Scientia Horticulturae 239 (2018) 234–241

Contents lists available at ScienceDirect

Scientia Horticulturae

journal homepage: www.elsevier.com/locate/scihorti

Morphotype diversity of *Corchorus olitorius* and influence of agricultural practices on its potential major pest insects

Aquilin E. Gbèdolo[a,b], Anicet G. Dassou[a,*], Hospice G. Dassou[b], Innocent Dossou Aminon[a], Bonaventure Aman Omondi[c], Alexandre Dansi[a]

[a] Laboratory of Biotechnology, Genetic Resources and Plant and Animal Breeding, National University of Sciences, Technologies, Engineering and Mathematics, BP: 14 Dassa, Benin

[b] Department of Plant Biology, FAST, University of Abomey-Calavi, Cotonou, Benin

[c] Bioversity International, IITA-Benin, 08 BP 0932 Tri Postal, Cotonou, Benin

ARTICLE INFO

Keywords:
Corchorus olitorius
Morphotypes
Constraints
Insect pests
Southern Benin

ABSTRACT

Corchorus olitorius L. is one of the traditional leafy vegetables of high food and socio-economic value in Africa. Although widely exploited, its varietal diversity is unknown and its domestication remains challenged by pests and diseases presently observed among subsistence users. This study aims to determine the morphotype diversity of *C. olitorius* in Southern Benin and the durability of its agroecosystem by the influence of agricultural practices on the major pest insects related to its production. Using participatory research methods, surveys were conducted in 21 villages randomly selected across the study area. Results revealed seven different morphotypes of *C. olitorius*, three of which were wild but used in traditional medicine and four were cultivated. Among the nine constraints reported by farmers, the attack of seven pest insects and the non-distinction of the seeds of the different cultivated morphotypes are the two most important constraints. The seven most common potential pest insects observed by between 10–100% of the farmers, in study area are: *Acrea* sp, *Aulacophora Africana, Helicoverpa armigera*, *Spodoptera litoralis, Zonocerus variegatus, Podagrica* spp. and *Acrea acerata.* The infestation by these insects were not linked to specific morphotypes of *C. olitorius*, but varied by locality. The agricultural practices that might influence the presence of any *C. olitorius* pests were intercropping and dormancy cutting, seedling after sowing and number of harvests. This information will contribute to a better production of the varieties of *C. olitorius* and the different crop associations could be integrated into methods of ecological management of the pests of *C. olitorius*.

1. Introduction

Traditional leafy vegetables play an important role in the diets of populations of the world by assuring them the essential part of their nutritional and medicinal needs (Dansi et al., 2011; Odhav et al., 2007; Uusiku et al., 2010). Their content of iron, vitamins A and C corresponds to health benefits particularly significant in countries where there are many cases of anemia caused by iron deficiency, and to counter the effects of malaria, and immune deficiency (Ndlovu and Afolayan, 2008; Ojiewo et al., 2013). The presence of high carotenoids rate in most African leafy vegetables would confer antioxidant properties favorable to human health (Oboh et al., 2009). Thus there has been a recent focus on the domestication breeding and production of traditional vegetables especially in peri-urban environments. Monocultural production of these vegetables in irrigated year-round systems may lead to new challenges associated with the cropping characteristics of the available varieties, product quality under intensive management and ability to withstand persistent defoliation associated with commercial production. Similarly consumer preferred qualities and post-harvest novel pest challenge and pest resistance may become new issues to pursue. Most significantly, the possibility of emergence of new pests of recently domesticated crops is a phenomenon that is difficult to predict, although some of the eventual pests might be among pests and pathogens already using these and closely related species for survival. Many traditional leafy vegetables exist as semi cultivated species, so, enable humans to exploit uncultivated environments or crop land off season. This increases the nutritional returns and mineral cycling in the environment.

Corchorus olitorius is one such vegetable. Commonly known as "Jew's mallow", "tossa jute", "bush okra", "krinkrin", "molokhia", "West African sorrel" and "jute mallow", it is rich in minerals, vitamins and other nutritional factors (Bailey, 2003). This is one of the most widely

* Corresponding author.
E-mail address: dassoua5@gmail.com (A.G. Dassou).

https://doi.org/10.1016/j.scienta.2018.05.047
Received 13 March 2018; Received in revised form 8 May 2018; Accepted 24 May 2018
Available online 30 May 2018
0304-4238/

consumed traditional vegetables in Africa (Ngomuo et al., 2017a,b) and is also consumed in Asia (Kar et al., 2009). Obtained from both cultivated and wild sources, it is rich in vitamins, mineral salts and folic acid, constituting an important nutritional contribution (Zeghichi et al., 2003). The leaves are consumed as a component of vegetable based dish that accompany starchy dishes. It may be prepared alone or in mixtures with legume leaves (East Africa) or other wild vegetables or in mixture enriched with fish sauce. Thus, it could play an extremely important role in food security and the fight against poverty in Africa (Attere, 1999).

Although *C. olitorius* is widely used in Asia and Africa and despite its socio-economic and nutritional importance, several constraints are linked to the development of the plant in the wild or cultivated. Previous studies have focused on the agromorphological and genetic evaluation of accessions towards boosting a breeding programme (Kiebre, 2016) on the agromorphological evaluation of *C. olitorius* accessions respectively in Burkina Faso and Ivory Coast. Others studies were on morphotype diversity (Akoroda, 1985); seed production in Nigeria (Akoroda and Akintobi, 1983); domestication, ethnobotany and production constraints in Ghana (Nyadanu et al., 2017). Being a plant in the process of domestication, its genetic diversity is little studied, meaning the existing studies may not be applied across the diverse ecological range of this vegetable. Similarly, most of these studies do not address the diversity and the potential impacts of insect pests that feeding off this plant in the wild and cultivated environments. Due to the fact that the plant is harvested from the wild and consumed, economic thresholds are tough to determine. Pests are potential threats to wider cultivation and efforts must be made to adapt varieties to them. At the same time, farmers suffer a decline in selling prices because of the low level of purchasing power of consumers (Adégbola and Singbo, 2001).

This study therefore investigated the morphological diversity of wild and cultivated *C. olitorius* existing in South Benin, as a basis for documenting desired characteristics and comparing potential diverse populations exploited. We also documented the potential pests affecting the crop, their prevalence and the farmer's knowledge of these pests, their symptoms and damage levels. Finally we investigated the link between the potential pests and crop management practices. Specifically, the aim was to: (i) make an inventory of the different morphotypes of *C. olitorius* in southern Benin; (ii) rank varietal preferences criteria and crop constraints of different morphotypes of *C. olitorius* in southern Benin; (iii) identify the key potential insect pests associated to the production and (iv) determine the influence of agricultural practices on the presence of major insect pests.

2. Material and methods

2.1. Study site

The study was carried out in 5 districts of Southern Benin, namely the Atlantic, Oueme, Plateau, Mono and Couffo. These districts are located in the Guineo-Congolese agroecological zone. It is subdivided into four phytogeographic districts: Costal zone, Pobe, Oueme Valley and Plateau (Adomou et al., 2006). It is characterized by two dry seasons that alternate with two rainy seasons with an annual average precipitation ranging from 1100 to 1400 mm/year (Yabi and Afouda, 2012). The study area is characterized by a subequatorial climate, marked by high but not excessive temperatures that revolve meanly around 27.5 °C per day. The average relative humidity is 80% per day. For the geomorphology, the Southern Benin region includes the low altitude coastal zone, including sandy soils of various ages, lagoons and swamps.

2.2. Farmers selection and participatory surveys on production constraints and preference criteria of C. olitorius

Twenty-one (21) villages were randomly selected for the survey across the five districts. The choice of these villages was initially made through documentary research in particular based on the study of Alissou (2011). We first identified three villages producing *C. olitorius* in the Mono-Couffo districts. It was once in these three villages that farmers informed us on other villages where *C. olitorius* is cultivated. The data were collected in the various villages during August to September 2016 through the use of tools and methods of participatory research approach, such as direct observation, group discussions, individual interviews and field visits (Kombo et al., 2012; Dansi et al., 2013; Dossou-Aminon et al., 2014). Information on the locality (district name, village name, ethnic group) was first documented after a detailed presentation of the research objectives to the authorities and farmers. Farmers were then asked to cite in vernacular names the different morphotypes of *C. olitorius* produced in their villages and identified on the basis of 6 morphological parameters: leaf size, margin form, leaf, stem, ribs and ligules. Discussions with farmers, different morphotypes produced, their morphological descriptions, their vernacular nomenclatures as well as the constraints linked to their production have been documented. The constraints were classified according to Dansi et al. (2013) by identifying and eliminating the most severe. The agronomic, economic and culinary performance of identified *C. olitorius* morphotypes were also documented using the spontaneous reaction evaluation method. For each parameter studied, morphotypes are evaluated farmer by farmer using 2 scores: 0 and 1. Score 1 is assigned when the performance of the morphotype is recognized by the farmer for the parameter considered. If not, the score is 0.

2.3. Determination of agricultural practices and major potential insect pests of C. olitorius

Information on agricultural practices was collected on the types of associated crops, seeds dormancy emergence, date of seeds lift after seeding, duration between seedling and harvest, number and date of harvest, the types of fertilizers and pesticides used by the farmers. During the visits to the *C. olitorius* production sites, insects and their damages were observed directly on the crops and recorded (or documented). Initially, they were asked to identify on a sheet the pest insects of *C. olitorius*. On this sheet, we put the photos of all the pest insects revealed by the documentary research. Farmers are individually then invited to list the other insects that attack their plants of *C. olitorius* and which are neither observed directly nor represented in image on the previous sheet. Then, the damages were observed directly on plants and noted in percentage. Insect pests known by farmers were collected and identified in our entomology Unit of laboratory BIORAVE of National University of Sciences, Technologies, Engineering and Mathematics (UNSTIM – Benin).

2.4. Data analyses

Correspondence Factorial Analysis (AFC) was carried out to determine the relationship between the localities of production of *C. olitorius* and the morphotypes of *C. olitorius* grown on the one hand and the presence of the main pests of *C. olitorius* on the other hand. The same AFC was carried out to determine the relationship between the crop associations with *C. olitorius* and the presence of the major insect pests. Analyses of Variances (ANOVA) of the Generalized Linear Model (GLM) distribution and logit link with the binomial family were carried out to determine the effects of agricultural practices and types of crop associations on the presence of the major insect pests of *C. olitorius*. All the analyses were carried out in R (R Developer Core Team 2014) at the significant level of 5%.

Fig. 1. Photos of morphotypes of C. olitorius wild (to left) and cropped (to right).

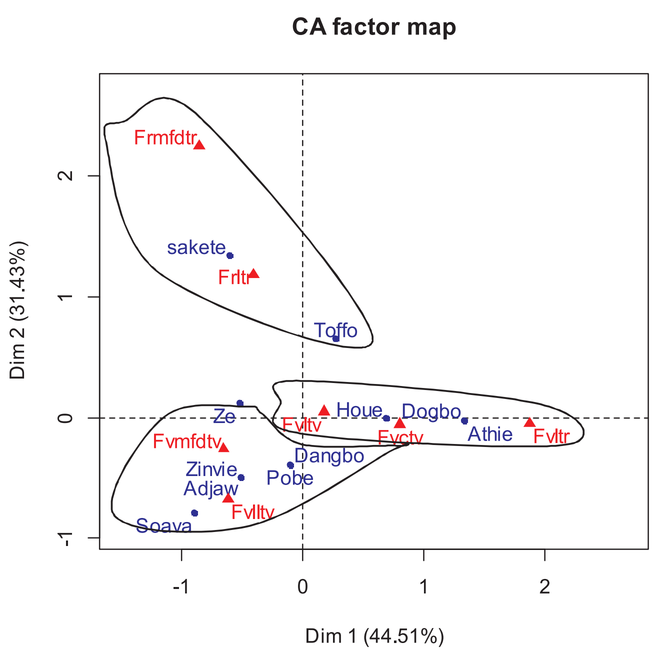

Fig. 2. Correspondence Factorial Analysis determining the localities of presence of different morphotypes of C. olitorius ; Fvltv (green leaves and long green stem), Fvctv (short green leaves and green stem), Fvltr (long green leaves and wide green stem), Fvmfdtv (green leaves with strongly toothed margins and green stem), Frltr (long red leaves and red stem), Frmfdtr (red leaves with heavily toothed margins and red stem) and Fvlltv (green leaves and wide green stem).

3. Results

3.1. Determination of different morphotypes of C. olitorius and their similarity to localities

Seven different morphotypes, three wild and four cultivated, were identified (Fig. 1). The prevalence of wild morphotypes per location is between 0 (for Oueme) and 2 (for Atlantic and Plateau). For cultivated morphotypes, specific richness is between 2 (Mono and Couffo) and 4 (Plateau).

The Correspondence Factorial analyses carried out to determine the localities of presence of different morphotypes revealed that the first factorial plane formed by axes 1 and 2 explained 75.93% of the total variability of the production sites of *C. olitorus* morphotypes. The first axis contributed to 44.51% and the second axis to 31.43%. The analysis of correlations between these axes and the morphotypes showed that the morphotypes Fvltv (green leaves and long green stem), Fvctv (short green leaves and green stem) and Fvltr (long green leaves and green stem) are positively correlated to axis 1 while Fvmfdtv (green leaves with strongly toothed margins and green stem) is negatively correlated to this axis. On the second axis, two correlations (mean correlation) are observed, one positive with the morphotypes Frltr (long red leaves and red stem) and Frmfdtr (red leaves with heavily toothed margins and red stem), and the other negatively with the morphotype Fvlltv (green leaves and wide green stem). The morphotypes Fvltv (green leaves and long green stem), Fvctv (short green leaves and green stem) and Fvltr (long green leaves and wide green stem) were correlated to the localities of Athieme, Houeyogbe and Dogbo (districts of Mono and Couffo). The morphotypes Fvmfdtv (green leaves with strongly toothed margins and green stem) and Fvlltv (long green leaves and wide green stem) were correlated to Zè, Abomey-Calavi, So-Ava, Dangbo, Pobe, Adja-Ouere, (districts of Atlantic, Oueme and Plateau). The morphotypes Frltr (long red leaves and red stem) and Frmfdtr (red leaves with heavily toothed margins and red stem) were correlated to the localities

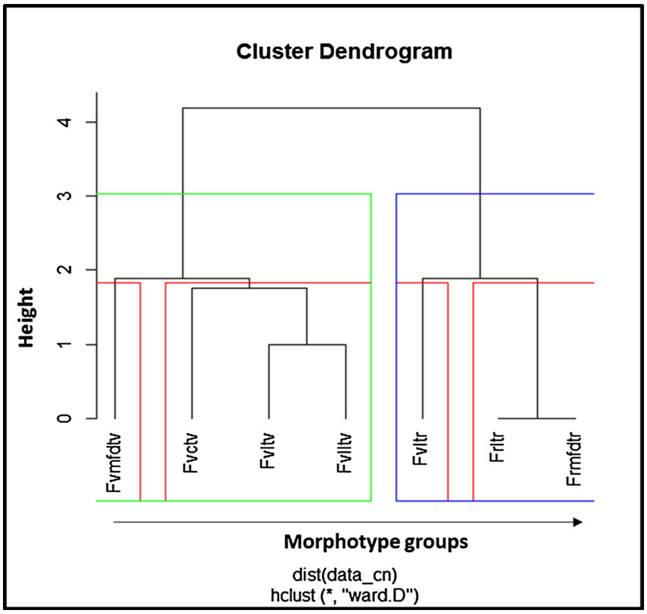

Fig. 3. Dendrogram of different morphotypes of C. olitorius grouped on the basis of their similarity between distinctive morphological traits; Fvltv (green leaves and long green stem), Fvctv (short green leaves and green stem), Fvltr (long green leaves and wide green stem), Fvmfdtv (green leaves with strongly toothed margins and green stem), Frltr (long red leaves and red stem), Frmfdtr (red leaves with heavily toothed margins and red stem) and Fvlltv (green leaves and wide green stem).

of Toffo and Sakete (districts of the Atlantic and the Plateau) (Fig. 2).

Using a dendrogram, the different morphotypes of *C. olitorius* were grouped on the basis of their similarity between distinctive morphological traits. At 60% of similarity of distinctive morphological traits, the 7 morphotypes of *C. olitorius* are grouped into 2 distinct classes. The first class included the 4 morphotypes namely, Fvlltv (long green leaves and wide green stem), Fvltv (long green leaves and green stem), Fvctv (short green leaves and green stem) and Fvmfdtv (green leaves with strongly toothed margins and green stem) which present many morphological traits in common. The second class included the 3 morphotypes namely Fvltr (long green leaves and wide green stem), Frltr (long red leaves and red stem) and Fvmfdtr (red leaves with heavily toothed margins and red stem) which have few distinctive morphological traits (Fig. 3).

3.2. Hierarchization of varietal preference criteria and the constraints related to the cultivation of different morphotypes of C. olitorius

Seven (7) preference criteria of three different types (agronomic, economic and culinary) justify the choice of the local morphotypes of cultivated *C. olitorius* (Table 1). Among them, agronomic criteria are the most used with a rate of 75.29%. Then, the culinary criteria and economic (high market value) criteria are noted with 12.36%. Considering the agronomic criterion, the most important are the mucilage rate of the leaf and the precocity of the cycle (23.6% of responses each).

Table 1
Preference of farmer criteria of morphotypes of *C. olitorius*.

Types of preference criteria	Preference criteria	% de responses	Rank
Agronomic	Mucilage rate of leaves	23.60	1
Agronomic	Precocity of cycle	23.60	1
Culinary	Water addition need after cuisson	12.36	2
Agronomic	Productivity in leaves and seeds	12.36	2
Economic	High value	12,36	2
Agronomic	Tolerance to poor soil	10.11	3
Agronomic	Brillance of leaves	5.62	4

Table 2
Production constraints of *C. olitorius* in southern Benin.

Constraints	% of responses	Rank
Attacks of insect pests	14.69	1
Non distinction of seeds	14.69	1
Dry season	13.99	2
Difficulties to purchase phytosanitary products	13.29	3
Variation of rainy calendary	12.59	4
Poor quality soils	12.59	4
Disponibility/Accessibility of water	8.39	5
Diminution of selling price in rainy season	5.59	6
Period of the flood	4.2	7

Corchorus olitorius production is limited by nine factors, the most important of which are insect pest attack and inability to differentiate seeds of different varieties/morphotypes (14.69% each) (Table 2). The decrease in market value in the rainy season (5.59%) and flooding (4.2%) are the least cited factors.

3.3. Determination of potential major pest insects associated with the cultivation of C. olitorius

Various types of damage are caused on *C. olitorius*. Leaf perforation is the most frequent attack and is caused by *Aulacophora africana*, *Helicoverpa armigera*, *Podagrica spp*. *Acrea* sp simply spoils the edges of the leaf limb while *Spodoptera littoralis* and the larva of *Acrea acerata* puff up and devour the leaf limbs and leave only the ribs thus giving a sweeping appearance to the plant or leaving black spots on the leaves. Seven major insect pests were identified (Table 3, Fig. 4). Among them, *Acrea* sp is the most common with a frequency of 100% of presence. *Zonocerus variegatus* (57.1%) and *Acrea acerata* (19.05%) have the lowest distributions.

Using a dendrogram, the districts of the production of *C. olitorius* were grouped on the basis of their similarity in the presence of the main pests (Fig. 5). A 60% similarity of the damage of insect pests, all 11 districts of production of *C. olitorius* are grouped into 3 classes. The first class C1 includes 7 districts which include Toffo, Zè, Dogbo, So-ava, Pobè, Houéyogbé, Sakété. These are mainly districts in which there is a low presence of insect pests of *C. olitorius*. The second class C2 includes 3 districts which is made up of Athiémé, Adja-wèrè and Abomey-Calavi. These 3 districts of production of *C. olitorius* present an average presence of the main pests of *C. olitorius*. The third class C3 includes only Dangbo as district. This latter is the district in which there is a very high presence of the main insect pests of *C. olitorius*. All the 7 main pests of *C. olitorius* studied were observed in all the farmer fields of this district (Fig. 5).

Table 3
Frequency of distribution of major pest insects of *C. olitorius*.

Major insect pests	Number of localities	Frequency of distribution (%)	Rank
Acrea sp	21	100	1
Aulacophora africana	17	80.95	2
Spodoptera litoralis	16	76.19	3
Helicoverpa armigera	16	76.19	3
Zonocerus variegatus	12	57.14	4
Acrea acerata (larvae)	4	19.05	5
Podagrica spp.	2	9.52	6

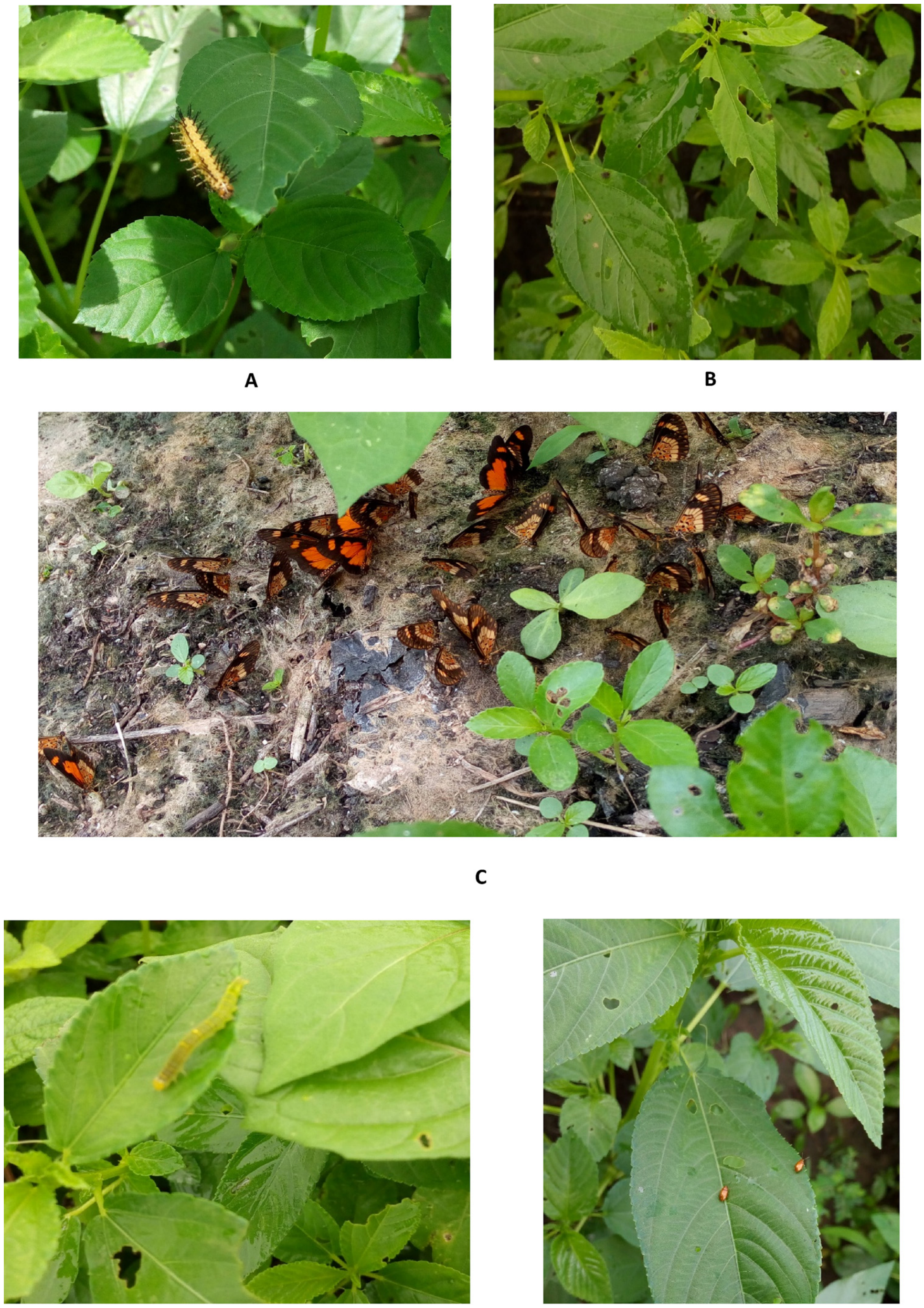

Fig. 4. Photos of some insect pests of *C. olitorius* and their damages, A - Laval stage of *Acraea acerata*, B - Damage on leaves by *A. acerata*, C - Adult butterflies of *Acraea* spp. in a *C. olitorius* field, D - Laval stage of *Helicoverpa armigera*, E - *Aulacophora Africana* on *C. olitorius* leaves.

3.4. Influence of agricultural practices on the presence of major pest insects of C. olitorius

The statistical analyses reveal a correlation between different practices and the presence of several insect pests of *C. olitorius*. No agricultural practices influence the presence of *Acrea* sp, while all agricultural practices except dormancy cutting, seedling after sowing and number of harvests have a significant effect on the presence of *Acrea acerata* and *Aulacophora africana* ($P < 0, 05$). The presence of *Podacrica* spp is influenced by dormancy cutting, date of first harvest and subsequent harvests and types of farms (field, garden) ($P < 0.05$), while *Spodoptera littoralis* and *Zonocerus variegatus* are influenced by all the agricultural practices except the types of field exploitation for *Spodoptera littoralis* and field-garden for *Zonocerus variegatus* (Table 4).

The statistical analyses carried out to determine the relationship between different types of crop associations and the presence of major insect pests in these cropping systems reveals a significant effect of association types on all insect pests ($Df = 28$, $P < 0.001$) except *Acrea* sp ($Df = 28$, $P = 0.9853$; Table 5).

4. Discussion

In Benin, *C. olitorius* is widely consumed in rural and urban communities, providing a key nutritional resource food security and is a

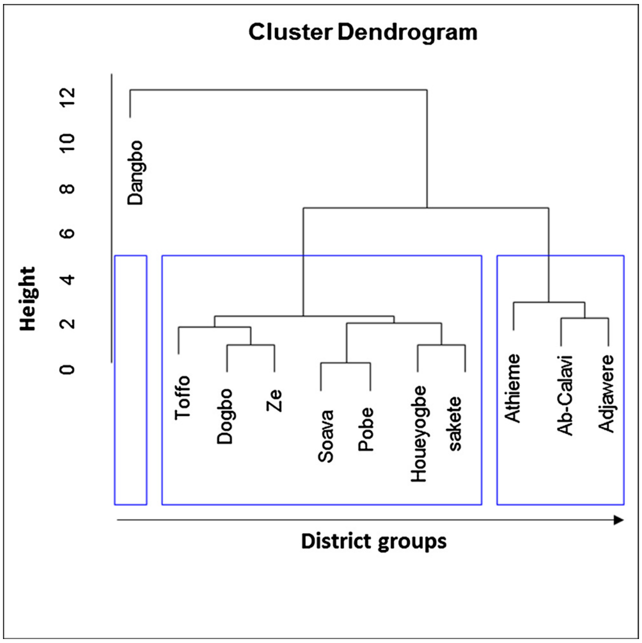

Fig. 5. Dendrogram grouping the different districts of production of C. olitorius according to the frequency of presence of insect pests.

significant source of income for rural populations. One of its major uses is the preparation of a slimy sauce with good organoleptic properties and high nutritional value. Compared to other studies, the uses of *C. olitorius* as reported by farmers in the study area are almost the same as those recorded in other countries in Burkina Faso (Kiebre, 2016). The inventory revealed the existence of 7 different morphotypes (3 wild and 4 cultivated) of *C. olitorius* in the 11 districts and 21 villages surveyed in the South of Benin. This low number could be justified by the fact that several morphotypes of *C. olitorius* are disappearing at the expense of morphotypes with a very good slimy character of the leaves. The slimy character of the leaves constitutes the first criterion of population preference and morphotypes not possessing this character would have been abandoned. It could also be explained by the lack of dynamics of introduction of new cultivars from neighboring countries.

Through the study areas, 23 vernacular names are used by local populations to designate *C. olitorius* in southern Benin. At the district level, each morphotype has a vernacular name got from villages which seem to have its own set of vernacular names. The same morphotypes can therefore have several names at the level of the zone. These results, which are specific to the vernacular nomenclature (Bhuwon et al., 2012), have already been reported on many crops, including traditional leafy vegetables (Adjatin et al., 2012) and the cassava (Kombo et al., 2012; Loko et al., 2013). These numerous synonymies and homonymies that exist in *C. olitorius* diversity can lead both to an overestimation (most often) and to an underestimation of the number of morphotypes

Table 5
Influence of associated crops on the presence of major insect pests of *C. olitorius*.

Ravageurs	Df	Deviance Resid	AIC	P(> |Chi|)
Acrea sp.	28	4.4987	62.5	0.9853
Acrea acerata	28	12.642	70.64	0.0005925
Aulacophora africana	28	24.609	82.609	0.001323
Helicoverpa armigera	28	10.746	68.746	< 0.00001
Podagrica spp.	28	4.499	62.499	< 0.00001
Spodoptera littoralis	28	3.819	61.819	< 0.00001
Zonocerus variegatus	28	21.018	79.018	< 0.00001

produced or not at the scale of the zone or the country (Dansi et al., 2011). On this basis, it is unlikely that all local names of morphotypes inventoried correspond to genetically distinct cultivars. Morphological and molecular characterizations should be carried out to detect duplicates and to establish equivalence between names as was the case with many crops such as rice (Chakanda et al., 2012), cassava (Lekha et al., 2011), sorghum (Abdel-Fatah et al., 2013), yams (Norman et al., 2011). Indeed, clarification of synonymies is a prerequisite for best management of crop genetic resources (Tsehaye et al., 2009). Among them, the most popular are Ninnouwi and Alôviaton. These results constitute an important contribution to the documentation of the various appellations for *C. olitorius* in the South of Benin. They also showed that, from a taxonomic point of view, the vernacular nomenclature of *C. olitorius* is based on the use of morphological, agronomic and cultural characteristics. Among the 4 criteria listed in the study, the slimy character of the leaves has more vernacular names than the other characters. This shows the importance of the slimy character in the denomination of *C. olitorius*. Agromorphological character is also important in the denomination of *C. olitorius* that the name of some morphotypes is based on the shape and colour of the leaves and stem. A similar study was carried out in Tanzania on the characterization of the morphological diversity of *C. olitorius* (Ngomuo et al., 2017a,b). The authors grouped the *C. olitorius* accessions into five major clusters based on their origins and morphological characters showing the importance of the denomination of plants by using the agromorphological characters. Similar results were obtained by Nyadanu et al. (2017) who grouped the accessions of Ghana into four district clusters based on *C. olitorius* agromorphological characters. In addition, the recent review of Ngomuo et al. (2017a,b) showed the exiting of variations among different accessions based on leaf shapes and color. The cultural character is also implicated in the denomination of *C. olitorius* in the sense some morphotypes are called Hèviossossi ninnou and Sodémi which are names related to the divinity vodoun. Nowadays, local populations are moving towards botanical characters in the nomenclature and identification of plant varieties and species (Spichiger et al., 2000). This was confirmed by Sawadogo and Balma, (2003) who showed that local communities name crop varieties based on agromorphological characteristics. The slimy character of the leaves is the first criterion of population preference and morphotypes not possessing this character would have been abandoned by farmers. The rate of mucilage of the leaf and the precocity of the cycle as main

Table 4
Influence of agricultural practices on the presence of major insect pests of *C. olitorius*. Values in the table are the probabilities of effects of agricultural practices on the presence of major insect pests. P < 0.05 means significant effects showing an influence of the agricultural practice on the presence of the insect pest and P > 0.05 means no significant effects showing no relation between the agricultural practice and the presence of the insect pest.

Agricultural practices	*Acrea* sp	*Acrea acerata*	*Aulacophora africana*	*Helicoverpa armigera*	*Podagrica* spp.	*Spodoptera littoralis*	*Zonocerus variegatus*
Dormancy cutting	0.09587	0.1145	0.956	0.01862	0.03686	0.00474	< 0.00001
Lifting seeds after sowing	0.961	0.4154	0.4677	0.07154	0.1323	0.002238	0.003637
Date of 1 st harvest	0.3796	< 0.00001	0.001714	0.002487	0.003213	0.004414	< 0.00001
2^e harvest and the following	0.6476	0.005155	0.02535	0.0004675	< 0.00001	0.0024	< 0.00001
Number of harvests	0.9705	0.05246	0.07147	0.1188	0.9301	0.001477	0.0002893
Field	0.1994	0.02225	0.03425	0.05823	0.0002018	0.3313	0.002492
Garden	0.3621	0.01545	0.007277	0.8987	0.008726	0.007277	0.001233
Field-Garden	0.4201	< 0.00001	0.7672	0.006266	0.02049	0.01626	0.6083

criteria of preference for the morphotypes of *C. olitorius* are explained simply by the fact that *C. olitorius* is first sought for its culinary use, its leaves for an accompaniment of the sauce.

The first major constraints related to the production of *C. olitorius* in southern Benin are attacks by insect pests and non-differentiation of different varieties of seed. The attack of insect pests as a main constraint is not very surprising because in South Benin similar observations have already been made on *C. olitorius* by Alissou (2011) and its associated crops in the lowlands of Mono and Couffo, but also on different leafy vegetable including large nightshade and cabbage (Ahoungninou, 2013). The same observations were also made by Atidégla, (2006) on urban and peri-urban market gardening in Grand-Popo. The seed problem of *C. olitorius* also becomes important and it will be necessary to develop seed production programs of *C. olitorius* on local varieties.

Insect pests are a major problem related to the production of *C. olitorius*. Across the study area, seven main insect pests were observed in the production systems of *C. olitorius* in southern Benin. These include *Acrea* sp, *Aulacophora africana*, *Spodoptera littoralis*, *Zonocerus variegatus*, *Helicoverpa armigera*, *Podagrica* spp, and *Acrea acerata*. The pests *Z. variegatus* and *Acrea* sp sponge the young shoots whereas the larvae of *A. acerata* puff the leaf blade leaving only the ribs giving the appearance of sweeps. *Podagrica* spp., *A. africana*, larvae of *H. armigera* and *S. littoralis* cause leaf perforations of both wild and cultivated *C. olitorius*. Our results showed the districts in which these main pests of *C. olitorius* were more observed. Abomey-Calavi, Athiémé and Adja-wèrè are medium attack zones of insect pests, while Dangbo is the area of strong insect attack. These areas of important insect pest attacks should be given priority in the development of sustainable pest management programs for *C. olitorius*. Four of these pests (*Z. variegatus*, *S. litoralis*, *A. acerata*, *Podagrica* spp) have already been identified in Côte d'Ivoire and cited by Fondio et al. (2012) as the main pests of *C. olitorius*. Contrary to our observations, Fondio et al. (2012) have also identified pests *Sclerotium rofsii, Curvularia* spp. These other pest species not found in this study can be explained by the period or season during which the survey and data collection was conducted, but also at the stage of crop growth at the time of collection of the data because certain pest insects intervene at precise stages of growth of the crops that they consume. *Acrea* sp, *A. africana* and *H. armigera* are the majority in the localities of Dogbo, Abomey-Calavi, Sakété, Houéyogbé, Pobè, Zè and So- ava whereas the other insects *Podacrica* spp, *A. acerata*, *S. littoralis*, *Z. variegatus* are in the localities of Dangbo, Athémé, Toffo and Adja-wèrè. These results, combined with those of the analysis of the relationships between the different morphotypes of *C. olitorius* and the associated pests, lead to the conclusion that there is no preference for pest insects for a given morphotype of *C. olitorius*. They therefore attack indifferently the different morphotypes of *C. olitorius*.

The production of *C. olitorius* in Southern Benin is done according to several different cultural practices from one locality to another. It is done by the technic of sowing on the fly in the fields of the Mono and Couffo districts (apart from a few exceptions), and on planks in gardens by market gardeners, preceded by a nursery phase of duration variable in the Atlantic, Ouémé and Plateau. Some do both, either in the field during the rainy season or in the garden as a crop of off-season or because the flood has gained the fields rendering any culture impossible at this place. Nearly 99% of the producers of *C. olitorius* do not do it in pure culture but rather in association with other legumes or food crops. Alissou, (2011) and Akplogan et al. (2007) have made similar observations in the lowlands of the Mono-Couffo and in the urban and peri-urban areas of Lokossa and Cotonou respectively. The mode of sowing on the fly widely practiced in the districts of Mono-Couffo makes of these districts the most producers of *C. olitorius* in all the South-Benin. On the other hand, our work revealed a significant effect of the different types of crop associations on the presence of all the main pest insects of *C. olitorius* whithout *Acrea* sp. Experiments should be carried out in a station to determine the influence of the association of these crops with the *C. olitorius* on the damage of insect pests. These various associations can be integrated into methods of ecological management of the pests of *C. olitorius*.

Acknowledgments

This work is part of Master thesis of Aquilin. E. Gbèdolo and was funded by BIORAVE. We thank farmers of Southern Benin who accepted to respond to interviews and to make available their cropped fields for observations.

References

Abdel-Fatah, B.E., Ali, E.A., Tag El-Din, A.A., Hessein, E.M., 2013. Genetic diversity among Egyptian sorghum (*Sorghum bicolor* L. Moench) Landraces in agromorphological traits and molecular markers. Asian J. Crop Sci. 5, 106–124.

Adégbola, Y.P., Singbo, A.G., 2001. Analyse Socio-économique de la filière des biopesticides en cultures maraîchères au Bénin. PAPA/INRAB et IITA, Cotonou, Bénin 30 p.

Adjatin, A., Dansi, A., Eze, C.S., Assogba, P., Dossou-Aminon, I., Akpagana, K., Akoegninou, A., Sanni, A., 2012. Ethnobotanical investigation and diversity of Gbolo (*Crassocephalum rubens* (Juss. ex Jacq.) S. Moore and *Crassocephalum crepidioides* (Benth.) S. Moore), a traditional leafy vegetable under domestication in Benin. Genetic Ressources Crop Evolution 59, 1867–1881.

Adomou, A.C., Sinsin, B., van der Maesen, L.J.G., 2006. Phytosociological and chorological approaches to phytogeography: a meso-scale study in Benin. Systematics Geography Plants 76, 155–178.

Ahoungninou, A.C.C., 2013. Durabilité de la Production Maraîchère au sud du Bénin: Un Essai de l'Approche Ecosystémique. Thèse de doctorat, Gestion de l'environnement, Université d'Abomey-Calavi 349 p.

Akplogan, F., Adégbola, P., et Assogba komlan, F., 2007. Production et commercialisation des légumes locaux dans les zones urbaines et péri-urbaines du Bénin. Unpublished Indigeno Vegetation Survey Report.

Akoroda, M.O., Akintobi, D.A., 1983. Seed production in Corchorus olitorius. Acta Horticulturae 123, 231–236.

Akoroda, M.O., 1985. Morphotype diversity in Nigerian land-races of *Corchorus olitorius*. Horticultural Science 6, 557–562.

Alissou, A.E., 2011. Analyse des pratiques culturales maraîchères dans les bas-fonds rizicoles d'Agbédranfo-Vovokanmey (Couffo) et de Houinga (Mono) au sud-Bénin, et effet de l'azote sur la croissance et la production du crincrin (*Corchorus olitorius L.*). Thèse d'Ingénieur Agronome, Sciences et Techniques de Production Végétale. Université d'Abomey-Calavi 128 p.

Atidégla, S.C.C., 2006. Atouts et Contraintes des Modes d'Irrigation dans les exploitations maraîchères urbaines et péri-urbaines de Grand-Popo. Mémoire de DEA, FLASH, UAC, Bénin.

Attere, F., 1999. Note introductive de l'atelier sur les légumes feuilles. In: Chwey, J.A., Eyzaguire, P. (Eds.), Biodiversity of Traditional Leafy Vegetables in Africa. International plant Genetic Resources Institue (IPGRI) via delle sette chiese 14200145, Rome, Italie 150p.

Bailey, J.M., 2003. Aliments du Pacifique: les feuilles vertes que nous mangeons. Version française du manuel de la CPS n° 31, 2000. Service de publication du Secrétariat général de la communauté du pacifique (CPS), Graphoprint, Nouméa 97p.

Bhuwon, S., Abhishek, S., Devra, J., Hugo, L., Ramanatha, R.V., 2012. Community based approach to on-farm conservation and sustainable use of agricultural biodiversity in Asia. Indian J. Plant. Genetic Resources 25, 97–110.

Chakanda, R., van Treuren, R., Visser, B., van den Berg, R., 2012. Analysis of genetic diversity in farmers' rice varieties in Sierra Leone using morphological and AFLP markers. Genet. Resour. Crop Evol. 60, 1237–1250.

Dansi, A., Dantsey-Barry, H., Dossou-Aminon, I., N'Kpenu, E.K., Agré, A.P., Sunu, Y.D., Kombaté, K., Loko, Y.L., Dansi, M., Assogba, P., Vodouhè, R., 2013. Varietal diversity and genetic erosion of cultivated yams (*Dioscorea cayenensis* Poir - *D. rotundata* Lam complex and D. alata L.) in Togo. Int. J. Biodivers. Conservation 5, 223–239.

Dansi, A., 2011. Collecting vegetatively propagated crops (especially roots and tubers). In: Guarino, L., Ramanatha Rao, V., Goldberg, E. (Eds.), Collecting Plant Genetic Diversity: Technical Guidelines - 2011 Update. Bioversity International, Rome, Italy978-92-9043- 922-6, . http://cropgenebank.sgrp.cgiar.org.

Dossou-Aminon, I., Loko, Y.L., Adjatin, A., Dansi, A., Elangovan, M., Chaudhary, P., Vodouhè, R., Sanni, A., 2014. Diversity, genetic erosion and farmer's preference of sorghum varieties [*Sorghum bicolor* (L.) Moench] growing in North-eastern Benin. Int. J. Curr. Microbiol. Appl. Sci. 3, 531–552.

Kar, C.S., Kundu, A., Sarkar, D., Sinha, M.K., Mahapatra, B.S., 2009. Genetic diversity in jute (*Corchorus* spp) and its utilization: a review. Indian J. Agric. Sci. 79, 575–585.

Kiebre, M., 2016. Evaluation agromorphologique d'accessions de corète potagère (Corchorus olitorius. L) du Burkina Faso. Int. J. Innovation Appl. Stud. 14, 198–209.

Kombo, G.R., Dansi, A., Loko, L.Y., Orkwor, G.C., Vodouhè, R., Assogba, P., Magema, J.M., 2012. Diversity of cassava (Manihot esculenta Crantz) cultivars and its management in the department of Bouenza in the Republic of Congo. Genet. Resour. Crop Evol. 59, 1789–1803.

Lekha, S.S., Teixeira da Silva, J.A., Pillai, S.V., 2011. Genetic variability studies between released varieties of cassava and central Kerala cassava collections using SSR markers. J. Stored Products Postharvest Res. 2, 79–92.

Loko, Y.L., Dansi, A., Agre, A.P., Akpa, N., Dossou-Aminon, I., Assogba, P., Dansi, M., Akpagana, K., Sanni, A., 2013. Perceptions paysannes et impacts des changements climatiques sur la production et la diversité variétale de l'igname dans la zone aride

du nord-ouest du Bénin. Int. J. Biol. Chem. Sci. 7, 672–695.
Ndlovu, J., Afolayan, A.J., 2008. Nutritional analysis of the South African wild vegetable *Corchorus olitorius* L. Asian J. Plant Sci. 7, 615–618.
Ngomuo, M.S., Stoilova, T., Feyissa, T., Kassim, N., Ndakidemi, P.A., 2017a. Leaf and seed yield of jute mallow (*Corchorus olitorius* L.) accessions under field conditions for two consecutive growing seasons. J. Hortic. Sci. Biotechnol. 92, 614–620.
Norman, P.E., Tongoona, P., Shanahan, P.E., 2011. Diversity in chromosome number and raphide morphology of yam (*Dioscorea* spp.) genotypes from Sierra Leone. Afr. J. Plant Sci. 6, 157–160.
Ngomuo, M., Stoilova, T., Feyissa, T., Kassim, N., Ndakidemi, P.A., 2017b. The genetic diversity of leaf vegetable jute mallow (*Corchorus* spp.): A review. Indian J. Agric. Res. 51, 405–412.
Nyadanu, D., Amoah, R.A., Kwarteng, A.O., Akromah, R., Aboagye, L.M., Adu-Dapaah, H., Dansi, A., Lotsu, F., Tsama, A., 2017. Domestication of jute mallow (*Corchorus olitorius* L.): ethnobotany, production constraints and phenomics of local cultivars in Ghana. Genet. Resour. Crop Evol. 64 (6), 1313–1329.
Oboh, G., Raddatz, H., Henle, T., 2009. Characterization of the antioxidant properties of hydrophilic and lipophilic extracts of jute (*Corchorus olitorius*) leaf. Int. J. Food Sci. Nutr. 60, 124–134.
Odhav, B., Beekrum, S., Akula, U.S., Baijnath, H., 2007. Preliminary assessment of nutritional value of traditional leafy vegetables in KwaZulu-Natal, South Africa. J. Food Composition Analysis 20, 430–435.
Ojiewo, C., Tenkouano, A., Hughes, J.D.A., Keatinge, J.D.H., 2013. Diversifying diets: using indigenous vegetables to improve profitability, nutrition and health in Africa. Diversifying Food Diets. 291p.
Sawadogo, M., Balma, D., 2003. Etude agromorphologique de quelques écotypes locaux de gombo cultivés au Burkina Faso. Science et Technique, Série Sciences Naturelles et Agronomie 27, 111–129.
Spichiger, R., Savolainen, V., Figeat, M., Perret, M., 2000. Botanique systématique des plantes à fleurs: une approche phylogénétique nouvelle des angiospermes des régions tempérées et tropicales. Collect. "Biologie". Presses polytechniques et universitaires romandes, Lausanne 372p.
Tsehaye, Y., Abera, Z., Kebede, A., Ghebremichael, B., 2009. A dynamic Sorghum (Sorghum bicolor (L.) Moench) diversity management in situ and livelihood resilience in South and Central tigray region, Ethiopia. Momona Ethiopian J. Science 1, 67–94.
Uusiku, N.P., Oelofse, A., Duodu, K.G., Bester, M.J., Faber, M., 2010. Nutritional value of leafy vegetables of sub-Saharan Africa and their potential contribution to human health. A review. J. Food Composition Analysis 23, 499–509.
Yabi, I., Afouda, F., 2012. Extreme rainfall years in Benin (West Africa). Quaternary International 1, 1–5. http://dx.doi.org/10.1016/j.quaint.2010.12.010.
Zeghichi, S., Kallithraka, S., Simopoulos, A.P., 2003. Nutritional composition of molokhia (*Corchorus olitorius*) and stamnagathi (*Cichorium spinosum*). In Plants Hum. Health Nutrition Policy 91, 1–21.