Our study pointed out a rate of loss of varietal diversity relatively high in Benin scarlet eggplant. We assumed that the loss of diversity would be due to production constraints, such as poor sales of fruit, absence of local eggplant enhancement products, and absence of sales markets. This is in agreement with previous studies in cowpeas and *Phaseolus* [32,56]. However, certain eggplant cultivars have given way to some totems attached with it in south of Benin, especially in Adja culture. These totems are linked with some traditional religious concepts. For example, the *Kumba* groups (group 1: flat, highly lobed, and round fruit eggplants) has been given deep and sacred meanings opposite to the deities of Adja people, which compel producers to gradually avoid growing, mostly for superstitious reasons. It is therefore evident that Benin indigenous cultures further contribute to the loss of eggplant varietal diversity. For example, many of the surveyed scarlet eggplant cultivars were restricted for growing in the south except *Gilo* group and *Shum* cultivars. Similar results have been reported in *Solanum macrocarpum* (Gboma eggplant) [36] and *Capsicum annuum* [49].

Recorded data of agronomic importance provide possible indications that geophysical conditions could not be truly adapted to climate change with a major negative impact on Benin eggplant production. This may be one of the reasons for the difficulty in achieving better production of scarlet eggplant in certain localities when compared to others. When the same genotype is subjected to different environments, it can produce a wide range of phenotypes. As demonstrated in several studies, plant agronomic performance is a function of the genotype and environmental diversity [56]. As a consequence, further experiments at multiple locations are required to estimate the actual yield potential of the current eggplant cultivars. Doing this, it will help to extend the scarlet eggplant cultivars to large scale cultivation if proved to be agronomically well-performing. It is thus expected that the loss of varietal diversity slowdown in Benin. Similar approaches have been successfully used on plants such as eggplant [1,9] and yam [57] across different countries and regions.

The cultivation practice of scarlet eggplants is similar to those of other leafy vegetables and fruits grown in the sub-region. To control the pest attacks on scarlet eggplants, they are commonly used synthetic pesticide whereas the plant extract used as insect repellents, rarely. It is worrying that poorly or uninformed populations end up with toxic products that have harmful consequences for both humans and the environment. On the other hand, bio pesticide plants pose no threat to human health and the environment [58,59]. Under certain conditions, plant extracts can be comparable in effectiveness to conventional insecticides. Although this latter efficacy is not complete, it can nevertheless make it possible to keep the pest population below the harmful threshold and reduce the use of synthetic pesticides on vegetables [60].

Many constraints to eggplant production of Benin were reported in this study. Poor sales, the absence of upgrading products, the lack of high-performing cultivars have been identified by farmers as major constraints they face. As a consequence, many efforts are still needed for developing better productive eggplant cultivars, resilient to many stress factors as possible including climate change and variability, diseases (viral and fungal), pests, and poor soil fertility [33,46]. The eggplant susceptibility to the soil moisture that we reported in southern Benin would result from the negative effect of rivers that, during floods, threaten the survival of the eggplant cultivars by destroying their natural habit. It causes root rot of the plants which resulted in premature falling of flowers and fruits off plants.

In any participatory agronomic study, several criteria determine the farmers' choice of plants to grow. Studies by Refs. [61,62] strongly recommended breeding for varieties that are suitable for local environmental conditions and production systems, with respect for preference criteria of the target communities. The farmers' preference criteria that we found should receive greater attention in our national eggplant breeding program with focus on their socioeconomic needs.

5. Conclusion

This study showed that Benin eggplant production still remains traditional and is of limited use across the country. The varietal inventory revealed the existence of a moderate varietal diversity level,

varying from one region to another. Farmers applied several selection criteria mostly related to agronomic and economic traits. In addition, eggplant production was affected by several constraints across the study area. Further studies are needed to characterize the entire germplasm collection, including neglected eggplant cultivars by using agro-morphological and molecular markers for subsequent Benin breeding program.

Authors' contributions

SA, RI, AD, YLEL, OIY, AG and AD participated in the study design; they analyzed and interpreted the data and drafted the manuscript. SA and RI carried out the field surveys. SA, RI, AD, YLEL, OIY, AG, PAA, AD and CA corrected the manuscript. All authors approved the final manuscript.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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