SSRG International Journal of Agriculture & Environmental Science
ISSN: 2394-2568/ https://doi.org/10.14445/23942568/IJAES-V11I5P102

Volume 11 Issue 5, 12-20, Sep-Oct 2024

Original Article

Diversity and Occurrence of Pests in Vegetable Agroecosystems in Southern Benin

Codjo DAGBA[1], Fernand A. SOTONDJI[2], Sylvie Sénadé HOUNZINME[3], Daniel C. CHOUGOUROU[4]

[1]*University of Abomey-Calavi, Faculty of Science and Technology, Applied Biology Research Laboratory at EPAC, Benin.*
[2,4]*Entomology and Plant Protection at the Ecole Polytechnique d'Abomey-Calavi (EPAC), Applied Biology Research Laboratory at EPAC, Benin.*
[3]*Phytosociology, Protected and Pastoral Areas, Agro-Ecosystems and Conservation of Endogenous Species at the Ecole Polytechnique d'Abomey-Calavi (EPAC), Applied Biology Research Laboratory at EPAC, Benin.*

[1]*Corresponding Author : dagbacodjoymail.com*

Received: 28 July 2024 Revised: 01 September 2024 Accepted: 20 September 2024 Published: 04 October 2024

Abstract *- Arthropod crop pests are a constant threat to horticultural production. Most arthropod families are poorly known in the agroecological zone of southern Benin, as little research has been carried out. A better knowledge of pests facilitates the choice of control strategies. This study aims to determine the occurrence and specific diversity of pests associated with vegetable crops. An inventory of arthropod crop pests was carried out in the communes of Sakété, Sèmè-kpodji, Lokossa and Djakotomey. Ecological indices were calculated to assess pest diversity. The intensity of the relationship between the different localities, taking into account the abundance of the species according to the different families, was determined using a simple factorial correspondence analysis. The inventory showed that the insects associated with tomato, cabbage, amaranth and greater nightshade cultivation in southern Benin are represented by nine (9) orders and forty-seven (47) families. Although the majority of these insects are pests, a number of predators and pollinators are also present. Determining the entomofauna of these crops in these localities is a tool that can be used to design insect pest management strategies.*

Keywords *- Vegetable crops, Biodiversity, Pests, Predators, Benin.*

1. Introduction

In Africa, food and nutritional security and poverty reduction remain the main challenges. Agriculture is one of the main sectors of activity that contributes to the socio-economic development of populations and reduces rural poverty (Adjatini *et al*., 2019). In countries with an agricultural vocation, agriculture employs 65% of the working population. In the Agriculture sector, market gardening plays an important role in human nutrition and effectively meets food demand (Thomas, 2012). Although agriculture is one of the main sectors of activity contributing to the socio-economic development of populations. This sector employs more than 40% of the world's working population, including more than 52% in Africa (Ajatin, 2019; Yarou *et al*.,2017). In the agricultural sector, market garden crops play an important role in human nutrition and are an effective response to urban food demand (FAO 2012). However, the income generated by market gardening enables several hundred families to meet their daily needs, contributing to the integration and poverty reduction of rural populations (Maniriho, 2021). Market gardening is an important source of food and one of the most income-generating activities (Tendeng *et al*., 2017). Market garden production, especially leafy vegetables, has become an important part of agriculture in the towns of southern Benin (Agossou *et al*., 2001). Indeed, in terms of market garden crops, leafy vegetables occupy second place in South Benin behind tomatoes, with a surface area of 1,496 ha and total production of 10,600 T (Colin., 1991). Among the market garden crops produced in Benin, leafy vegetables are the most widely consumed (62.5%), with traditional leafy vegetables accounting for the majority (89%). These traditional leafy vegetables are part of the daily diet of almost all Beninese (Houssou., 1995). The production of leafy vegetables is an equally important branch of the market-gardening sector, as leafy vegetables are an important part of Beninese gastronomy. In southern Benin, the most widely produced leafy vegetables are gboma (Solanum macrocarpon), amaranth (Amaranthus cruentus), basil (Ocimum gratissimum) (Ahouangninou *et al*., 2013).

According to Mensah *et al*. (2019), gboma is a traditional vegetable much appreciated by people in southern Benin. This being said market garden crops face enormous constraints, including those linked to land tenure (precarious rental status, scarcity of available land), the precariousness and vulnerability of production systems (Aman *et al*., 2021), insect attacks and pathologies affecting the qualitative and quantitative yield of produce (Soro *et al*.,2018), the marketing of agricultural produce and, above all, insalubrity and pollution due to the presence of uncontrolled landfill sites on market garden crop sites. In Benin's agroecological zones, vegetable production is subject to a number of constraints, including the pressure of insect pests. Insect pests are a constant threat to horticultural production. Chemical control is the main strategy advocated against pests. To control pests in Benin, growers most often use chemical pesticides (Ahouangninou *et al.*, 2019). The use of pesticides and chemical fertilizers presents health risks for producers, consumers and the environment (Le Bars *et al*., 2020). These crops provide cheap protein, vitamins and other essential elements for health and well-being (James *et al*., 2010).

Unfortunately, with the development of new vegetable production zones, the list of pests of certain crops such as tomato, nightshade, pigweed and cabbage is not yet sufficiently established in southern Benin. So, the preliminary step to successfully protecting these The key to success in crop production is knowledge of pests. It is for this reason that the present study proposes to inventory the entomofauna of tomato, greater nightshade, amaranth and cabbage fields in order to envisage more effective and sustainable phytosanitary protection of these crops in the communes of Sakété, Sèmé-Kpodji, Lokossa and Djakotomey. The specific aim is to collect samples of insect pests and beneficial insects found on the plants and to identify each insect sample collected.

2. Material and Methods

2.1. Study Area

The study was carried out in the southern Benin region. It was carried out in four localities in the southern region of Benin from April to September 2022. These were the departments of Mono, Couffo, Oueme and Plateau in the municipalities of Lokossa, Djakotomey, Sèmè-kpodji and Sakété, respectively (Figure1). This area enjoys a sub-equatorial climate, with two rainy seasons (March to July and September to November) and two dry seasons (December to March and July to September).

Daily temperatures range from 26°C to 31°C, with annual rainfall averaging 1,200 mm (INSAE, 2012). The study sites are located at (Lokossa: 6°21'48.31 "N; 2°05'31.18 "E; Djakotomey: 6°21'32,034 "N, 2°23'11,44 "E; Sèmè: 6°25'19,70", 2°35'45,60 "E; Sakété: 6°26'17,71 "N, 2°1'24,95 "E) latitude and longitude. Trapping was carried out in the four departments where the four different crops (cabbage, tomato, greater nightshade and amaranth) are grown, in different localities within each department. Insect trapping was carried out from the transplanting stage through to fruiting and ripening of the first fruits. The fields in which the traps were set were at least 100m^2 (10 m x 10 m) in size. No phytosanitary treatments were applied to these fields throughout the trial period.

2.2. Methods

2.2.1. Insect Collection and Identification

Four active methods were used to collect insects associated with amaranth, cabbage, nightshade and tomato. Barber or pitfall trap (Barber, 1931): used to capture mobile epigeous insects. It consists of a pipe 15 cm high and 10 cm in diameter. A 10 cm-diameter funnel was placed above a bottle containing 70% alcohol.

The whole unit is placed in a previously dug hole. The upper end of the pipe is level with the ground. Eight of these traps are installed in each field. Four traps are installed at the ends of each field and four in the middle, eight meters apart. A plastic roof is fitted over the traps to prevent flooding by direct rainfall and clogging by leaves or debris. Bottles are changed every 4 days.

The mowing net was used for collection. Its use consisted of moving forward in the field mowing any insects flying over the plants under study. This method is difficult to standardize, as the way of mowing varies from one individual to another. Capture was carried out 3 times a week during the experimental period. Capture was carried out between 8 and 10 a.m. in the morning and between 5 and 7 p.m. The third active method consisted of beating with a stick.

The crops under study were lightly shaken so as to cause the insects on the plants to fall into a 10 cm diameter funnel placed above a bottle containing 70% alcohol. The water trap was the final method used in this study: the water trap consisted of a coloured bowl filled with water, which attracts many flying insects. It was placed on the ground or a raised support if the vegetation was tall. The insects enter and drown. Depending on their color, the traps attracted different groups of insects. The traps were filled with water to within 3 cm of the rim, and a few drops of detergent were added to reduce surface tension.

2.2.2. Preparation and Storage of Collected Insects

Collected insects were preserved in vials containing a 70% ethanol solution. After sorting and classification on the basis of external morphology, the insects were identified at the Applied Biology Research Laboratory of the Ecole Polytechnique d'Abomey-Calavi up to family taxonomic level using a binocular magnifying glass. Several entomological systematics keys were used for identification (Delvare & Aberlenc, 1989; Eardley *et al*., 2009; Chinery, 2012; Mignon *et al*., 2016) and the catalog Arthropods of vegetable crops in West and Central Africa, Mayotte and Réunion by Bordat & Arvanitakis (2004); catalog of the main pests of vegetable crops in Benin Bordat et Goudegnon (1991) to categorize insect families into functional groups. Specimens were then recognized and classified into genus and species by observation of the samples collected and comparison with collections in the IITA Benin Entomological Museum by the specialist.

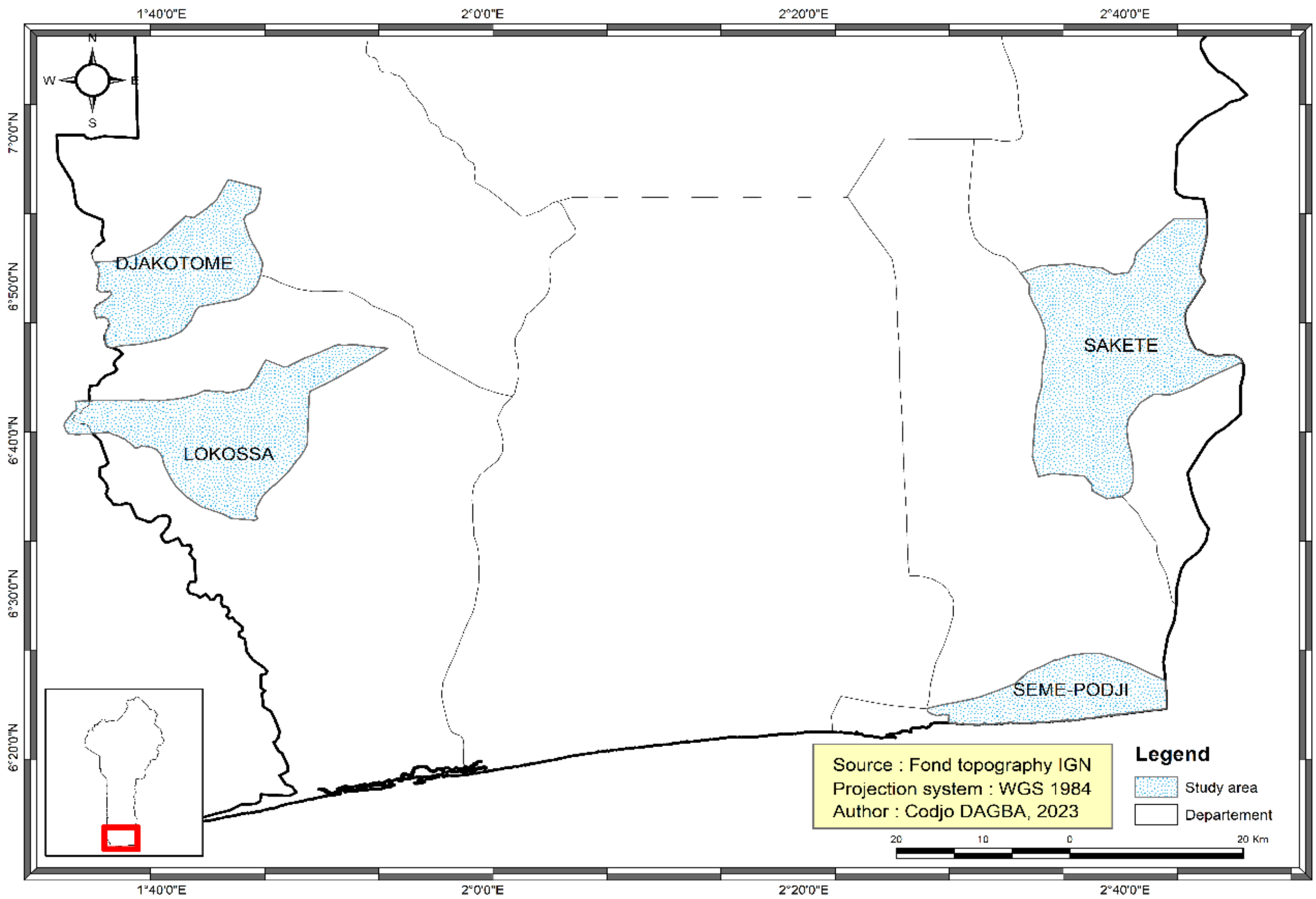

Fig. 1 Location map of collection sites in southern Benin

3. Data Analysis

3.1. Estimation of Relative Abundance and Diversity of Insect Families

3.1.1. Assessment of Pest Diversity

Relative abundance (F) was determined after counting individuals per family. F(%)=n_i×100/N, where n_i is the number of individuals at a given taxonomic level. To assess family diversity, the Shannon index (H^'), which evaluates the diversity of taxa (in this case, families) in each environment under consideration, was determined using Magurran's (2004) formula: H^'=-∑p_i ln(p_i); p_i=n_i/N with n_i the abundance of the ith family, and N the total abundance. Next, the equitability (E) associated with the Shannon index was calculated. It is defined by: E=H^'/(H^' max) with H^' max=ln(S) (maximum Shannon diversity) and S the total number of families E lies between 0 and 1. If it tends towards 0, this means that almost all the numbers are concentrated in one family. On the other hand, if all families have the same abundance, E tends towards 1. Finally, Simpson's index (D), which measures the probability that two randomly selected individuals belong to the same taxonomic level, was also determined and is defined by :

$$D = 1 - \frac{\sum n_i(n_i - 1)}{N(N-1)}$$

With n_i, the number of individuals in the given family and N, the total number of individuals in all the families considered. This index varies between 0 (minimum diversity) and 1 (maximum diversity).

3.2. Correspondence Factor Analysis (CFA)

The intensity of the relationship between different localities, taking into account the abundance of the species according to the different families, was determined using a factorial analysis. Simple Correspondence Analysis (SCA) with the CA function of the FactoMineR package (Solymos *et al*., 2020) of the R 4.1.3 software (R Core Team, 2022).

3.3. Poisson Mixed-effects Model

Two generalized linear mixed-effect models were fitted, including the Poisson model with the glmer function from the lme4 package (Douglas *et al*.,2015) and the negative binomial model using the glmer.nb function from the MASS package (Venables & Ripley, 2002) of R 4.1.3 software (R Core Team, 2022). The speculation factor was considered a fixed factor, and the locality factor was a random factor. To select the best model, the Akaike Information Criterion (AIC) was used. The best-performing model is the one with a low AIC. The marginal and conditional R^2 of the Generalized Linear

Mixed Poisson model were calculated using the r.squaredGLMM function in the MuMIn package (Barto, 2016), which implements the method developed by Nakagawa and Schielzeth (2013). The marginal R^2 gives the variance explained by the fixed effects, and the conditional R^2 gives the variance explained by the whole model, i.e. both the fixed and random effects.

4. Results

4.1. Overall Insect Abundance

A total of 6906 insects were collected in the four communes of southern Benin, as follows: Djakotomey (2078 individuals), Lokossa (1522 individuals), Sakété (1410 individuals) and Sèmè-Kpodji (1896 individuals). These insects were identified at the family taxonomic level. They are divided into nine (09) orders: Heteroptera (7.95%), Homoptera (20.55%), Coleoptera (12.57%), Lepidoptera (24.63%), Diptera (8.71%), Orthoptera (8.24%), Hymenoptera (9.31%), Thysanoptera (4.31%), and Odonata (3.73%). The relative abundance of these species is shown by locality (Figure 11).

4.2. Pest diversity by crop and locality

The nine (09) orders of insects are present on the four crops (cabbage, nightshade, tomato and amaranth) in given proportions in each department covered by our study. The most represented orders are Lepidoptera, Homoptera, Coleoptera and Hymenoptera. The following table shows the abundance of these insects by species for each of the localities covered by the data collection.

Table 1. Pest diversity by species and locality

Speculation	Order	Djakotomey	Lokossa	Sakété	Sèmé-kpodji
Amaranthus	Coleoptera	66 (15,82%)	72 (20,16%)	51 (13,89%)	60 (12,24%)
	Diptera	27 (6,47%)	19 (5,32%)	11 (2,99%)	25 (5,51%)
	Hemiptera	38 (9,11%)	78 (21,84%)	50 (13,62%)	47 (10,37%)
	Lepidoptera	26 (6,23%)	40 (11,20%)	34 (9,26%)	54 (11,92%)
	Orthoptera	12 (2,87%)	14 (3,92%)	11 (2,99%)	14 (3,09%)
	Homoptera	205 (49,16%)	105 (29,41%)	157(42,77%)	200 (44,15%)
	Hymenoptera	31 (7,43%)	20 (5,60%)	46 (12,53%)	35 (7,72%)
	Thysanoptera	9 (2,15%)	8 (2,24%)	5 (1,36 %)	10 (2,20 %)
	Odonates	3 (0,71%)	1 (0,28)	2 (0,54 %)	8 (1,76 %)
Brassica oleracea	Coléoptera	30 (6,03%)	65 (11,26%)	36 (11,42%)	71 (14,03%)
	Diptera	11 (2,21%)	22 (3,81%)	21 (6,66%)	16 (3,16%)
	Hemiptera	242 (48,69%)	249 (43,15%)	137 (43,49%)	225 (44,46%)
	Hymenoptera	28 (5,63%)	34 (5,89 %)	18 (5,71%)	24 (4,74%)
	Lepidoptera	54 (10,86%)	63 (10,91%)	45 (14,28%)	84 (16,60%)
	Orthoptera	31 (6,23%)	41 (7,10 %)	18 (5,71%)	30 (5,92%)
	Thysanoptera	6 (1,20%)	11 (1,90%)	4 (1,26%)	7(1,38%)
	Homoptera	92 (18,51%)	87 (15,07%)	35 (11,11)	45 (8,89%)
	Odonates	3 (0,60%)	5 (0,86%)	1 (0,31%)	4 (0,79%)
Solanum macrocapon	Coléoptera	28 (7,90%)	50 (13,73%)	27 (6,65%)	51 (11,15%)
	Diptera	25 (7,06%)	23 (6,26%)	37 (9,11%)	82 (17,94%)
	Hemiptera	105 (%)	81 (22,07%)	179 (44,08%)	148 (32,38%)
	Lepidoptera	42 (29,66%)	49 (13,35%)	44 (10,83%)	43 (9,40%)
	Orthoptera	53 (14,97%)	21 (5,72%)	23 (5,66%)	46 (10,06%)
	Homoptera	45 (12,71%)	70 (19,07%)	51 (12,56%)	25 (5,47%)
	Hymenoptera	51 (14,40%)	60 (16,34%)	37(9,11%)	54 (11,81%)
	Thysanoptera	3 (0,84%)	5 (1,36%)	7(1,72%)	4 (0,87%)
	Odonates	2 (0,56%)	5 (1,36%)	1(0,24%)	4(0,87%)
Solanum lycopersicum	Coleoptera	28 (11,81%)	43 (15,80%)	50 (12,95%)	53 (14,13%)
	Diptera	20 (8,43%)	27 (9,92%)	29 (7,51%)	51 (13,60%)
	Hemiptera	50 (21,09%)	53 (19,48%)	152 (39,37 %)	156 (41,60%)
	Hymenoptera	25 (10,54%)	22 (8,08%)	31 (8,03%)	30 (8%)
	Lepidoptera	31 (13,08%)	39 (14,33%)	64 (16,58%)	51 (13,6%)
	Odonates	2 (0,84%)	4 (1,47%)	3 (0,77%)	5 (1,33%)
	Orthoptera	15 (6,32%)	29 (10,66%)	29 (7,51%)	21(5,6%)
	Thysanoptera	9 (3,79%)	8 (2,94%)	3 (0,77%)	8 (2,13%)
	Homoptera	57 (24,05%)	47(17,27%)	25 (6,47%)	57 (15,2%)

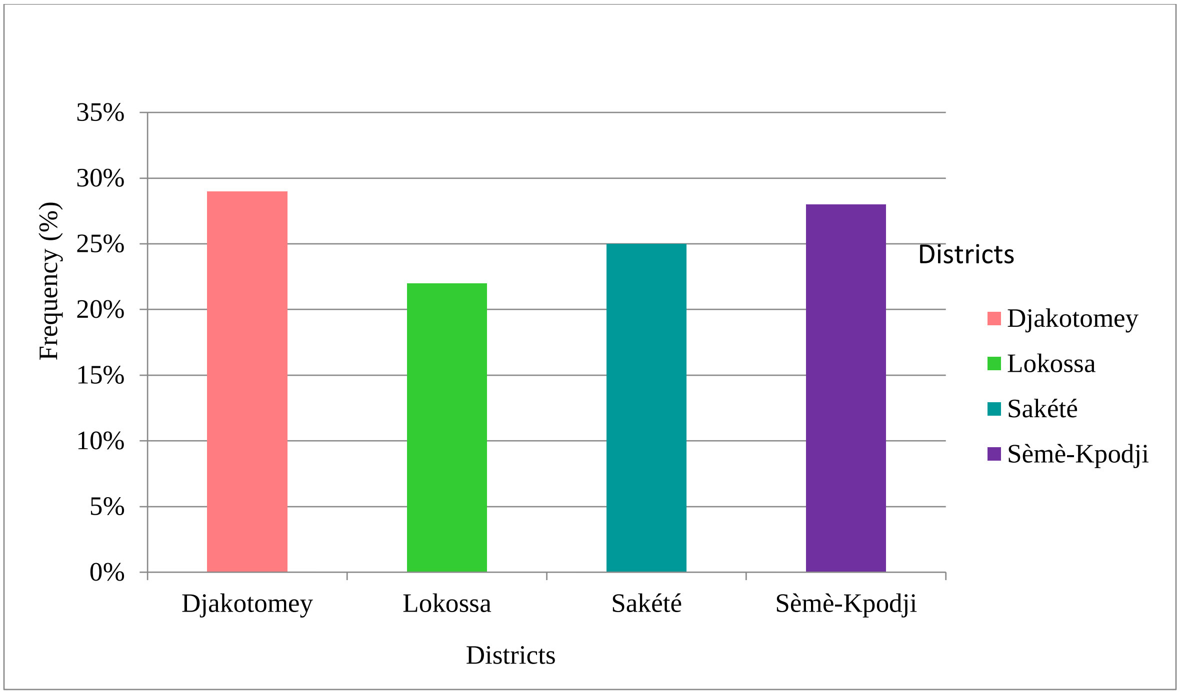

Fig. 2 Frequency and abundance of insects collected by locality

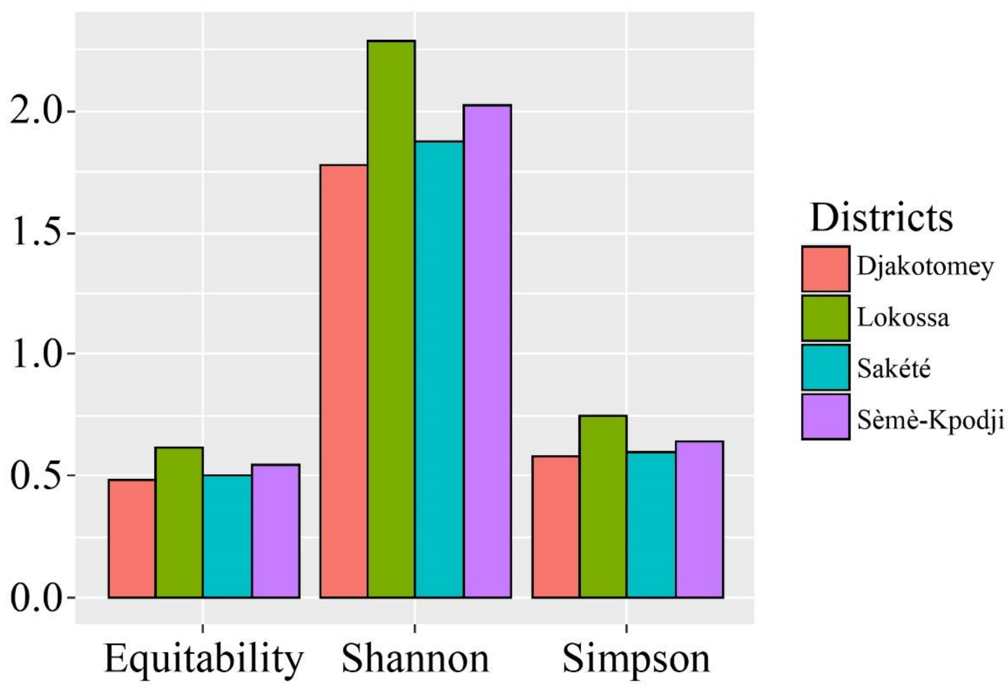

Fig. 3 Diversity indices of identified insect families by locality

Table 2. Percentage of variance explained by axes

	Axe.1	Axe.2	Axe.3
Variance	0,07	0,02	0,01
Pourcentage variance	71,83	16,92	11,25
Variance cumulée (%)	71,83	88,75	100

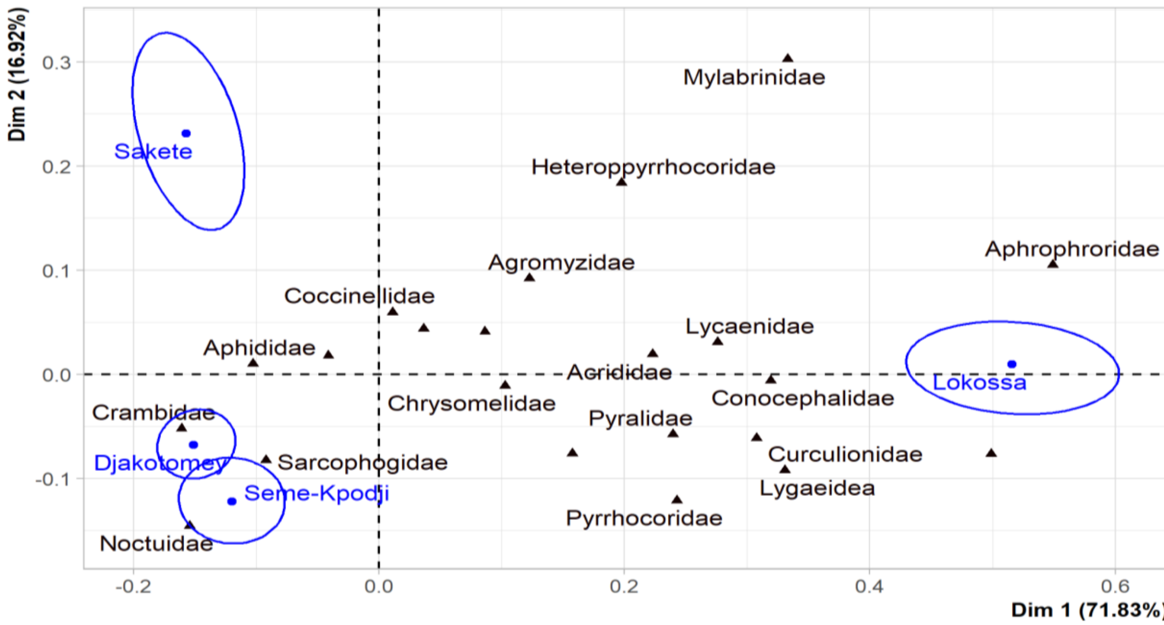

Fig. 4 Graph showing the intensity of the relationship between families and the different localities studied

4.3. Diversity of insect taxonomic families

Forty-seven taxonomic families have been identified, divided into nine (09) orders. The largest number of families (18) was observed among the Hemiptera, with a predominance of the Aphididae, Coreidae, Aleyrodidae and Pentatomidae. Coleoptera comes in second place with 16 families, mainly Chrysomelidae, Coccinellidae, Scarabaeidae and Curculionidae. Lepidoptera comprises thirteen (13) families, with Noctuidae, Pyralidae and Pieridae predominating. Diptera comprises seven (07) families, including Calliphoridae, Tephritidae, Sarcophogidae and Asilidae are the most abundant. Orthoptera has three families, of which Acrididae and Tettigoniidae are the most represented. Hymenoptera has four families, of which Aphididae and Anthophoridae are the most represented, while the other orders each have a single family, Odonata (Aeshnidae) and Thysanoptera (Thripidae).

The Shannon indices observed in the localities considered are high, with the highest values in the commune of Lokossa (2.29) and Sèmè-kpodji (2.02) (Figure 12). This could indicate diversity within insect families in these localities, compared with the municipality of Djakotomey (1.78) and Sakété (1.87). Equitability is low and almost similar for all localities, with the highest value observed in the municipality of Lokossa (0.61) compared to the municipality of Djakotomey (0.48), Sakété (0.50) and Sèmè-kpodji (0.54). This would indicate a homogeneity in the abundance of species representative of each of these localities. Similarly, Simpson's index shows a similar trend similar trend towards equitability, with a high value observed in the municipality of Lokossa (0.74) and in the municipality of Sèmè-kpodji (0.64) (Figure 12). This would indicate a greater diversity of species identified in these localities than in the communes of Djakotomey (0.58) and Sakété (0.59).

5. Discussion

The results showed that the insects that swarm tomato, nightshade, amaranth and cabbage fields in the communes of Sakété, Sèmè-Kpodji, Lokossa and Djakotomey are of several orders and belong to different trophic groups. Knowledge of the insects associated with tomato, cabbage, nightshade and pigweed crops in these communes is the starting point for developing methods to control insect pests of these vegetable crops in these different agrosystems. A total of 6906 insects belonging to nine (09) orders were collected in the four communes of southern Benin on cabbage, greater nightshade, amaranth and tomato. Insect abundance was higher in Djakotomey than in the other communes, and insects were more abundant in cabbage in all the localities surveyed. The five most representative orders in terms of number of specimens collected are Hemiptera, Homoptera, Coleoptera, Orthoptera and Lepidoptera. These orders present very large numbers of individuals collected in the agroecosystems of cabbage, tomato, amaranth and greater nightshade. This result confirms the work of Martin & Sauerborn (2013), who showed that of the seven main orders of insect pests recorded on several crops in three West African countries, Coleoptera, Hemiptera and Lepidoptera are the most numerous. According to Powell (2003), Lepidoptera represents the most diverse lineage of organisms to have evolved from plants, outnumbering other phytophagous insects. Lepidoptera are all phytophagous or carpophagous, unlike Hemiptera (Gillott, 2005) and Coleoptera (Martin & Sauerborn, 2013). Coleoptera are very numerous, accounting for a quarter of all described species among all officially described life forms (Hunt et al., 2007).

Their diet partly explains the large number of hemipterans. This result confirms the work of Tendeng et al. (2022) on the diversity and occurrence of pests in market garden agroecosystems in Lower Casamance, Senegal. Diversity is very high and practically similar in all localities. This high biodiversity of the entomological fauna of pests can be explained in part by the presence of several speculations that constitute food resources for these pests (Aquilino *et al*., 2005; Eisenhauer *et al*., 2013; Vasseur *et al*., 2013). The fact that the same speculations are found in these localities shows the similar presence of the pests. These results are similar to those of (Tendeng *et al*., 2022), who collected 65 pest species on 17 host plants in market garden agrosystems in the lower Casamane region of Senegal. The presence of a high diversity of species in the agroecosystems of these four localities shows an ecosystemic balance. According to Gaucherel et al. (2007), agrosystems maintain ecosystem balance through the maintenance of arthropod diversity. Indeed, arthropods and particularly insects are important links in the food chain in agrosystems (Amiaud & Carrère, 2012; Blanchart *et al*., 2017). The presence of numerous pest species in an environment does not necessarily explain the presence of significant damage to agricultural production. In fact, in most cases, an insect only becomes harmful when the number of individuals increases. The abundance of a single pest species often indicates an imbalance in biodiversity. The locality of Agamè in the commune of Lokossa is more resilient, with a lower abundance linked to the presence of greater diversity. Indeed, the presence of high diversity shows the balance of the environment, which translates into low pest abundance. The work of Tscharntke *et al*. (2007) confirms these results, showing that the resilience of an agroecosystem is materialized by the diversity of its animal and plant species. Indeed, the host plant influences the presence of a pest in an environment. Some crops attract certain pest species while others repel them (Midega *et al*., 2018). Plants emit volatile compounds that attract natural enemies but repel pests (Will *et al*., 2007). This result is confirmed by Le Roux *et al*. (2008), who assert that the entomological fauna is most often influenced by the nature of the crops grown in the environment. This large number of pests shows that vegetable crops, in general, and tomatoes, cabbage, nightshade and pigweed, in particular, harbor a sufficient number of enemies. These results are similar to those obtained by Atachi et al. (1989) and Djéto-Lordon et al. (2007), who demonstrated in their work that tomato crops harbour a multitude of insects belonging to different orders. James *et al.* (2010) have also shown that tomato crops are particularly vulnerable to various insect pests, which can seriously compromise yields. Inventories of shea insects in Ghana enabled Dwomoh (2003) to identify 53 pest genera and species.

As for Odebiyi *et al*. (2004), they succeeded in classifying 33 genera and species for the same plant in Nigeria. The inventory of insect pests and vectors of rice yellow mottle in North Cameroon by Sadou *et al*. (2008) identified 46 species belonging to seven orders and 26 families. The orders Lepidoptera and Hemiptera were the most dominant. Diptera, Coleoptera and Hymenoptera were moderate in the plantations. It should be noted, however, that the majority of insects inventoried were present at the vegetative stage, notably on leaves and stems. Lepidopteran larvae, Coleoptera, Orthoptera, Homoptera and Diptera were more conspicuous and frequent on these different parts of the plant. According to Atachi *et al.* (1989), these species attack the vegetative organs of cultivated plants to a greater extent, preventing them from developing. Fabre *et al.* (2001) confirm this, stating that the main pests of tomato crops are found among Lepidoptera, Coleoptera, Orthoptera and Homoptera. The presence of these pests seriously affects the proper growth and development of the plant. The inventory revealed that several quarantine pests are rampant in tomato, nightshade, amaranth and cabbage fields in southern Benin. To meet this new requirement to improve the production of certain market gardens crops such as cabbage, nightshade, pigweed and tomato in the Commune of Djakotomey, Sakété, Lokossa and Sèmè-kpodji, it is urgent to consider short-term measures involving a minimum of chemical or biological treatment. Phytosanitary treatment trials with different insecticides should, therefore, be carried out. According to Parrella *et al.* (1984), certain synthetic insecticides, in particular pyrethrinoïdes, are effective against leaf miners. Biopesticides such as Topbio, neem oil and other botanical extracts are also effective on certain lepidopteran larvae that cause more damage to plants.

6. Conclusion

The present study provided information on the biodiversity of insects associated with the cultivation of cabbage, tomato, nightshade and Amaranth in Southern Benin and suggested the possibility of integrated pest management using biological pesticides in conjunction with agroecological practices. The insects inventoried belonged to the orders Lepidoptera, Orthoptera, Hemiptera, Coleoptera, Diptera, Homoptera, Hymenoptera, Thysanoptera and Odonata. Insect pests cause various types of damage to the different parts of the plants studied. We observed leaf and fruit perforations, as well as flower and fruit drop and rotting of infested fruit. These results form the basis of our knowledge of the various pests infesting these crops in southern Benin. Knowledge of the diversity, abundance and distribution of pests will enable alternative control strategies to be put in place with a view to preserving the market garden sector.

Acknowledgements

The realization of this work was the participation of several people to whom we would like to express our deepest gratitude. In particular, Dr. GOERGEN Georg. The authors are grateful to the farmers and the agriculture extension staff in Benin who participated in this study.

Funding

This work was not funded by any organization and was carried out using our own funds.

References

[1] Arlette Adjatini et al., “Biological Diversity and Characterization of Market Gardening Activity at the Grand-Popo Site in Southern Benin,” *International Journal of Biological and Chemical Sciences*, vol. 13, no. 6, pp. 2750-2764, 2020. [CrossRef] [Google Scholar] [Publisher Link]

[2] Claude Ahouangninou et al., “Analysis of the Determinants of Phytosanitary Practices of Market Garden Producers in Southern Benin,” *Afrique Science*, vol. 15, no. 5, pp. 252-265, 2019. [Google Scholar]

[3] Ahouangninou Claude, “*Sustainability of Vegetable Production in South Benin: A Trial of the Ecosystem Approach*,” Doctoral Thesis, University of Abomey-Calavi, pp. 1-349, 2013. [Google Scholar] [Publisher Link]

[4] Aman Assoh Hortance, and Koffi-Bikpo Céline Yolande, “Impact of Urbanization in the Abidjan District on Peri-Urban Market Gardening,” *La Revue de Géographie de l’Université Jean Lorougnon Guédé de Daloa, DaloGéo*, 2021. [Publisher Link]

[5] B. Amiaud, and P. Carrère, “The Multifunctionality of the Grassland for the Provision of Ecosystem Services,” *Fourrages*, vol. 211, pp. 229-238, 2012. [Google Scholar]

[6] Kristin M. Aquilino, Bradley J. Cardinale, and Anthony R. Ives, “Reciprocal Effects of Host Plant and Natural Enemy Diversity on Herbivore Suppression: An Empirical Study of a Model Tritrophic System,” *Oikos*, vol. 108, pp. 275-282, 2005. [CrossRef] [Google Scholar] [Publisher Link]

[7] P. Atachi, M. Desmidts, and C. Durnez, “Stinging Moths (Lepidoptera, #Noctuidae#) Pests of Citrus Fruits in Benin: Damage they Cause and Morphological Characteristics,” *FAO Phytosanitary Bulletin*, pp. 111-120, 1989. [Publisher Link]

[8] Kamil Barton, "MuMIn: Multi-Model Inference," 2024. [CrossRef] [Google Scholar] [Publisher Link]

[9] Anne Blanchart et al., “Soils Contribution to the Production of Ecosystem Services in Urban Areas – A Review,” *Environnement Urbain*, vol. 11, 2018. [CrossRef] [Google Scholar] [Publisher Link]

[10] Bordat Dominique, and Arvanitakis Laurence, “Arthropods of Vegetable Crops in West and Central Africa, Mayotte and Reunion, ” *Cirad - Agritrop*, 2024. [Google Scholar] [Publisher Link]

[11] Michael Chinery, *Insects of Britain and Western Europe*, 3rd ed., Bloomsbury, pp. 1-320 2012. [Publisher Link]

[12] J.E. Colin, J.C. Heyd, “The Situation of Leafy Vegetables in Market Garden Production in Southern Benin,” *Tropicultura*, vol. 9, no. 3, pp. 129-133, 1991. [Google Scholar] [Publisher Link]

[13] Gerard Delvare, and Henri-Pierre Aberlenc, *Insects of Africa and Tropical America: Keys to Family Recognition*, Laboratoire de Faunistique, pp. 1-302, 1989. [Google Scholar] [Publisher Link]

[14] Djiéto-Lordon Champlain, Aléné Désirée Chantal, and Reboul Jean-Louis, “Contribution to the Knowledge of Insects Associated with Market Gardening in the Vicinity of Yaoundé-Cameroun Region,” *Cirad - Agritrop*, 2005. [Google Scholar] [Publisher Link]

[15] Emmanuel Agyemang Dwomoh, “Insect Species Associated with Sheanut Tree (Vitellaria Paradoxa) in Northern Ghana,” *Tropical Science*, vol. 43, no. 2, pp. 70-75, 2006. [CrossRef] [Google Scholar] [Publisher Link]

[16] Nico Eisenhauer et al., “Niche Dimensionality Links Biodiversity and Invasibility of Microbial Communities,” *Functional Ecology*, vol. 27, no. 1, pp. 282-288, 2013. [CrossRef] [Google Scholar] [Publisher Link]

[17] Frédéric Fabre, and Philippe Ryckewaert, “Integrated Pest Management for Vegetable Crops in Réunion,” *Fifth Annual Meeting of Agricultural Scientists*, 2002. [Google Scholar] [Publisher Link]

[18] G. Thomas, “*Growing Greener Cities in Africa: First Status Report on Urban and Periurban Horticulture in Africa*,” Food and Agriculture Organization of the United Nations, 2012. [Google Scholar] [Publisher Link]

[19] Cédric Gaucherel, Françoise G. Burel, and Jacques Baudry, “Multiscale and Surface Pattern Analysis of the Effect of Landscape Pattern on Carabid Beetles Distribution,” *Ecological Indicators*, vol. 7, no. 3, pp. 598-609, 2007. [CrossRef] [Google Scholar] [Publisher Link]

[20] Cedric Gillott, *Entomology*, 3rd ed., Springer Netherlands, pp. 1-831, 2005. [Google Scholar] [Publisher Link]

[21] Huat Joël, and David-Benz Hélène, “Industrial Tomatoes in Senegal: Production Performance and Challenges for the Sector," *Proceedings of the Seminar for Sustainable Development of Irrigated Agriculture in the Sudano-Sahelian Zone*, Dakar, Senegal, pp. 167-187, 2000. [Google Scholar] [Publisher Link]

[22] B. James et al., *Integrated Pest Management in Vegetable Production: A Guide for Extension Workers in West Africa*, Iita, 2010. [Google Scholar] [Publisher Link]

[23] Marjorie Le Bars et al., “Assessment of risks associated with the use of pesticides in cotton growing in Mali,” *Cahiers Agricultures*, vol. 29, pp. 1-9, 2020. [CrossRef] [Publisher Link]

[24] Xavier Le Roux et al., “*Agriculture and Biodiversity: Synergies to be Exploited*,” Collective Scientific Expertise Report, *INRA*, pp. 1-637, 2008. [CrossRef] [Google Scholar] [Publisher Link]

[25] Aristide Maniriho, "*Productivity, Efficiency and Profitability of Small Farms in the Lava Soil Region of Rwanda*," Doctoral Thesis, pp. 1-256, 2021. [Google Scholar] [Publisher Link]

[26] Konrad Martin, and Joachim Sauerborn, *Origin and Development of Agriculture*, Agroecology, Springer, Dordrecht, pp. 9-48, 2013. [CrossRef] [Google Scholar] [Publisher Link]

[27] Jacques Mignon, Éric Haubruge, and Frédéric Francis, *Identification Key to the Main Insect Families of Europe*, Gembloux Agronomic Presses, pp. 1-87, 2016. [Google Scholar] [Publisher Link]

[28] Shinichi Nakagawa, and Holger Schielzeth, "A General and Simple Method for Obtaining R^2 from Generalized Linear Mixed-Effects Models," *Methods in Ecology and Evolution*, vol. 4, no. 2, pp. 133-142, 2012. [CrossRef] [Google Scholar] [Publisher Link]

[29] J.A. Odebiyi et al., "Vertebrate and Insect Pests and Hemi-Parasitic Plants of Parkia Biglobosa and Vitellaria Paradoxa in Nigeria," *Agroforestry Systems*, vol. 60, pp. 51-59, 2004. [CrossRef] [Google Scholar] [Publisher Link]

[30] M.P. Parrella, C.B. Keil, and G.J. Morse, "Insecticide Resistance in Liriomyza Trifolii [Leafminer, Chrysanthemums]," *California Agriculture California Agricultural Experiment Station*, vol. 38, pp. 22-33, 1984. [Google Scholar] [Publisher Link]

[31] Jaimie S. Powell, and Kenneth F. Raffa, "Fate of Conifer Terpenes in a Polyphagous Folivore : Evidence for Metabolism by Gypsy Moth (Lepidoptera : Lymantriidae)," *Journal of Entomological Science*, vol. 38, no. 4, pp. 583-601, 2003. [CrossRef] [Google Scholar] [Publisher Link]

[32] R Core Team, "R A Language and Environment for Statistical Computing, R Foundation for Statistical," *Computing*, 2020. [Google Scholar]

[33] Sadou Ismaël et al., "Inventory of Devastating and Vectorial Insects of the Rice Yellow Mottle Virus in the Irrigated Perimeter of Maga (Far-North of Cameroon)," *Tropicultura*, vol. 26, no. 2, pp. 84-88, 2008. [Google Scholar] [Publisher Link]

[34] Gbombélé Soro et al., "Use of Phytosanitary Products in Market Gardening around the Drinking Water Supply Dam in the Town of Korhogo (Northern Ivory Coast), Risks for Public Health," *Environnement, Risques & Santé*, vol. 17, no. 2. pp. 155-163, 2018. [CrossRef] [Google Scholar] [Publisher Link]

[35] Etienne Tendeng et al., "Diversity and Occurrence of Pests in Vegetable Agroecosystems in Basse Casamance, Senegal," *European Scientific Journal*, vol. 18, no. 27, pp. 104-120, 2022. [CrossRef] [Google Scholar] [Publisher Link]

[36] Etienne Tendeng et al., "Updating the Entomofauna of Market Garden Crops in Basse Casamance (Senegal)," *International Journal of Biological and Chemical Sciences*, vol. 11, no. 3, pp. 1023-1028, 2017. [CrossRef] [Google Scholar] [Publisher Link]

[37] G. Thomas, "*Growing Greener Cities in Africa: First Status Report on Urban and Peri-urban Horticulture in Africa*," Food and Agriculture Organization of the United Nations, pp. 1-111, 2012. [Google Scholar] [Publisher Link]

[38] Chloé Vasseur et al., "The Cropping Systems Mosaic: How does the Hidden Heterogeneity of Agricultural Landscapes Drive Arthropod Populations?," *Agriculture, Ecosystems & Environment*, vol. 166, pp. 3-14, 2013. [CrossRef] [Google Scholar] [Publisher Link]

[39] Yarou Boni Barthélémy et al., "Pesticidal Plants and the Protection of Vegetable Crops in West Africa (Literature Review), " *Biotechnology, Agronomy and Society and Environment*, vol. 21, no. 4, pp. 288-304, 2017. [CrossRef] [Google Scholar] [Publisher Link]