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Phenotypic diversity, uses and management of local varieties of *Corchorus olitorius* L. from central Benin

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Abstract

Corchorus olitorius L. is a grown traditional leafy vegetable that contributes highly to food and nutritional security and to poverty reduction in Benin. Unfortunately, its culture is confronted with many undocumented constraints that limit its production. In order to collect information that will help to preserve its diversity, ethno botanical investigations and germination tests were conducted. Nine production constraints of *C. olitorius* were identified among which the most important are the susceptibility to drought, low productivity, lack of quality seeds, rot of seeds and susceptibility to insects. In total, 34 varieties of *C. olitorius* and 28 vernacular names were identified in the study area. The shape and nature of leaves are the most parameters used for denomination of *C. olitorius* varieties. Based on denomination criteria, 7 morphtypes were identified. Varieties are selected following 11 criteria of preference. Most producers used local seeds stored in eight materials. Among these, pieces of cloth (42.62% of responses), polythene bag (29.3% of responses) and piece of paper (10.52% of responses) are the most used. Apart from food uses, *C. olitorius* has medicinal properties and is relatively rich in iron that would prevent anemia especially among children from 0 to 5 years. A significant difference ($p \leq 0.05$) is observed between the germination rates of the seed morphotypes studied, indicating the necessity to provide quality seed to producers. The implementation of a varietal improvement program and seed production according to the criteria of preference of producers is highly recommended for a better production of *C. olitorius* in Benin.

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Introduction

Many plants are used by people to meet food, nutritional and health needs and constitute a source of additional income and employment (FAO, 2012). Among them, they are consumed as traditional leafy vegetables (LFTs) which play an important role in food, nutrition and health of populations because of their availability and richness in nutrients; They supply the body with minerals, vitamins and certain hormones precursors in addition to protein and energy (Antia *et al.,* 2006; Adjatin *et al.,* 2013a). *Corchorus olitorius* L. is an annual herb used as a traditional leafy vegetable in Africa (Dansi *et al.,* 2008; Nyadanu *et al.,* 2016). The genus *Corchorus* has undergone many taxonomic revisions. It was originally placed in the family Tiliaceae, subsequently in the family Malvaceae but it has now been placed in the family Sparmaniaceae (Akoègninou *et al*., 2006; Heywood *et al*., 2007). In Europe and in Asia, *C. olitorius* is cultivated as a textile plant, especially for the production of burlap from its stem and as a food plant by the use of its leaves. In West Africa, it is most popular among the population as weaning soup for children and good delicacy for adults (Mavengahama and Lewu, 2012). In Benin, *C. olitorius* is a plant grown in all agro-ecological zones and consumed in all sociolinguistic areas with a very varied local nomenclature (Dansi *et al*., 2008). This species also occupies an important place among the crops and is one of the most widely consumed vegetables (Komlan *et al*., 2013). Its leaves and young fruits are used to make a sticky sauce that accompanies starchy foods and dried and ground leaves are also used as spices (Dansi *et al*., 2008). Nutritional analysis of *C. olitorius* reveals that it is a good source of proteins, lipids, carbohydrates and minerals such as calcium and iron (Adeniyi *et al*., 2012). Also, it is known to contain high levels of iron and foliate which are useful for the prevention of anemia (Oyedele *et al*., 2006). Its leaves, roots and fruits are used in traditional medicine to treat various diseases such as gonorrhea, chronic cystitis, pain, fever and tumors (Kumawat *et al*., 2012). Also, analyzes of marketing systems for *C. olitorius* identified the chain of distribution and the profitability of *C. olitorius* following to actors (Komlan *et al*., 2013).

In spite of the food, medicinal and economic importance of *C. olitorius*, many constraints that are not still documented, hinder its production in central region of Benin that is zone of high production and consumption (Dansi *et al*., 2008). In addition, the factors that influence *C. olitorius* production, distribution and extent of the varieties and rate of diversity loss are not documented yet. In recent years, local knowledge was increasingly studied using quantitative ethno botanical studies to identify plants with high nutritional, medical and commercial potentials likely to contribute to improving the livelihood of local populations (Guimbo *et al.,* 2011). Knowledge of folk-nomenclature of a crop is necessary in order to understand the reason for use of a crop by sociolinguistics groups, existence of same name across ethnic groups and distribution of the crop (Dansi *et al*., 2010). In order to develop a concrete research and development program for *C. olitorius* promotion for the producers and consumers benefit, indigenous knowledge should be considered. Therefore, ethno botanical investigations of *C. olitorius* were carried out in the central region of Benin as well as germination tests of certain morph types for breeding and varietal improvement purposes. The objectives of this survey were fourfold: i) identify the constraints related to the production of *C. olitorius* in the various sociolinguistic groups; (ii) Assess, in participatory way, the varietal diversity and their distribution and extent; (iii) identify producers' preference criteria and (iv) determine the germination rate of some morph types of *C. olitorius* obtained in the study area.

Materials and methods

Presentation of the study area

The study was conducted in the Department of Collines located in center of Benin. The area counts six districts (Bante, Dassa-Zoume, Glazoue, Ouesse, Savalou, Save) and is dominantly occupied by five socio-linguistic groups (Idaasha, Itcha, Ife, Mahi and Tchabe). The climate is subequatorial humid with annual rainfall ranging from 1000 to 1100 mm, two rainy seasons and two dry seasons with an average temperature ranging from 24°C to 29°C with oils mostly ferruginous (Adomou *et al*., 2005).

In order to ensure a good coverage of the study area and from a map showing all the localities of Benin, particularly those of the department of Collines, one to two villages were randomly selected by district (Fig. 1).

A total of 10 villages, belonging to different sociolinguistic groups, were selected based on cultural diversity, accessibility and effective production of *C. olitorius* (Adjatin *et al.*, 2012).

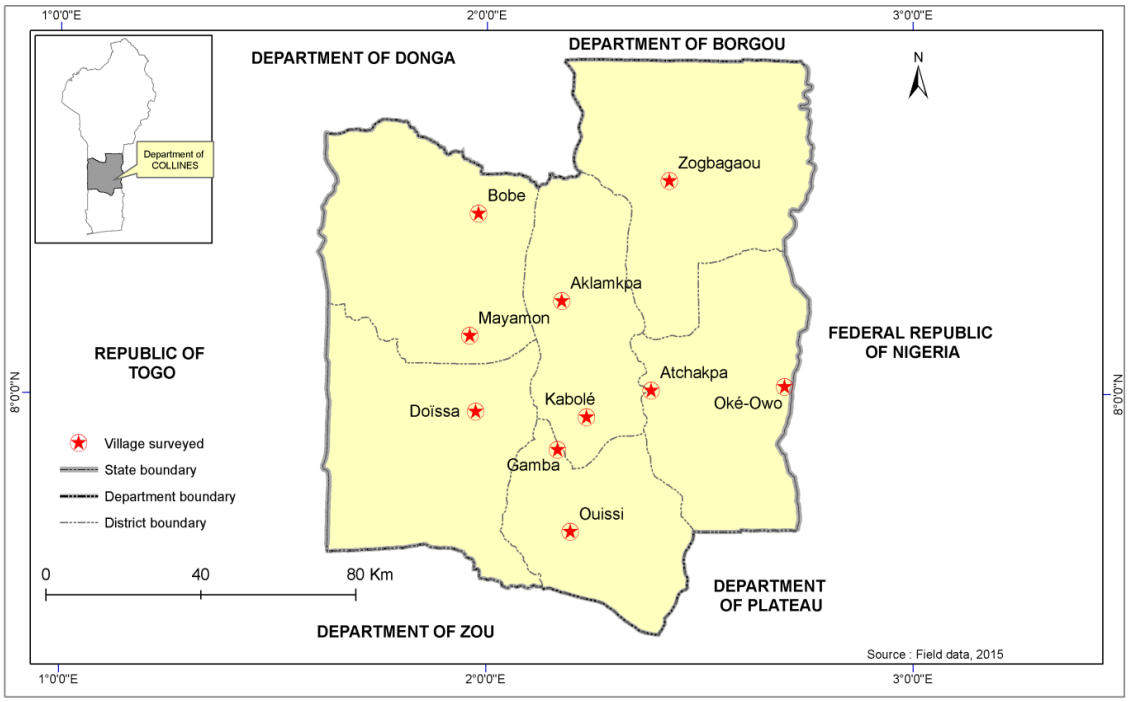

Fig. 1. Map of department of Collines showing the villages surveyed.

Data collection

In each village, group and individual interviews were conducted using tools and participatory research appraisal following Ekpélikpézé *et al.* (2016a). Per village, producers of *C. olitorius* of both sexes and of different ages were assembled with the help of the village chief. Producers were asked to list and to prioritize the various constraints related to the production of *C. olitorius* by the method of identification and gradually elimination of the most severe one (Ekpélikpézé *et al.,* 2016a). Distribution and extent of the different varieties were evaluated using Four Square Analysis method described by Dansi *et al.* (2010) and used by Ekpélikpézé *et al.* (2016b). This method allows classify the different varieties of *C. Olitorius* in each village, taking into account two parameters: the relative area (large or small) devoted to each variety and the relative number of households (few or many) which cultivate it.

In addition, this Four Square Analysis method allows to identify elite varieties, endangered varieties and also to assess the rate of genetic diversity loss. The criteria of varietal preferences, fundamental basis of adoption of varieties introduced by producers were also evaluated. In each village, producers were subjected, through group surveys, to an exercise consisting of listing the characteristics that a variety of *C. olitorius* must have in order to be adopted. Thus, both agronomic and culinary criteria were cited by the producers and prioritized using the same approach of identification and gradually elimination of the most important criteria (Ekpélikpézé *et al.,* 2016b). Then, the specific information (vernacular name and its meaning, modes of consumption, intra-specific morphological diversity, seed management, food importance and medicinal properties) were collected on each variety. At the end of the discussions, the seed samples of some varieties were collected for assessment of germination rates in the laboratory.

Germination rates evaluation of three morphotypes of C. olitorius

The seeds of three main morph types of *C. olitorius* (lobed indented, lance late and simple rounded leaves) obtained from producers on the one hand and those resulting from the multiplication in the laboratory on the other hand, were assessed against their germination rate.

A total of six samples of three morph types of *C. olitorius* were tested. For each sample, 20 seeds were seeded in petri dishes containing Whatman filter paper according to Mavengahama *et al.* (2012). The dishes were then placed in an incubator set at a temperature of 25°C. Germination was detected by the emergence of the radicle out of the seed coat (Mavengahama *et al.*, 2012). The germination rate was recorded daily for 14 days, and as germinated seeds was removed from the petri dish.

Data analyses

Data collected were analyzed by the descriptive statistics (means, percentages, etc.) and results then presented in the form of Fig. and tables. For the study area, identified constraints were prioritized following Ekpélikpézé *et al.* (2016a) based on the means of the following three parameters: the total number of villages (TNV) in which the constraint was noted, the number of villages in which the constraint was classified among the principal constraints (PCO) as the first five; the number of villages where the constraint is the major one or ranked first (MAC).

The importance of a constraint (IMC) was then determined by the formula IMC= (TNV + PCO+MAC)/3. The rate of varietal loss (RVL) at village level was calculated using the formula described by Ekpélikpézé *et al.* (2016b). RVL = (n-k)/N x 100 where n is the number of varieties cultivated by few households on small areas; k is the number of newly introduced varieties among those cultivated by few households on small areas and N is the total number of varieties recorded in the village. To analyze the relationship between the identified varieties according to their denomination parameters, these were taken as individuals and the evaluation parameters used as variables and scored 1 where applicable and 0 if not. The binary matrix compiled was used to design a dendrogram through XLSTAT-Excel Software version 2017.02.

The germination rate is determined by the formula described by (Rao *et al.*, 2006) and used by Maroufi *et al.* (2011) and Mavengahama and Lewu (2012): Germination percentage = number of germinated seeds/number of total seeds x 100.A variance analysis was performed to determine whether significant differences exist between the germination rates of the morph types studied.

Results

Socio-demographic characteristics of surveyed producers

Producers of *C. olitorius* randomly selected and surveyed were both women (52,63%) and men (47.37%). Considering the sociolinguistic groups, a high proportion of women (77.78%) compared to men (22.22%) was observed in Idaatcha while among the Mahi, 83.33% of those surveyed are men. Producers are not uniformly distributed following sociolinguistic groups: Idaatcha (47.37%), Mahi (28.95%), Ife (13.16%), Tchabe (5.26%) and Itcha (5.26%). The age of surveyed producers varied from 24 to 65 years with a mean of 41 years. Producers of the 30-40 age groups were the most numerous (76.31%) while only 23.69% producers have more than 50 years. They have a mean of 17 years' experience in the production of *C. olitorius* and more than half (52.63%) are illiterate, nevertheless 28.95% and 18.42% having a primary and secondary level respectively.

The household size of respondents varies from 3 to 16 with a mean of 7 people per household. The number of able-bodied men per household is between 1 and 7 with a mean of 2 people per household and the number of laborers for the culture of *C. olitorius* varied from 1 to 7 with a mean of 2 per household. The majority of surveyed producers (73.68%) grow *C. olitorius* on areas less than 0.5 ha whereas the large areas ranging from 1 to 5 ha are planted by 26.32% of producers (Table 1).

Table 1. Socio-demographic parameters of producers surveyed.

N°	Paramètres	Range	Mean ±standard error
1	Age (years)	24 - 65	41±11.46
2	Cultivated area (ha)	0.01- 5	0.5±1.02
3	Size of household (persons)	3 - 16	7±3.05
4	Number of active member in farming	1 - 7	2 ±1.39
5	Experience in Production of *C. olitorius* (years)	1 - 50	17±11.98

Importance, cultural practices and constraints of C. olitorius production

C. olitorius occupies an important place among the horticultural crops, in the department of Collines. It is ranked first by 73.68% of producers, second by 15.79% of producers and only 5.26% of producers rank it third and fourth. The main reasons for *C. olitorius* farming are self-consumption (100% respondents), marketing in local and urban markets (84% respondents), and ease of production (78% respondents). In the villages surveyed, *C. olitorius* is grown on clay soils (84.21% responses), in lowlands (10.53% responses) and on all types of soils (5.26% responses). For the production of *C. olitorius*, all producers surveyed (100% responses) sows by broadcasting on boards (94% responses) or in the shallows (6% responses).

However some practices related to *C. olitorius* production are adopted by producers. Crop association is practiced by 75.26% of the producers against 24.74% which make the sole cropping. Also 63.16% of producers use organic fertilizers against 36.84% who use chemical fertilizers.

The most common harvesting method is the superficial cutting of the stem, allowing producers to make several harvests over several weeks. Nine constraints affecting *C. olitorius* production were identified in study area (Table 2). Their prioritization allowed ranking susceptibility to drought as first followed by low productivity, lack of seed quality, rot of seeds during storage and susceptibility to insect. Other constraints such as susceptibility to poor soil, diseases and weeds and difficult harvest of leaves appear to be of lesser importance for the cultivation of *C. olitorius*.

Table 2. *C. olitorius* constraints in Central Benin.

Constraints	TNV	PCO	MAC	IMC	Ranking
Susceptibility to drought	10	10	3	7.67	1
Low productivity	8	8	3	6.33	2
Lack of quality seeds	8	6	2	5.33	3
Rot of seeds	6	4	1	3.67	4
Susceptibility to insects	5	3	1	3	5
Susceptibility to poor soil	2	2	0	1.33	6
Susceptibility to diseases	2	1	0	1	7
Susceptibility to weeds	1	1	0	0.67	8
Difficult harvest	1	1	0	0.67	9

TNV: Total Number of Villages, PCO: Principal Constraints, MAC: Major Constraints, IMC: Importance of a Constraint.

Varietal diversity of C. olitorius in the study area

Subject to synonymy, 34 varieties of *C. olitorius* were listed trough villages surveyed in Central Benin. Among these, 85.29% are local varieties and only 14.70% are introduced varieties mainly from Nigeria. Of these 34 varieties, 10 have elongated leaves, 11 serrated leaves and 13 rounded leaves. The number of varieties varied from 2 to 8 per village with a mean of 4 varieties per village.

The lowest diversity was observed at Okéowo and the highest diversity was observed in Bobè (Table 3).

Analysis of the distribution and extent of the identified varieties indicate that varieties Aladjlélé (50% of villages), Yoyo-doundoun (30% of villages), Yoyo-yabada (20% of villages), Ninnouwi (20% of villages) and Kinmlin (20% of villages) are cultivated by many households over large areas.

Table 3. Diversity, distribution, extent and rate of diversity loss of *C. olitorius* varieties.

Villages	TNV	H+A+	H+A-	H-A+	H-A-	NNV	RVL (%)
Aklamkpa	6	3	2	0	1	0	16.67
Atchakpa	3	1	0	0	2	0	66.67
Bobè	8	2	4	0	2	1	12.5
Doïssa	4	1	1	0	2	0	50
Gamba	3	1	0	0	2	1	33.33
Kabolé	3	2	0	0	1	0	33.33
Mayamon	6	2	3	0	1	1	0
Okéowo	2	1	0	1	0	0	0
Ouissi	4	2	1	0	1	1	0
Zogbagaou	4	1	1	0	2	1	25
Moyenne	4						29.58

TNV: Total number of varieties; H+A+: Many households and large area; H+A-: Many households and small area; H-A+: Few households and large area; H-A-: Few households and small area; NNV: Number of New varieties; RVL: Rate of varieties loss

According to the producers, these varieties are good agricultural, culinary and economic characteristics and are considered elite varieties. Moreover, certain varieties such as Alazè2, ayoyo-ibile and kpahè-ninnouwi are cultivated by several households on small areas. These are varieties with some interesting characteristics (glossy leaves giving a very sticky sauce, high market value) but with some undesirable traits (seed unavailability, low productivity, difficulties in harvesting small leaves). In the study area, only one variety, Ninnouwi-dodo, found in the village of Oké-owo, is cultivated by few households over large areas; this variety has small shiny rounded leaves very glossy and highly prized by consumers. Finally, other varieties such as Afinblikpotoè, ayoyo okpolo 3 and ninnouwi 2 are cultivated by few households on small areas (Table 4). According to producers, these varieties have many undesirable traits such as low productivity, non-glossy appearance of the leaves, which give a non-sticky sauce, but these varieties are insect and drought resistant.

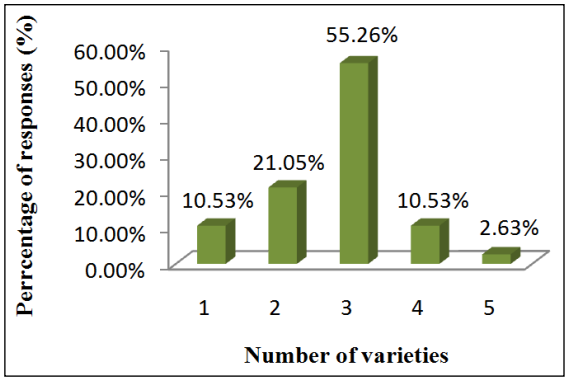

Fig. 2. Diversity of *C. olitorius* maintained at households level in central Benin.

At village level, a significant proportion of varieties are threatened. The loss of varietal diversity per village varied from 0% (Mayamon, Okeowo and Ouissi) to 66.67% (Gamba and Atchakpa) with a mean of 29.58% (Table 4). There are various causes of this loss of diversity listed by producers. It is mainly the low market value of some varieties, low productivity, the unwanted taste, not shiny leaves, and little slimy after cooking and low productivity in seeds. Then, subject to synonymy, 14 varieties (41.17%) are in the process of disappearance and 5 either 14.70% are newly introduced (Table 4). At household level, the number of *C. olitorius* varieties varies from 1 to 5. In total, 55.26% of households cultivate 3 varieties of *C. olitorius* and only 2.63% of households produce 5 varieties of *C. olitorius* (Fig. 2).

Folk nomenclature and taxonomy

In central Benin and through the five sociolinguistic groups, 28 vernacular names of *C. olitorius* were recorded, including 10 main names and 18 others secondary (Table 5). The secondary names derived from three main names Ayoyo (Ifê, Itcha), Ninnouwi (Mahi) and Yoyo (Idaasha). In some sociolinguistic groups, *C. olitorius* has a single name as the Tchabè (Owoyo), but in other ethnic groups such as Mahi, this species is designated under five local names (Afinblikpotoé, Aladjlélé, Alazé, Kinmlin and Ninnouwi). Recorded *C. olitorius* local names have meanings which refer to different parameters such as the shape, nature or aspect of leaves. The color of stems, the taste. the origin or age of varieties corresponding to criteria of denomination.

Table 4. Distribution and extent of *C. olitorius* varieties in the study area.

N°	Varieties	Number of villages	Distribution and extent
1	Afinblikpotoè	1	Doïssa (- -)
2	Aladjlélé	5	Ouissi (++), Zogbagaou (++), Aklamkpa (++), Bobè (++), Doïssa (++)
3	Alazé1	1	Aklamkpa (+-)
4	Alazé2	1	Aklamkpa (+-)
5	Ayoyo ékô	1	Mayamon (++)
6	Ayoyo étigbokia	1	Bobè (++)
7	Ayoyo ibilè	1	Mayamon (+-)
8	Ayoyo kprékété	1	Mayamon (++)
9	Ayoyo okpolo 1	1	Mayamon (+-)
10	Ayoyo okpolo 2	1	Mayamon (+-)
11	Ayoyo okpolo 3	1	Mayamon (--)
12	Ayoyo oléti wèyè wèyè	1	Bobè (+-)
13	Eyobè1	1	Bobè (--)
14	Eyobè2	1	Bobè (+-)
15	Ifanyé	1	Bobè (--)
16	Kinmlin	2	Aklamkpa (++), Zogbagaou (+-)
17	Kpahè ninnouwi	1	Bobè (+-)
18	Ninnouwi dodo	1	Oké-owo (-+)
19	Ninnouwi sangan	1	Zogbagaou (--)
20	Ninnouwi Tchigan	1	Ouissi (++)
21	Ninnouwi togbodjagbadja	1	Bobè (+-)
22	Ninnouwi1	2	Oké-owo (++), Aklamkpa (++)
23	Ninnouwi2	1	Doïssa (--)
24	Ninnouwi3	1	Doïssa (+-)
25	Ninnouwi4	1	Aklamka (--)
26	Ogan ninnouwi	1	Zogbagaou (--)
27	Owoyo1	1	Atchakpa (--)
28	Owoyo2	1	Atchakpa (++)
29	Yoyo doundoun	3	Kabolé (++), Ouissi (- -), Atchakpa (- -)
30	Yoyo édjo	1	Gamba (--)
31	Yoyo kpokoto	1	Gamba (--)
32	Yoyo olèssèkpikpa	1	Ouissi (+-)
33	Yoyo oyinbo	1	Kabolé (--)
34	Yoyo yabada	2	Gamba (++), Kabolé (++)

Table 5. Folk nomenclature of *Corchorus olitorius* varieties in Central Benin.

Varieties	Ma	Id	Tc	If	Nt	Meaning	Criteria of denomination
Afinblikpotoè*	x					Leaves of ash colour	Non-shiny leaves
Aladjlélé*	x					Wide leaves	Shape of leaves
Alazé*	x					Wide leaves	Shape of leaves
Ayoyo*						Jew's mallow	Sticky leaves
Ayoyo ékô					x	Nigéria Jew's mallow	Origin
Ayoyo étigbokia				x	x	Jew's mallow with wide leaves	Shape of leaves
Ayoyo ibilè				x		Jew's mallow of antique	Age
Ayoyo kprékété				x		Jew's mallow with small leaves	Shape of leaves
Ayoyo okpolo				x		Jew's mallow of frog	Shiny leaves
Ayoyo wèyè wèyè				x		Exotic Jew's mallow	Origin
Eyobè*				X		Jew's mallow	Sticky leaves
Ifanyé*					x	Jew's mallow	Sticky leaves
Kinmlin*	x					Jew's mallow	Sticky leaves
Ninnouwi*	x					Jew's mallow	Sticky leaves
Kpahè ninnouwi	x					Jew's mallow of duck	Shape of leaves
Ninnouwi dodo	x					Exotic Jew's mallow	Age
Ninnouwi sangan	x					Jew's mallow of good quality	Organoleptic quality
Ninnouwi Tchigan	x					Jew's mallow of good quality	Organoleptic quality
Ninnouwi togbadjagbadja	x					Jew's mallow with wide ears	Shape of leaves
Ogan ninnouwi	x					Jew's mallow of good quality	Organoleptic quality
Owoyo*			x			Jew's mallow	Sticky leaves
Yoyo *		x				Jew's mallow	Sticky leaves
Yoyo doundoun		x				Exotic Jew's mallow	Age
Yoyo édjo		x				Jew's mallow of snake	Shape of leaves
Yoyo kpokoto		x				Jew's mallow with small leaves	Shape of leaves
Yoyo olèssèkpikpa		x				Jew's mallow with red stem	Stems color
Yoyo oyimbo		x				Exotic Jew's mallow	Origin
Yoyo yabada		x				Jew's mallow with spread fingers	Shape of leaves

*: mean; Ma: Mahi; Id: Idaasha; Tc: Tchabè; If: Ifè; Nt: N'tcha.

Among these criteria, the shape (32.14% of responses) and nature (25% of responses) of leaves are the most used (Fig. 3).

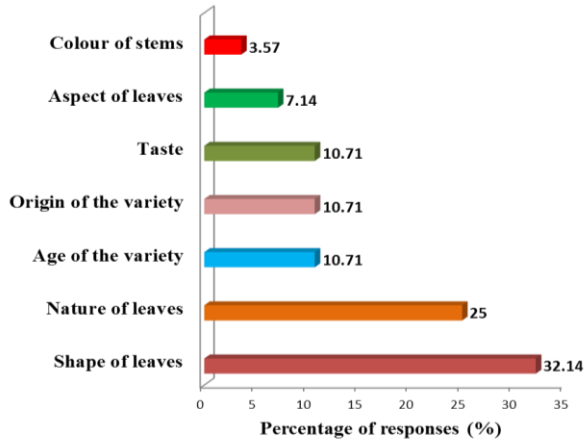

Fig. 3. Criteria of denomination of *C. olitorius* varieties and their importance.

Using the criteria of denomination as variables, the 34 inventoried varieties in the study clustered into seven (7) clusters (Fig. 4). At first, cluster C1 groups varieties that are no-shiny elongated leaves (Fig. 5a), cluster C2 is characterized by varieties having shiny elongated leaves (Fig. 5b) and cluster C3 is characterized by a variety having elongated leaves with limbs with lateral lobes (Fig. 5c). The three clusters are categorized by the varieties having elongated leaves. Afterward, cluster C4 gathers the varieties whose leaves are serrated and shiny (Fig. 5d), cluster C5 consisting of shiny rounded leaves varieties (Fig. 5e) while cluster C6 includes a non-shiny rounded leaf varieties (Fig. 5f). The clusters C5 and C6 have the varieties having rounded leaves. Finally, cluster C7 is characterized by a variety with elongated leaves but with red stems (Fig. 5g) unlike all other groups with green stems (Fig. 5h).

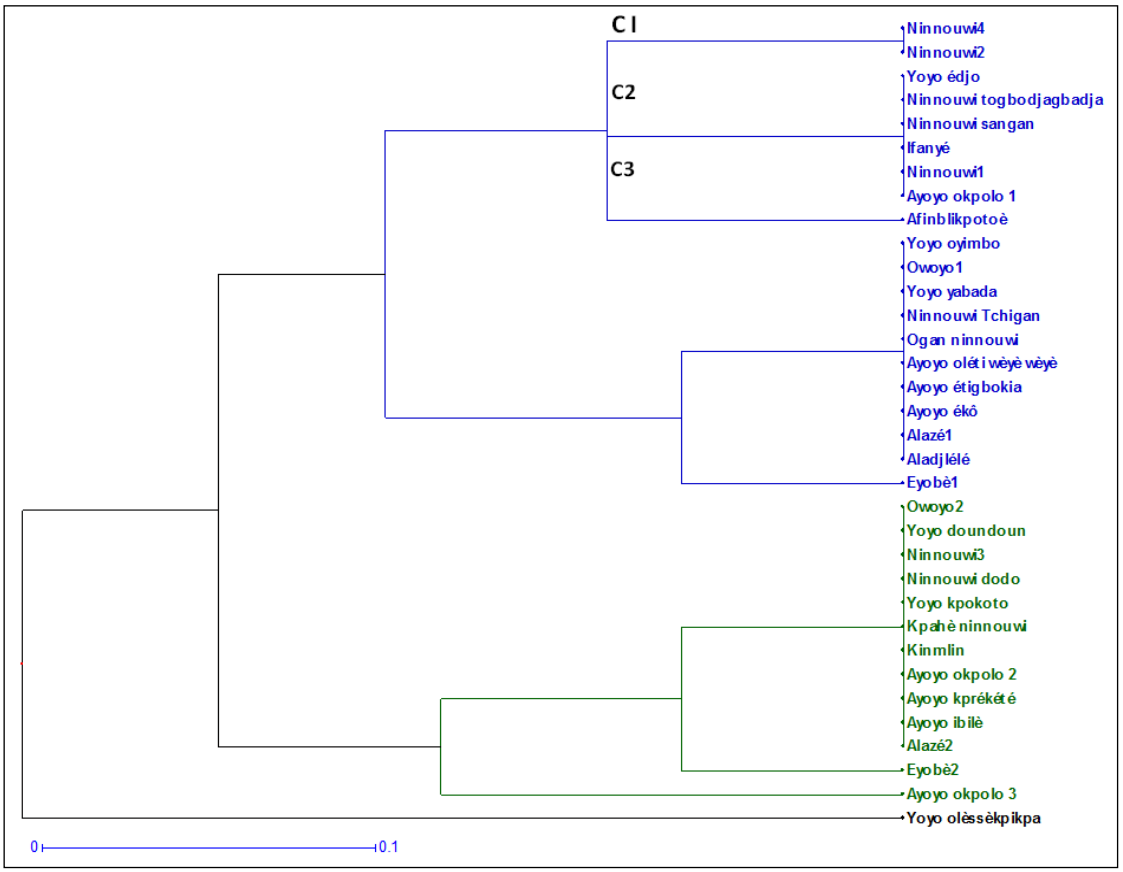

Fig. 4. Dendrogram shoving clusters based on denominations criteria used by producers to identify *C. olitorius* varieties in the study area.

Cluster C1= varieties that are no-shiny elongated leaves, Cluster C2= varieties having shiny elongated leaves, Cluster C3= variety having elongated leaves with limbs with lateral lobes, Cluster C4= varieties whose leaves are serrated and shiny, Cluster C5= consisting of shiny rounded leaves varieties, Cluster C6= includes a non-shiny rounded leaf varieties, Cluster C7= variety with elongated leaves but with red stems.

Fig. 5. Variability of leaves (shape, shiny) and stem (colour) of *C. olitorius* collected in central Benin.

Criteria of varietal preference

Within the existing diversity, *C. olitorius* varieties are chosen by producers on the basis of 11 criteria (Table 6). These criteria can be classified into three categories: agronomic preference criteria which are the most numerous (8 criteria) followed by culinary criteria (2 in total) and economic criteria represented by only one.

Of these, leaf' high productivity, very sticky sauce, seed productivity, availability of good quality seeds and market value are the most important criteria. These criteria are followed by shiny leaves, tolerance to drought, very taste, earliness and low fertilizer requirements which are the least important but cited as main criteria in some prospected villages (Table 6).

Table 6. Farmers' varietal preference criteria in Central Benin.

Categorization	Preferences	TNV	PCO	MAC	IMC	Ranked
Agronomic	High Productivity	8	6	4	6	1
	Productivity in seeds	6	4	2	4	3
	Availability of good quality seeds	6	3	1	3,67	4
	Shiny leaves	5	4	0	3	6
	Earliness	2	2	0	1,33	9
	Tolerance to drought	4	2	0	2	7
	Tolerance to pets and diseases	2	2	0	1,33	9ex
	Adaptability to infertile soils	2	1	0	1	11
Culinary	Very stick sauce	8	5	2	5	2
	Very taste	4	1	0	1,67	8
Economic	High market value	6	4	1	3,33	5

Seeds system

Various methods of seed production are adopted by the producers of *C. olitorius*. Throughout the study area, 54.74% of the surveyed producers exclusively use seeds from their own harvest for the next planting while 31.21% of surveyed producers supplement their seeds with purchases. Other producers either (11.42%) obtain their seeds only through purchases from the market or agricultural promotion agency and only 2.63% of producers received them by donations. Once harvested, seeds are stored either as cloves (23.68% responses) or as seeds (76.32% responses) in various storage structures. Eight (8) storage utensils (pieces of cloth, polythene bags, plastic buckets, calabashes, bottles, papers, canary pots and tins) have been inventoried. Among these, pieces of cloth (42.62% responses) and polythene bag (29.3% of responses) are the most frequently used (Fig. 6).

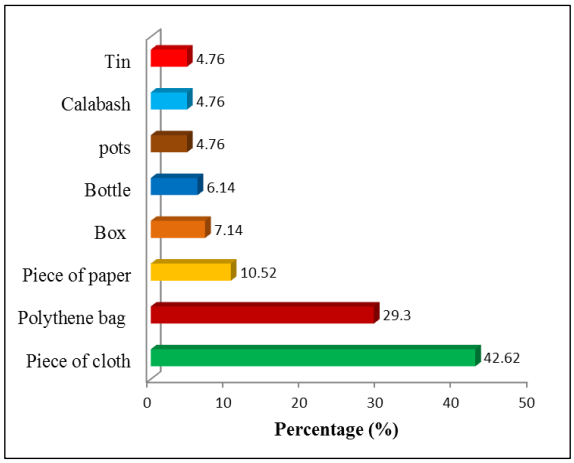

Fig. 6. Seeds conservation methods.

Food uses, medicinal properties and wealth of C. olitorius varieties in iron

Across the study area, all of the producers surveyed (100%) regularly consumed *C. olitorius* such as a sauce which is the main mode of consumption of this vegetable. The fresh or dried leaves give a stick sauce which is served as the accompaniment to the starch staple (paste of maize, sorghum or millet and pounded yam). According to the respondents, relying on the stick side sauce which is the culinary search criteria and subject to synonymy, 11 varieties including 5 varieties of rounded leaves shiny (ayoyo-ibile, kinmlin, ninouwi-dodo, yoyo-doundoun and yoyo-kpokoto) and 6 varieties of serrated leaves shiny (aladjlele, alaze, ayoyo-eko, ayoyo-weyeweye, ninouwi-tchigan, yabade) were the most sticky according to the producers (Fig. 7).

All the respondents reported that *C. olitorius* is used also for its medicinal values (Fig. 8). Indeed, a decoction of these leaves would treat many diseases whose the most important are typhoid fever (95.23% of villages), anemia (74.38% of villages), malaria (52.22% of villages) and ulcer (26.38% of villages). The frequencies of citation of the illnesses treated by the leaves of *C. olitorius* are shown in Fig. 9. Most of surveyed producers (87%) thought that shiny leaf varieties would be rich in iron; According to these, the iron content is proportional to the brightness of the leaves.

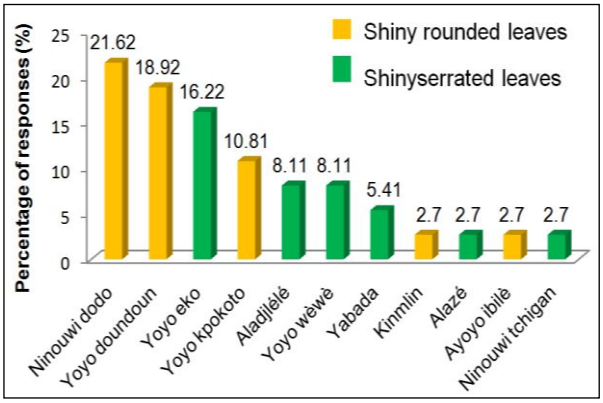

Fig. 7. Frequency of citations of *C. olitorius* varieties very stick.

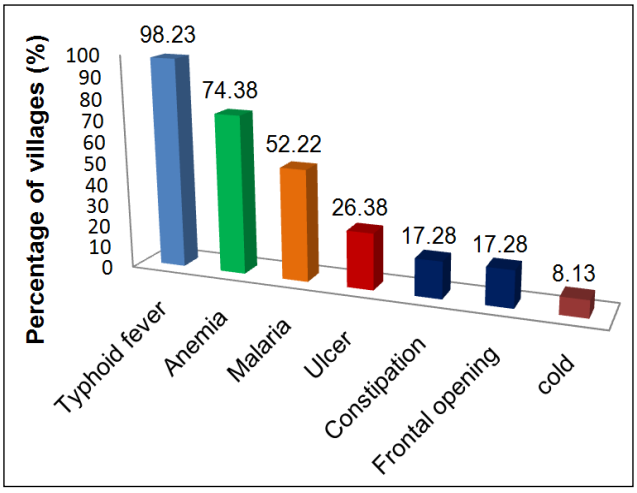

Fig. 8. Importance of citations of the illnesses treated by *C. olitorius* across ethnic areas.

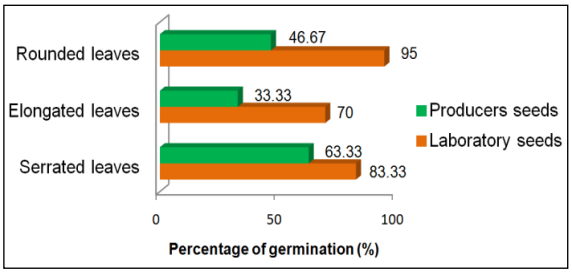

Fig. 9. Variation of germination percentage of three morphotypes of *C. olitorius* following the source.

Comparative evaluation of the germination capability of three morph types of C. olitorius

The germination test carried out on the seeds of *C. olitorius* three morphotypes (serrated leaves, rounded leaves and elongated leaves) have given positive results. Therefore, the final percentage of germination varies from 33.33% to 63.33% for seeds of producers and from 70% to 95% for laboratory seeds (Fig. 9). The analysis of the germination graph allowed obtaining three phases: a phase of latency corresponding to the absorption of water by seeds during which the rate of germination is zero (Fig. 9). The duration of this phase varies according to the provenance of seeds. It is short in the seeds of the laboratory but becomes longer in the seeds of producers for which this phase can last up to 3 days.

Then, a linear phase corresponds to a rapid increase of the germination rate which evolves proportionally with time. For laboratory seeds, this phase is very short (6 to 7 days) while it is relatively long for producer seeds (10 to 12 days).

Finally, the third phase corresponds to a landing representing the final germination rate, reflecting the germinate capacity of seeds following to the morphotype and provenance.

This result indicated that final germination rates vary from one morphotype to another and whatever the morphotype, final germination rates of seeds from the laboratory after multiplication are higher than those of seeds directly from producers (Fig. 10).

Analysis of the data indicated that there was a significant difference ($p < 0.05$) in the germination rate of the seeds studied. There was also a significant interaction ($P < 0.05$) between the replicates and the different seeds studied. However, the interaction between days and repetitions showed no significant difference ($P > 0.05$) (Table 7). In addition, there was a significant difference ($p < 0.05$) in the germination percentage of the samples studied with the highest values for the morph types of laboratory whereas those of producers recorded lowest values (Table 8).

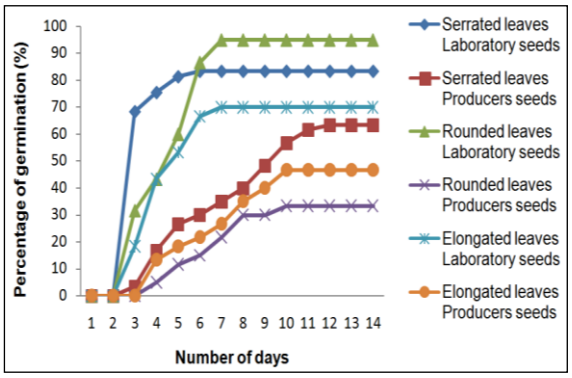

Fig. 10. Evolution means rate germination samples of three morph types of *C. olitorius*.

Table 7. Analysis of variance of germination rate of three morphotypes of *C. olitorius*.

Source		Model	Days	Repetition	Type*Seed	Rep.*Seed	Days*Rep
DF		57	13	2	1	2	26
Serrated leaves	MS	1420.139	3744.62	37.80	177.68	23166.96	5.75
	F	168.107	443.27	4.47	21.03	2742.37	0.68
	Pr > F	< 0.0001	< 0.0001	0.021	< 0.0001	< 0.0001	0.834
Rounded leaves	MS	1074.922	2400.11	744.94	119.94	22836.01	24.43
	F	87.762	195.96	60.82	9.79	1864.44	1.99
	Pr > F	< 0.0001	< 0.0001	< 0.0001	0.001	< 0.0001	0.042
Elongated leaves	MS	1845.395	4418.86	211.61	300.30	37719.05	17.70
	F	92.972	222.63	10.66	15.13	1900.31	0.89
	Pr > F	< 0.0001	< 0.0001	0.000	< 0.0001	< 0.0001	0.614

DF: Degree of freedom, MS: Mean Squar, F: Fisher, Pr: Probability, Rep: repetition,

Table 8. Means comparison.

Seeds type	Laboratory seeds	Producers seed	Pr > F
Serrated leaves	83.33 a	63.33 b	0.000
Rounded leaves	95 a	33.33 b	0.000
Elongated leaves	70 a	46.67 b	0.000

Pr: Probability; F: Fisher; (a,b): means of the same line followed by letter don't differ at 5% threshold.

Discussion

C. olitorius is a traditional cultivated leaf vegetable that contributes strongly to food security of populations in the department of Collines situated in Center of Benin. For most of producers surveyed, it is the most important market gardening in terms of area. These results are similar with those of Adebooye *et al.* (2003) which showed that *C. olitorius* is classified among the most cultivated leafy vegetables. Also, *C. olitorius* is the most widely used species in the genus *Corchorus* in Benin (Akoègninou *et al.*, 2006, Dansi *et al.*, 2008) and in Ivory Coast (Ta-Bi *et al.*, 2016). However, its production is facing enormous difficulties in the department of Collines. The constraints cited by the producers are mainly of agronomic order as was the case on the pepper (Orobiyi *et al.*, 2016). The major constraints are drought, low productivity, lack of quality seeds, rot of seeds and susceptibility to insect, and could be overcome by agronomic research which, in a participatory way, must develop or identify in the existing diversity of high-performing varieties according to their varietal assessment criteria. It is therefore important to establish *C. olitorius* breeding program in the study area designed to address these constraints. These observations are similar to those of Ekpelikpézé *et al.,* (2016a) and Orobiyi *et al.,* (2016) on sugarcane and chili pepper respectively.

The success of plant breeding is found in the nature and degree of diversity in a germplasm (Das and Kumar, 2012). In central Benin, there is rich in phenotypic diversity of *C. olitorius*. The number of *C. olitorius* varieties inventoried in the villages of Bobe and Mayamon is high compared to other villages, indicating the predominance of this crop in these villages. The distribution and extent of *C. olitorius* varieties vary following the village.

In most of the surveyed villages, there are varieties cultivated by few producers on small areas and are therefore endangered. Thus, the rate of varietal diversity loss is high in some villages indicating the need to collect and preserve ex situ these varieties threatened. This observation is not specific to *C. olitorius*. Similar results were reported on other crops as cowpea (Gbaguidi *et al.*, 2015) and sugar (Ekpelikpeze *et al.*, 2016b).

In folk taxonomy, local names generally vary following the sociolinguistic groups, the villages, and sometimes following the household within the same village (Adjatin *et al.*, 2012, Ta-Bi *et al.*, 2016). This nomenclature facilitates transactions and communication around the recognition, cultivation and use of these varieties: agronomic performance, culinary qualities, etc. Variations of names through ethnic areas is very common and was reported on leafy vegetables (Dansi *et al.*, 2008; Adjatin *et al.,* 2012), chili pepper (Orobiyi *et al.*, 2016) and sugar (Ekpelikpeze *et al.*, 2016b). It is very unlikely that all these correspond to different clones. In fact, the secondary names derived from of three main names Ayoyo (Ifê, Itcha), Ninnouwi (Mahi) and Yoyo (Idaasha) make it possible to note the variability existing within the species. To avoid duplicates, synonymies and homonymies should be eliminated through both morphological and molecular characterization (Ekpelikpeze *et al.*, 2016b). Based on the morphological characters used as criteria of denomination by producers, 34 varieties identified were classified into 7 morphotypes. These results are contrary to those of Kiebre *et al.* (2016) which found two types of elongated and serrated leaves without referring to the shiny appearance of the leaves. In addition, their findings identified three types of green, red-green and red stems. In the case of our study, only the green and red stems were inventoried in the study area.

These differences could be explained by the fact that *C. olitorius* is still in domestication in Burkina Faso, which is situated in an arid zone, although it is already widely grown in fields and vegetable gardens in central Benin which is relatively humid.

According to the surveyed producers, varieties of shiny leaves are the most appreciate because not only do these leaves give sticky sauces but contain iron to prevent anemia especially in children under five years of age. According to Oyedele *et al.* (2006), *C. olitorius* is known to contain high levels of iron and foliate which are useful for the prevention of anemia, and it is usually recommended for pregnant women, nursing mother and infant in weaning because it is believed to be rich in iron. Moreover, the agronomic, culinary and economic criteria contributed to the selection of varieties by producers. Among the major criteria, the most cited are the high productivity and the sticky sauce. For *C. olitorius* and like all leafy vegetables, high productivity in leaves or consumable biomass is the most sought character by both producers and consumers. These results are similar to those obtained by Adeoti *et al.*, (2012) on *Sesamum radiatum*. In addition, a sticky sauce is the most important culinary criterion to be involved in breeding programs. According to Nyadanu *et al.*, (2016), in select and breeding of improved varieties of *C. olitorius*, the slimy nature of leaves is an important trait to consider. Then, in the absence of this information, researchers risk to eliminate the traits that make indigenous vegetables so desirable in the first place.

Sauce is the main mode of consumption of *C. olitorius* which is prepared with fresh or dried leaves according to the second mode reported by Dansi *et al.*, (2008). Thus, leaves are washed by rubbing between the hands, sliced and cooked in soups with a little potash to give slimy consistency. Apart from food uses, the surveyed use *C. olitorius* to treat typhoid fever, anemia, malaria and ulcer. This suggests medicinal and pharmaceutical importance of the crop. Several authors have reported the medicinal values of this leafy vegetable (Dansi *et al.*, 2008, Parvin *et al.*, 2015). Thus, *C. olitorius* can be considered as neutraceutical like other leafy vegetables such as *Crassocephalum crepidioides, Crassocephalum rubens* (Adjatin *et al.*, 2013a), *Launea taraxacifolia* (Sanoussi *et al.*, 2015) and *Lippia multiflora* (Djengue *et al.*, 2017). Phytochemical analyzes on the extracts of the leaves of *C. olitorius* should be carried out in order to invalidate or confirm these medicinal properties.

Seeds are stored in material which were the same in all the villages surveyed but their frequency of utilization was highly variable. Pieces of cloth and polythene bag were the mostly used material because they are available through the study ear. These finding are similar to those obtained by Djengue *et al.* (2017) on *Lippia multiflora*. According to Eteka *et al.* (2011), availability, culture and habit are the reasons for frequent use of the above utensils. Seeds represent an important factor in food production and their quality determines the performance of a crop (Achigan-Dako *et al.*, 2010). Analysis of seed germination rate of *C. olitorius* morphotypes studied indicates variability of rate according to the shape of leaves. The significant difference observed among the morphotypes provides to the plant breeder an opportunity to select the best in relation to germination percentage. The observed variability could be attributed to the genetic differences among the accessions. Olanrewaju and Nwangburuka (2012) also reported significant differences in accessions of *C. olitorius* collected in Nigeria. The germination rates of the samples from the producers are lower than those of the laboratory seeds. Seed viability depends not only on shelf life (Nour and Brinis, 2016) but also on storage structures (Gbaguidi *et al.*, 2015) and harvest days (Feyem *et al.*, 2016). Lack of quality and rot of seeds caused the low germination capacity and held up the *C. olitorius* production in study area. There is also the lack of structures of seeds production which constrain most producers to satisfy themselves with seeds derived from their own production. This situation calls for by the development of local seed programs including commercial seed supply small-scale seed enterprises and community-based seed supply systems that will ensure production and marketing of quality seed.

According to Olanrewaju and Nwangburuka (2012), the production and supply of quality seeds constituted a crucial step in the promotion of *C. olitorius*. Thus, research and extension structures should help to promote not only improved varieties but also seed production structures for better production of *C. olitorius* in the study area.

Conclusion

Ethnobotanical investigations carried out in central Benin have revealed a high diversity of *C. olitorius* which is subject to many constraints. These last led to low productivity and loss of several varieties. The names vary from one sociolinguistic group to another, and on the basis of their naming criteria, the form of the leaves, the color of the stems and the organoleptic quality, this diversity was structured into seven morphotypes. Thus, agro-morphological and molecular characterizations are necessary to identify duplicates and clarify synonymy for the implementation of a varietal improvement program. The criteria, identified with participative way, must be involved in selection and breeding programs. Apart from food uses, *C. olitorius* has some medicinal values and is used as nutraceutical, it is important to look for the phytochemical elements that confer to the leaves its medicinal properties attributed by the surveyed. Though the study area, most of *C. olitorius* seeds from farmers are self-produced and variability in the germination rate of accessions was observed. This variability is highly influenced by local practices. For better production of *C. olitorius*, it is important to establish quality seed production structures according to the needs or preferences of the producers.

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