



Research article

Farmers' knowledge, practices and use of sesame genetic resources in the production systems of Benin: case study of agro-ecological zone IV

Gazali B.T.A. Sanni, Vincent Ezin^{*}, Adam Ahanchede

Department of Crop Production, Faculty of Agricultural Science, University of Abomey-Calavi, Abomey-Calavi, Benin

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ABSTRACT

Sesame (*Sesamum indicum* L.) is an important crop cultivated for its grains, which demand is constantly increasing in Africa. In Benin, sesame is produced on a small area despite its high economic potential. The overall objective of this study was to reinforce local knowledge (cultural methods) related to the management of different *Sesamum indicum* cultivars in Benin's Agro-ecological Zone IV. A total of 273 producers were surveyed using the non-probabilistic snowball method supported by systematic census. The typological analysis consisted of a Multiple Correspondence Analysis (MCA) and a Hierarchical Ascending Classification (HAC) using RGui.4.1.0 software. The result of the MCA revealed four types of sesame production systems based on several variables. The characterization of the producers of each production system according to the townships showed that there was a dependency relationship between the production systems and the townships. 100% of producers in the township of Coby used the traditional production system (Type IV). 94.7% of producers in Matéri township practiced the modern production system (Type I). The different cultural methods for sesame production varied from one ethnic group to another. The Wama and Mossi ethnic groups practiced the modern semi-intensive production method (Type II). The conservative production system (Type III) was specific to the Ditamari. 61.8% Farmers planted sesame in August and 56.1% farmers harvested in October. Only 0.6% of respondents applied mineral fertilizer for sesame production. The number of cultivars used per village varied from 2 to 4 with an average of 2 over the entire study area. Toucountouna and Matéri had the most diversity with the largest number of cultivars (03) each. Only 1 cultivar was obtained Tanguieta. Sesame processing is low throughout the study area. Sesame cultivation can be intensified because of its low production costs.

1. Introduction

Sesame (*Sesamum indicum* L.) is a tropical annual crop that has been cultivated for a long time, mainly for grain yields and high protein contents of its seeds [1]. It has been introduced in Africa to increase the income of rural populations and to contribute to food security [2, 3]. Sesame expanded quickly in West Africa because of its high market value [4, 5].

Sesame can grow in low input soils and can thrive under higher temperatures, low water supply (up to 300 mm water) [1, 3, 6], thus it is a crop of present and future due to its aptitude to climatic resilience. Sesame seeds have a high oil content (between 55 and 59% of the seed) [7, 8]. Protein content of sesame seeds is about 25% [7]. It is also an important source of Vitamin E, calcium, potassium, phosphorus, iron, Magnesium and Zinc [7, 8, 9, 10, 11]. Sesame appears to be an essential

ally not only for food security in rural areas; but also, for increasing the rural economy.

Sesame world production has been increasing in recent years. It exceeded 5.5 million tons in 2019 at the global level [12]. In West Africa, it has reached nine hundred thousand tons (941021 T) in 2020 against three hundred thousand tons in 2010 [13]. Faced with this growing demand, countries such as Senegal, Nigeria, Burkina-Faso, Niger and Mali have seen their annual production increase considerably. However, the sesame sector in Benin is struggling to get off the ground. Despite its significant economic value, it is produced in small areas (less than 0.5 hectares) and often ranked second after other crops [14, 15]. Moreover [16], pointed out that sesame is not a priority crop for research in Benin. Therefore, these plant genetic resources remain underutilized and neglected.

Success of any crop breeding or enhancement program depends mostly on the nature and richness of the existing genetic variability [17,

^{*} Corresponding author.

E-mail addresses: ishola.vincent@yahoo.com, awevincent@gmail.com (V. Ezin).

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18, 19]. The lack of knowledge on the performance of different available sesame cultivars is a limitation for its improvement in breeding program. The general objective of this study was to identify the different production systems and collect the different cultivars of *Sesamum indicum* grown in northwestern Benin.

2. Methodology and materials

2.1. Study area

This study was conducted in the northwest of the Republic of Benin due to high production of sesame, which has served as the main criterion for selecting the townships. Five (5) townships namely Toukoutounan, Tanguiéta, Matéri, Coblí and Boukoubé were surveyed (Supplementary Figure S1). Table 1 present the location, villages and ethnic groups interviewed in the townships.

2.2. Data collected

A total of 273 producers were interviewed across the study area. Producers were identified using the non-probabilistic “snowball” method chosen because of the low production of sesame in Benin [20].

In this method, the first producers interviewed inform on the other sesame producers and also become additional informants. All sesame producers identified in an area were systematically interviewed. Respondents were approached individually to collect the information required sesame production. The interviews were conducted with the assistance of some translators in the villages. The cultivars were collected

in the storerooms (granary, canister and bags). They were kept in khaki envelopes protected in polyethylene bags.

2.3. Statistical analysis

The different data collected were encoded and entered in an Excel database (2013). A pretreatment and database cleaning were performed. The RGui.4.1.0 software was used for the data analysis. Descriptive statistical analysis (frequency, mean, standard deviation, minimum, maximum) was calculated on the socio-demographic characteristics of the respondents using the *summary()* and *tbl_summary()* functions of the “gtsummary” package to generate pivot tables. The typological analysis consisted of a multiple correspondence analysis (MCA) using the “ade4” package [21].

A total of 18 variables were used for hierarchically ascending classification (HAC). The characterization of the different production systems was performed with the function *catdes()* of the package “FactoMineR” [22]. χ^2 test was used to test the dependence between sesame production systems and categorical socio-demographic characteristics (age, gender, ethnic group and experience) in the first step, and the different study areas in the second step. The relationship between a qualitative variable and an axis is assessed by examining the class/modality and modality/class indicators as well as the test value (v-test). The class/modality (cla/mod) indicates the percentage of all individuals presenting this modality and being in this class (cluster, category). On the other hand, the modality/class (mod/cla) indicates the percentage of all individuals in the class presenting this modality. A modality better characterizes a class if its two indicators are large, simultaneously [23]. The v-test is a measure of association between qualitative variables, it measures the association of the modality with the class. Indeed, the significance of the coordinate with respect to zero is tested using the v-test statistic [24]. In this case, a category is considered “significant” in the formation of an axis if its test value is greater than 2 in absolute value (at the 5% threshold).

3. Results

3.1. Socio-demographic characteristics of farmers

The producers were mostly men (77%). The majority (43.7%) were between 30 and 58 years old. 47.8% producers were not educated. Berba (27.6%) were the main ethnic group. It is important to mention that 2.7% of the respondents were migrants from Burkina (Mossi and other related groups). 74.8% of respondents said they have started producing sesame 2–5 years ago.

3.2. Sesame adoption factor

There were five (05) important criteria that motivated the adoption and production of sesame in Agro-ecological Zone IV. 45.5% farmers prioritized financial profitability as a principal criterion for the adoption of the crop. Other criteria such as low cost of production (9.3%) or the food consumption behavior of the population (4.7%) were also reported. Table 2 presents the criteria for adoption of sesame by producers in northern Benin.

3.3. Typology of sesame production systems

The Multiple Correspondence Analysis (MCA) is an analysis for qualitative variables. In this case, 18 categorical variables were used. The total inertia was 2.889 and the first axis (axis 1) accounted for 8.93%. The cumulative projected inertia indicates that the first five axes together explained 36.62% of the variations observed in the sample. The projection of the variables on the first two dimensions revealed that education level, gender, age, and harvest date are well explained by the first dimension of the MCA. The second dimension was for plant density, number of treatments, area cultivated, and types of varieties produced.

Table 1. Surveyed villages and ethnic groups interviewed (n = 273).

No	Townships	Villages	Ethnic group	Number of respondents surveyed per Township
1	BOUKOUMBÉ	Koudahongou	Lamba, M'bermè	49
		Mantchari	Lamba, Ditamari	
		Dimansouri	M'bermè	
		Agbonte	Lamba	
2	COBLY	Datori	Tchokossi, Gamgamba	43
		Kadieni	Gamgamba	
		Tapoga Centre	Gamgamba, Natinba, Gourmantché	
3	MATERI	Gouandé –Centre	Berba	71
		Kouforpissiga	Berba, Ditamari	
		Nagassega-Kani	Berba	
		Kankini-Seri	Berba	
		Tchanhouncossi	Ditamari; Berba	
4	TANGUIETA	N'dahonta	Natinba	62
		Tchaeta	Natinba	
		Taiacou	Natinba	
		Bouniessou	Berba	
		Yarka	Wama	
5	TOUCOUNTOUNA	Nabaga	Ditamari, Wama	48
		Tampegre	Ditamari	
		Fatiya	Gourmantché, Mossi	
		Tchakalakou	Wama, Berba	
		Tampatou	Ditamari	
		Tectibayaou	Mossi	
		Toucounouna	Ditamari, Wama	

Table 2. Criteria for adoption of sesame by farmers.

Variables	Township	% Township	% Total
Domestic consumption and cultural reason	Tanguieta	11.8	4.7
	Toucountouna	11.1	
Good profitability	Boukoumbé	12.7	45.5
	Cobly	47.9	
	Matéri	55.2	
	Tanguieta	50.1	
	Toucountouna	57.4	
Good profitability and Domestic consumption	Cobly	37.5	11.3
	Matéri	13.2	
	Tanguieta	8.8	
Good profitability and Low production cost	Boukoumbé	87.3	20.3
	Cobly	10.4	
	Tanguieta	8.8	
	Toucountouna	3.7	
Low production cost	Matéri	28.9	9.3
	Tanguieta	2.9	
	Toucountouna	7.4	
Others			8.9
Total			100

%Township: percentage of producers having cited this criterion in the township;
 %Total: percentage of producers who cited this criterion in the overall population.

Figure 1 shows the projection of the variables in the factorial plan formed by the first two dimensions.

Hierarchical Ascending Classification (HAC) realized using the coordinates of the observations on the two dimensions retained from the MCA revealed four types of sesame production systems that are characterized by several variables such as age, gender, number of cultivars, area sown, number of cultivars owned, criteria for adopting sesame, sowing period, harvesting period, and number of weeding. Table 3 describes the diversity of the four (04) systems identified. These are the conservative production system (Type III), the traditional production system (Type IV), the modern production system (Type I) and the modern semi-intensive production system (Type II). 2.7% of respondents practiced conservative production system. It is followed by the traditional, modern semi-intensive and modern production systems with 15.9%, 31.9% and 49.5% of respondents, respectively.

Conservative production systems were practiced by 100% women with over 50 years old and uneducated. 75% producers in this class had more than 10 years of experience. The areas cultivated were between 0.25 and 01 ha. The common cultivar produced was the intermediate type (3 months). Sowing was done in July and harvesting in September. No plant spacing was observed, 100% of the crops were sown by broadcasting. Manual weeding was done twice during sesame production. This group was aware of the existence of three different cultivars. And each producer had at least 2 cultivars which he cultivated. The sesame production was for home consumption (50%) in the majority of cases.

Traditional production systems were practiced by 15.9% of respondents, who were mainly men (81%). 44% farmers in this class were

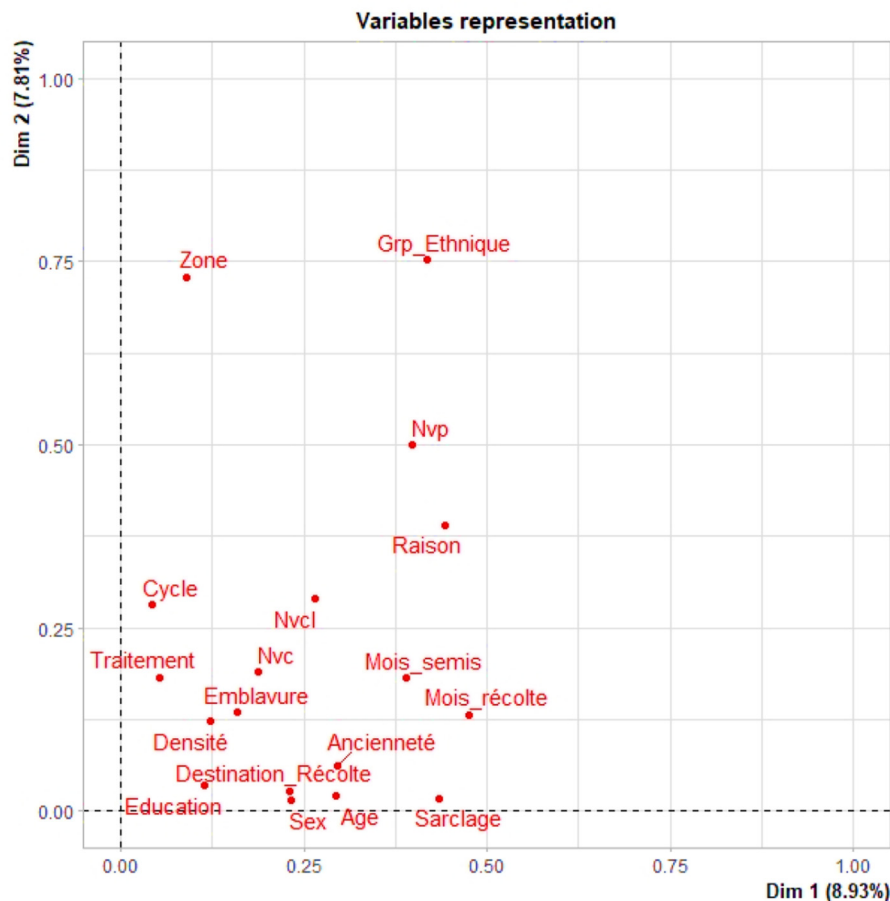
**Figure 1.** Projection of the variables in the first two dimensions of the MCA.

Table 3. Diversity of sesame production systems.

Variables		Modalities	TYPE I	TYPE II	TYPE III	TYPE IV
Sex of farmers		Female	16%	28%	100%	19%
		Male	84%	72%	0%	81%
Farmer age		[19; 30]	34%	33%	0%	21%
		[30; 50]	45%	43%	0%	35%
		[50]; and more	21%	24%	100%	44%
Education		Illiterate	50%	30%	100%	67%
		Primary	25%	39%	0%	23%
		Secondary	15%	19%	0%	6.2%
		University	9.4%	12%	0%	4.2%
Years of experience		[2; 05]	81%	62%	12%	92%
		[05; 10]	16%	20%	12%	2.1%
		[10]; and more	3.4%	18%	75%	6.2%
Cultivated areas (ha)		[0.25; 01]	23%	61%	100%	25%
		[01; 02]	34%	22%	0%	46%
		[02]; and more	42%	17%	0%	29%
Reason for sesame adoption		Domestic consumption and cultural reason	0%	8.3%	75%	0%
		Good profitability	42%	54%	0%	48%
		Good profitability and Domestic consumption	5.4%	8.3%	0%	38%
		Good profitability and Low production cost.	32%	8.3%	0%	10%
		Low production cost.	18%	1.0%	0%	0%
		Low production cost. and Domestic consumption	0%	2.1%	0%	4.2%
		Cultural reason	2.7%	5.2%	0%	0%
Type of cultivars used		Others	0%	12%	25%	0%
		Early (2 months)	8.1%	12%	0%	4.2%
		Intermediate (3 months)	50%	75%	100%	33%
		Late (4 months)	40%	12%	0%	54%
Sowing period		Very late (5 months)	2.7%	0%	0%	8.3%
		August	66%	50%	0%	83%
		July	23%	4.2%	100%	8.3%
		September	11%	46%	0%	8.3%
Harvest period		November	28%	42%	0%	71%
		October	66%	58%	0%	29%
		September	6%	0%	100%	0%
Plant density		Broadcasting	84%	42%	100%	92%
		40 × 40	16%	50%	0%	8.3%
		40 × 60	0%	8.3%	0%	0%
Weeding frequency		0	68%	90%	0%	79%
		1	29%	10%	0%	12%
		2	2.7%	0%	100%	8.3%
Respondents' knowledge level of cultivars	Existing	1	13%	0%	0%	0%
		2	60%	74%	0%	21%
		3	27%	23%	100%	75%
		4	0%	3.1%	0%	4.2%
	Current production	1	13%	0%	0%	0%
		2	72%	99%	0%	46%
		3	14%	1.0%	100%	54%
	Number of cultivars used	1	100%	96%	0%	62%
		2	0%	4.2%	100%	8.3%
		3	0%	0%	0%	29%
Treatment number		2	0%	0%	0%	17%
		3	4.0%	54%	0%	4.2%
		4	96%	46%	100%	79%
Utilization of seeds after harvest		Self-consumption	18%	19%	50%	4.2%
		Self-consumption/sale	59%	17%	50%	25%
		Commercialization	23%	65%	0%	71%

over 50 years old. Experience in production (92%) varies between 2 and 5 years. The producers (48%) were interested in sesame cultivation chiefly because of its good financial return. The cultivated areas were between 01 and 02 ha. The cultivar most produced by this group is the intermediate type (3 months). Sowing was carried out in August and harvesting in November. Broadcast sowing was more practice over row sowing, which is practiced by a minority. Manual weeding is carried out 0 times throughout the production cycle because producers use herbicides before sowing and at emergence. Three cultivars are used by these producers. And each producer used at least 1 cultivar. The sesame production was for sale (71%).

Modern semi-intensive production was practiced by 31.9% of respondents, who were men (72%) with above 30 years of age. Experience varied between 2 and 5 years. Sesame was cultivated mainly for its good financial return. The area cultivated was between 0.25 and 02 ha. The most produced cultivar was the intermediate type (3 months). Sowing is carried out in August (50%) and September (46%). The harvest was carried out in November and October. Broadcasting (42%) and sowing in row (50%) were practiced with the plant spacing of 40 × 40 cm. Manual weeding was carried out 0 time because these producers use herbicides before sowing and at emergence. Two cultivars were used by these producers. And each producer used at least 1 cultivar. The sesame production was for sale (65%).

49.5% of respondents practiced modern production systems and they were mainly men (84%). The age range was between 30 and 50 years. Experience varied between 2 and 5 years. Sesame was cultivated mainly for its good financial return and easy production. The cultivated areas were between 0.25 and 02 ha. The cultivar most used by this group is the intermediate type (3 months). The sowing is done in August and the harvest in October. Broadcasting practiced by 84% of farmers. Manual weeding was carried out 0 time because these producers use herbicides before sowing and at emergence. These farmers used two cultivars. The sesame production was for sale (59%).

3.4. Characterization of sesame production systems

The characterization of the *Typology* variable indicated that it was highly correlated with many other variables of the MCA; such as education levels, age, gender, ethnic group and years of experience in sesame production. Supplementary Tables S1 shows the chi-square statistics for all the other variables that better discriminate the *Typology* variable. It appears that a relationship exists between the different sesame cultivation practices and socio-demographic characteristics.

Table 4 presents the characteristics (chi-square and calculated v-test) of the Type I production system according to the modalities that best characterized it. The Type I cropping system includes 60.82% of

respondents who produced the 4-month-old cultivar and 39.59% of farmers classified in this system produced the 3- or 2.5-month-old cultivar. This system also includes 67.74% of the respondents who cultivated an area of more than 02 ha and 53.33% of those who have been cultivating sesame for 02–05 years. This class also includes 57.30% of the producers who practiced broadcast seeding; 61.37% and 72.88% of the individuals who carried out respectively 4 phytosanitary treatments and 0 manual weeding per production cycle because these producers use herbicides before sowing.

Table 5 shows the characteristics (chi-square and v-test derived) of the TYPE II sesame production systems, according to the modalities that best characterized it. This cultivation system, includes 42.35% of the respondents who produced the 3-month-old cultivar. This system also includes 51.75% of respondents who cultivated an area of between 0.25 and 01 ha and 54.88% of individuals who have been farming for more than 10 years. This class also includes 63.15% of producers who practiced sowing in rows (40*40 cm). Then 88.66% and 38.05% of the individuals who applied 3 phytosanitary treatments, respectively.

The characteristics (chi-square and calculated v-test) of TYPE III sesame production systems based on the modalities that most characterize it (Table 6). This system was practiced by 2.7% of the farmers who cultivated the 3-month-old cultivar. This class also includes 7.01% of respondents who cultivated an area of between 0.25 and 01 ha and 19.35% of individuals who have been farming for more than 10 years. This category also includes 50% of individuals who carried out only one 1 weeding operation per production cycle.

The characteristics (chi-square and calculated v-test) of the TYPE VI sesame production systems are presented in Table 7. 54.16% farmers in this system cultivated the 4-month cultivar. This class also includes 23.40% of the respondents who cultivated an area of between 01 and 02 ha and 19.55% of the individuals who have been cultivating sesame for 02–05 years. This class also includes 20.27% of the producers who practiced broadcast planting; and 100% of the individuals who carried out 2 phytosanitary treatments per production cycle.

3.5. Socio-ethnic characteristics of producers in each sesame production system

The characterization of producers of each production system by township showed that there is a dependency relationship between production systems and townships ($p = 1.772412e-15$). The producers (100%) surveyed in the township of Cobly practiced production system IV. In the township of Boukoubé, 98.2% of the producers surveyed practiced cropping system I when compared to 1.8% for system II. The majority of producers (94.7%) in the township of Matéri used cropping system I. Cropping system III was found only in the township of

Table 4. Characteristics of the Type I production system.

Type I cropping system					
Variable/modality	Cla/Mod	Mod/Cla	Global	p-value	v-test
Cultivar type = late	60.82474	39.597315	32.225914	7.027349e-03	2.695545
Area cultivated = [02]; and more	67.74194	42.281879	30.897010	2.323436e-05	4.231301
Age = [2; 05]	53.33333	80.536913	74.750831	2.291791e-02	2.274800
Planting period = July	68.62745	23.489933	16.943522	2.814509e-03	2.987303
Planting density = flock	57.60369	83.892617	72.093023	738004e-06	4.535820
Treatment = 4 Treatments	61.37339	95.973154	77.408638	1.129451e-15	8.011905
Weeding = 1 Weeding	72.88136	28.859060	19.601329	5.874607e-05	4.017792
Harvest period = October	58.57988	66.442953	56.146179	3.799907e-04	3.553604
Harvest destination = Self-consumption/commercialization	73.33333	59.060403	39.867110	1.142246e-11	6.787334

Cla/Mod: class/modality (percentage of individuals with the modality who are included in the class).

Mod/Cla: modality/class (percentage of individuals in the class who are included in the modality).

V-test: test value (measures the association of the modality with the class).

Table 5. Characteristics of the Type II production system.

TYPE II Sesame Production Systems					
Variable/Modality	Cla/Mod	Mod/Cla	Global	p-value	v-test
Cultivar type = Intermediate	42.352941	75.000000	56.478405	7.440217e-06	4.480690
Area cultivated = [0.25; 01]	51.754386	61.458333	37.873754	1.206966e-08	5.698739
Age = [10]; and more	54.838710	17.708333	10.299003	5.843137e-03	2.756457
Planting period = September	68.750000	45.833333	21.262458	6.583686e-12	6.866412
Planting density = 40*40	63.157895	50.000000	25.249169	5.734780e-11	6.550492
Treatment = 3 Treatments	86.666667	54.166667	19.933555	2.949514e-23	9.934398
Manual Weeding = 0	38.053097	89.583333	75.083056	3.415067e-05	4.143861
Harvest destination = commercialization	47.692308	64.583333	43.189369	3.462584e-07	5.096353

Cla/Mod: class/modality (percentage of individuals with the modality who are included in the class).

Mod/Cla: modality/class (percentage of individuals in the class who are included in the modality).

V-test: test value (measures the association of the modality with the class).

Table 6. Characteristics of the Type III production system.

CROP PRODUCTION SYSTEM III					
Variable/Modality	Cla/Mod	Mod/Cla	Global	p-value	v-test
Cultivar type = Intermediate	4.7058824	100.0	56.478405	9.620378e-03	2.589184
Area cultivated = [0.25; 01]	7.0175439	100.0	37.873754	3.617082e-04	3.566553
Age = [10]; and more	19.3548387	75.0	10.299003	1.851711e-05	4.282060
Planting period = July	15.6862745	100.0	16.943522	4.185098e-07	5.060340
Harvest period = September	50.0000000	100.0	5.315615	8.458753e-12	6.830554
Manuel Weeding = 1	50.0000000	100.0	5.315615	8.458753e-12	6.830554
Harvest destination = Self-consumption	7.8431373	50.0	16.943522	3.481649e-02	2.110486

Cla/Mod: class/modality (percentage of individuals with the modality who are included in the class).

Mod/Cla: modality/class (percentage of individuals in the class who are included in the modality).

V-test: test value (measures the association of the modality with the class).

Toucountouna. Figure 2 shows the characterization of producers of each sesame production system by township.

The characterization of the different modalities of the typology variable (Type I, Type II and Type IV) and of the ethnic group variable shows that they are related ($p = 1.253960e-95$). The different sesame cultivation practices varied across ethnic groups. Chi-square statistic and the v-test calculated for each modality of the Ethnic Group variable that most discriminated between the different production systems are shown in Supplementary Tables S2.

Figure 3 shows that 100% Wama and Mossi ethnic groups practiced System II. It is the same for the Natinba (91.7%) and the Gourmantché (66.7%). Respondents from the M'Bermè (100%), Lamba (97.4%) and

Berba (94%) ethnic groups, they prefer system I. System III is specific to the Ditamari.

3.6. Description of cultural practices

The cultivation areas for sesame are relatively small, from 0.25 to 2 hectares. No agricultural structure or agricultural extension agents were present in the areas to help the farmers. Management is purely traditional. The majority of respondents (91.36%) used the seeds (plant material) from the previous harvest. Conservation is done in situ, with annual renewal by 100% of respondents. Some producers (5.3%) practiced mass selection. The characteristics of interest are: plants with at

Table 7. Characteristics of the Type VI production system.

CROP PRODUCTION SYSTEM VI					
Variable/Modality	Cla/Mod	Mod/Cla	Global	p-value	v-test
Cultivar type = Late	26.804124	54.166667	32.225914	6.526589e-04	3.408731
Area cultivated = [01; 02]	23.404255	45.833333	31.229236	2.132086e-02	2.302254
Age = [2; 05]	19.555556	91.666667	74.750831	1.769125e-03	3.126480
Planting period = August	21.505376	83.333333	61.794020	5.505751e-04	3.454862
Harvest period = November	29.310345	70.833333	38.538206	9.356971e-07	4.904701
Planting density = broadcast	20.276498	91.666667	72.093023	4.279872e-04	3.522196
Treatment = 2	100.000000	16.666667	2.657807	2.480110e-07	5.159197
Harvest destination = commercialization	26.153846	70.833333	43.189369	3.017817e-05	4.172118

Cla/Mod: class/modality (percentage of individuals with the modality who are included in the class).

Mod/Cla: modality/class (percentage of individuals in the class who are included in the modality).

V-test: test value (measures the association of the modality with the class).

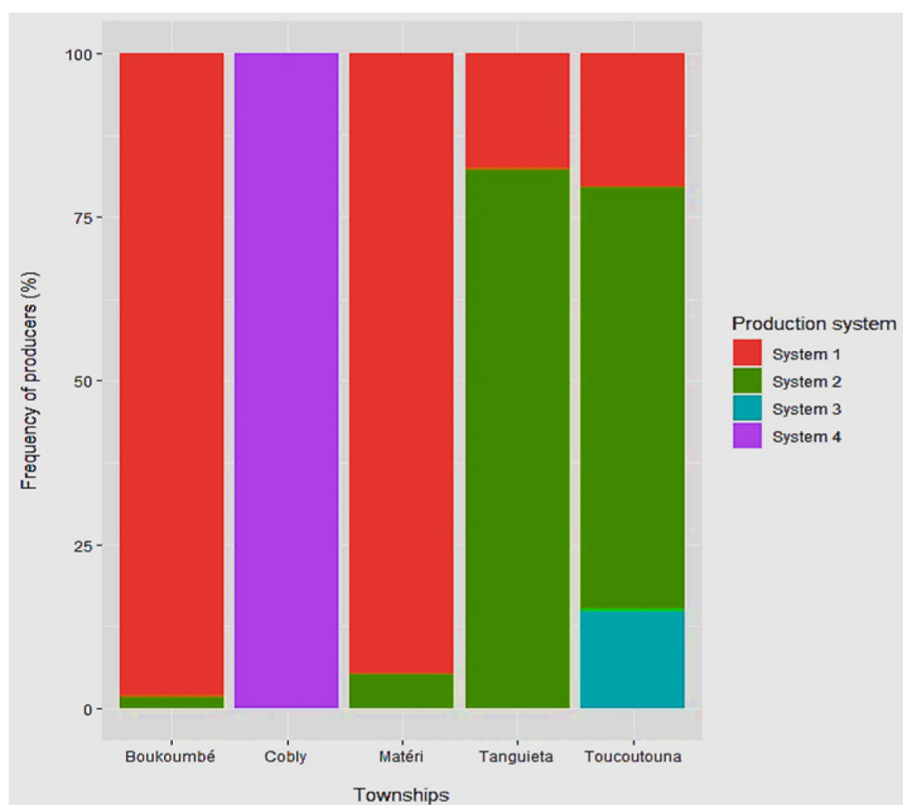


Figure 2. Characterization of the producers of each system by township.

least 2 to 3 pods per node; well close pods and did not dehiscence at maturity; and big plants. In general, planting is carried out throughout the study area (61.8% of respondents) in August. Except in Tanguieta where planting was in September (70.6%) (Supplementary Table S3).

90% of respondents produced sesame monoculture. Only 10% farmers practiced intercropping of sesame with Bambara groundnut and groundnut. Broadcast planting was the most common method used by producers (72.09%). The two planting spacing recorded were 40×40 cm

and 40×60 cm, used by 25.24% and 2.65% of producers, respectively. In order to avoid several plants being in the same place, the seeds are mixed with rice bran or sand before sowing.

Farmers were not applying mineral fertilizer throughout the study area but only 0.6% did apply fertilizer. Meanwhile, synthetic pesticides are used by producers (73.42%) with four treatments per production cycle on average. Over the entire study area, producers who planted in August and September did not manually weed.

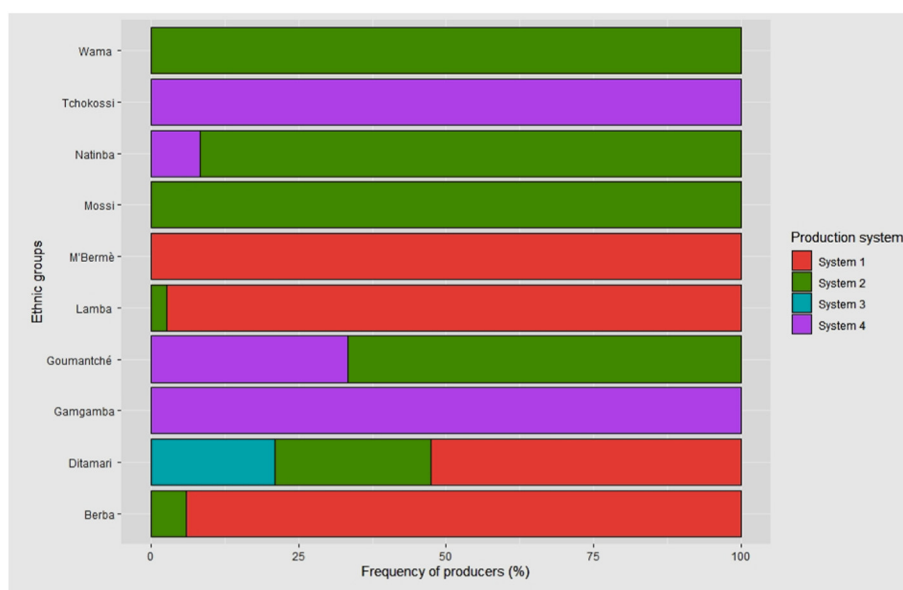


Figure 3. Characterization of producers in each system by ethnic groups.

Harvesting was performed mostly by 56.1% farmers in October at the physiological maturity of the pods. 63.45% of the respondents used some observations such as significant defoliation, which indicated the beginning of pods maturation. Harvesting was done manually by cutting the stems at the base with harvesting knife (Supplementary Figure S2).

After harvesting, the sesame was placed in bundles or small piles for drying. Supplementary Figure S3 describes the process of drying sesame in the field. Drying duration vary between 1 (51.82% of respondents) and 2 weeks (32.89% of respondents). After drying, the sesame was vanned. The winnowing is done mechanically with basins following the direction of the wind. Most of the production (83.38%) was destined for sale. The remaining of the harvested products was for domestic consumption, donations and seed conservation for next planting season production. Supplementary Figure S4 shows the winnowing and bagging of sesame in 100 kg bags ready for sale. The main constraint to sesame production mentioned by farmers was seed dehiscence. Indeed, the dehiscent nature of the pods means that they open at maturity, leaving their contents (seeds) to spill onto the ground.

3.7. Sesame genetic resources identified

A total of 24 villages were surveyed. The number of villages at the communal level was 04 in Boukoubé, 03 in Coby, 05 in Matéri, 05 in Tanguiéta and 07 in Toucountouna (Supplementary Tables S4). On average (56.5%), producers were aware of two cultivars. The number of cultivars collected per village ranged from 2 to 4 with an average of 2.2 for the entire survey area. Toucountouna and Matéri had the most diversity. They had the greatest diversity of cultivars (03) each. A small number of cultivar (01) was obtained in the township of Tanguiéta.

A total of 13 local names, including synonyms, were identified to appreciate the diversity of sesame cultivars by producers. These local names are assigned to cultivars based on three criteria of varietal nomenclature: cycle length (46.5%), seed coat color (36.9%) and seed size (16.6%) (Supplementary Table S5). The local names attributed to the sesame cultivar varied according to ethnic groups. Thus, for the Berba sociolinguistic group, sesame is known as “*Sonni*”. It is referred to as “*Saari*” in Wama, and as “*N'sòromou*” and “*N'guètè*” respectively by the M'Bermè and the Tchokossi.

Sesame processing is low over the entire study area. It is not really processed. However, 92.32% reported using the seeds to make sauce or roasted as a snack.

4. Discussion

Sesame cultivation has long been practiced by women, either for its leaves (black sesame, especially in sticky sauce) or for its seeds (roasted as snakes or to make the sauce). The origin and the first producers of sesame are not clearly identifiable. According to the respondents, sesame have been produced years back by their ancestors. Nevertheless, the analysis of the experience of the farmers showed that 93.54% of respondents had between 1 and 30 years of experience. The first major interests were shown in sesame production about 30 years ago. This is consistent with authors such as Quenum, and al. [25] who reported that an elite cultivar “38-1-7” was introduced in most major production areas of Benin about 20 years ago. The first large areas cultivated with sesame would therefore be in this interval. The highest sesame production would have started around 2013 according to [14]. This result is similar to that observed during the investigations, as the proportion of producers who started producing sesame between 2013 and 2019 was 78.74%. This boom is probably due to increased demand on regional markets (Burkina Faso, Ghana and Nigeria) and to the fact that the incomes generated by this crop helps to pay off the debts contracted by producers during the sale of cotton [14].

Sesame is mainly produced by men. Even if many authors [26, 27] indicate that it was once a women's crop. Its production is still dominated by men who are the real actors in agricultural production in rural

areas [28, 29]. This could sometimes be explained by cultural factors that did not often allow women to own land [30]. Low level of education among sesame producers was observed. These results corroborate those of Adoukonou-Sagbadja et al. [31]. A diversity of ethnic groups was involved in sesame cultivation, with the Berba ethnic group dominating. This could be explained by the fact that the Berba were the ethnic group found mainly in the Atacora, and as far away as Burkina and Togo [32].

Four different sesame production systems were identified. They are clearly distinguished by several variables such as age, gender, number of known cultivars, surface areas cultivated, number of cultivars used, sesame adoption criteria, planting period, harvesting period, and number of weeding operations [33] also identified four (4) types of production systems in regions of Benin. The producers (100%) surveyed in the township of Coby practiced production system IV. The cropping systems are township specific. Production systems are also specific to sociolinguistic groups [34] obtained similar results.

Seeds used for production comes from the previous harvest for the majority of producers. Similar practices were reported by [31] in Togo. This in-situ management method preserves the genetic identity of the cultivars quite well by limiting the risks of mixture associated with the simultaneous use of several cultivars of such small seed size [35]. Mass selection by a small group could strongly improve varietal performance even if it is not really controlled. Pure culture is more widely used than association culture. These results corroborate those of Kunen et al. [36]. However, in a dynamic of diversification and fight against global warming, several authors suggest the crop association which has already shown convincing results, for maize [37] and sorghum [38].

Intercropping methods allow farmers to ensure food security (availability, stability, avoidance of crop failure, access and use of different agricultural products), to diversify sources of incomes and to manage the soil sustainably [2, 3] recommend a spacing of 60 cm × 20 cm and an N-P-K fertilizer application rate of 80 kg/ha for sesame cultivation. Conversely, in our study, no form of mineral fertilization was observed and the planting spacing adopted was 40 × 40 cm. Similar results were obtained by Traoré et al. [39] in Burkina Faso.

Knowledge of genetic variability is essential in breeding. The identification of this genetic variability for certain morphological traits is the first essential step in the description of genetic resources [40, 41]. In total, 13 local names were recorded. These local names varied from one ethnic group to another. This same finding was reported by several authors [42, 43, 44]. Each village most often had its own set of names and specific naming criteria. To avoid over- or underestimation of varietal diversity and to facilitate efficient use of local variety, these should be collected and characterized on the basis of both morphological and molecular markers [44].

Poor cultivar diversity observed in the study area could suggest better conservation of sesame genetic resources. But it could also suggest the maximum threshold of variety abandonment. Similar results were observed for fonio [42], yam [44], cowpeas [38] and pepper [45]. Sesame genetic resources is a key component of plant genetic resources in Benin which have been used for food, feed, and income generating. It is also a vital raw plant material for breeding programs. The collection of sesame varieties during the survey will increase the genetic diversity of the existing accession, and moreover the loss of those varieties and will definitely contributing to crop amelioration for sustainable development in the country and regions. This results corroborate those of [46].

According to our investigations, sesame processing is very limited. Apart from domestic consumption, no form of industrial processing was observed [14] also observed similar results. This investigation is carried out to increase the knowledge and understanding on the use of sesame varieties, the number of varieties available and its collection for conservation ex-situ, and the production system. It is important that research continues so as to improve this crop for high yield and income of the farmers.

5. Conclusion

This study, conducted in the townships of Toukoutounan, Tanguiéta, Matéri, Cobli and Boukoubé in northern Benin, identified the different production systems and the different cultivars of *Sesamum indicum* grown in northwestern Benin. Four main sesame cultivation systems exist. Some systems are specific to townships. The different cultivation methods are influenced by characteristics such as ethnic groups. It is very clear that sesame is an emerging crop in these areas. Its production is of great economic importance to the populations. It does not require special management such as fertilizer application and many weeding. Despite the growing importance of production, current cultivation methods do not allow for a significant increase in production. However, the development of this crop will increase the level of diversification and income security of rural populations.

Declarations

Author contribution statement

VE, AA and GBTAS: Conceived and designed the experiments.

GBTAS: performed the experiments.

VE, AA and GBTAS: analyzed and interpreted the data, Wrote the paper.

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No data was used for the research described in the article.

Declaration of interest's statement

The authors declare no conflict of interest.

Additional information

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