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Insect's Diversity of *Capsicum Annuum* L. (Solanaceae) and Damage Due to *Cryptophlebia Leucotreta* (Lepidoptera: Tortricidae) on Fruits

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Abstract

Capsicum annuum (pepper) is a vegetable plant whose fruits are used as spices or condiments and present in many African dishes. This crop is subject to numerous attacks by insect pests causing significant damage to crops despite the use of various means of control which negatively affect the environment and cause significant damage to the health of the producer. Very often, market gardeners do not have a good knowledge of the different varieties likely to increase their production. In order to increase the yield of this crop, this study is a contribution to the knowledge of the resistance of certain varieties of *C. annuum* to pests. It was carried out from May to September 2019 on an experimental plot set up for this purpose within the campus of the Higher Teacher Training College of the University of Yaoundé I. This study allowed us to inventory and compare the associated entomofauna to the red and yellow varieties of *C. annuum*. To do this, we carried out sampling, inventories and direct field observations of the entomofauna and their activity. Following this study, we noted that the entomofauna was quite diversified. The number of insect orders was 06 for the yellow variety and 05 for the red variety. On yellow pepper, the Coleoptera order presented the highest abundances with 42.85% of all individuals, followed by Hemiptera (22.45%) and Orthoptera (20.81%). On red pepper, the Coleoptera order presented the highest abundances with 45.71% of all individuals, followed by Diptera (28.57%), and Orthoptera (14.29%). The analysis of the variation of the average abundances of the pests on the two varieties of pepper revealed that the phenology influences on this one. Indeed, during flowering, the orders of Coleoptera, Orthoptera, Hemiptera were the most represented with respectively 13 individuals (i.e. 46.42% of all individuals), 06 individuals (i.e. 21.42%) and 05 individuals (i.e. 17.85%) for the yellow pepper while at the flowering-fruiting stage, the Coleoptera and Diptera orders were the most represented with respectively 08 individuals (i.e. 44.44% of all individuals) and 07 individuals (i.e. 38.88%) for the Red pepper. The yellow pepper produced a total of 28 individuals at the flowering stage (i.e. 57.14% of the orders combined) and the red pepper 18 individuals at the flowering-fruiting stage (i.e. 51.42% of the orders combined). The attack rates on fruits due to *Cryptophlebia leucotreta* presented significant differences from one variety of pepper to another with higher values on the yellow pepper at the third harvest ($P=0.01$; $F=6.83$), fourth harvest ($P=0.001$; $F=44.67$) and at the fifth harvest ($P=0.003$; $F=4.43$) with respectively average rates of 13.9±3.2% ($N=49$); 35.33±3.90% ($N=110$) and 24.76±8.62% ($N=23$).

Keywords: Diversity, Fruit Damage, *Capsicum Annuum*, *Cryptophlebia Leucotreta*, Phenology

1. Introduction

Agriculture is the lever of economic growth in the world. In Cameroon, agriculture is the main provider of jobs, since it employs about 60% of the active population, mainly within family farms. It also plays an irreplaceable role in generating income in the countryside for some 2 million agricultural households identified (INS 2017) [9]. The ever-increasing rate of urbanization in Cameroon forces some populations to engage in income-generating activities such as market gardening to improve their living conditions. The State, through its agricultural policy, pays considerable attention to the revival and increase of market gardening production; among other things the cultivation of peppers). The economic slowdown in Central

African countries and the lack of investment in agriculture puts significant pressure on the growing populations of cities: unemployment, food insecurity. Raising the level of production of urban and peri-urban horticulture has become crucial to ensure a decent standard of living for populations, especially women and young people (FAO 2014) [6]. Pepper, along with okra, tomato and eggplant, are the main cultivated vegetables. Global marketed pepper production has been on the rise for several years, to 10 million tons over more than one million hectares (Fondio *et al*. 2015) [7]. The word pepper evokes for most people the pungent flavor of a plant or a culinary preparation. Pepper belongs to the Solanaceous family. It is a plant very widespread in tropical and subtropical regions whose fruits like so many other spices are used directly in human food or indirectly after transformation. Botanists recognize about 100 species currently grouped into two main species: *Capsicum annuum* L. and *Capsicum frutescens* L. characterized by the existence of many varieties distinguished by their shape, color and pungency. Varieties of peppers with large red fruits (Caribbean Safi, etc.) and varieties of peppers with large yellow fruits (Big Sun, Burkina yellow, etc.) are the most recommended on the local Cameroonian market (LVDP 2017) [11]. The development of pepper cultivation, a source of income for many families, is subject to many constraints, including: inadequate cultivation techniques, soil depletion, anarchic and inappropriate use of pesticides and chemical fertilizers, lack of a marketing policy, diversification of predators (Mbanyé 2000, Elono Azang 2007) [12, 3]. Due to the use of agricultural inputs in order to remedy the presence of pests on the one hand and the massive production of crops on the other hand, human health (farmer and consumer) and the environment are threatened (Elono Azang 2007) [3]. Certain varieties of pepper would present significant differences on the basis of the damage caused to them by predators, thus presenting a significant asset for increasing yield. In the integrated fight against predators, a good knowledge of the different varieties resistant to them is necessary for an optimal yield (Djiéto-Lordon *et al*. 2008) [2]. This study contributes to the knowledge of the resistance of certain pepper varieties against pests. In order to achieve this objective, we propose: (i) to highlight the diversity of insects associated with two varieties of *Capsicum annuum*; (ii) to study the influence of the phenology of yellow and red peppers on the abundances of insect orders of economic importance and finally, (iii) to evaluate the attack rates due to *Cryptophlebia leucotreta* on the fruits of yellow and red peppers.

2. Materials and Methods

2.1 Sampling period and study site

The test was conducted in the forest region of southern Cameroon, precisely in urban area of Yaoundé corresponding to the following geographical coordinates: longitude 3°57'35, 5"N and latitude 011°30'37.1"E (Fig 1). Yaoundé is under the dominance of the Guinean-type equatorial climate with four seasons with bimodal rainfall: short dry season, long dry season, short rainy season and long rainy season (Suchel 1987) [15]. Our study period was limited from May 3 to September 11, 2019, therefore covering the short rainy season, short dry season and the start of the long rainy season.

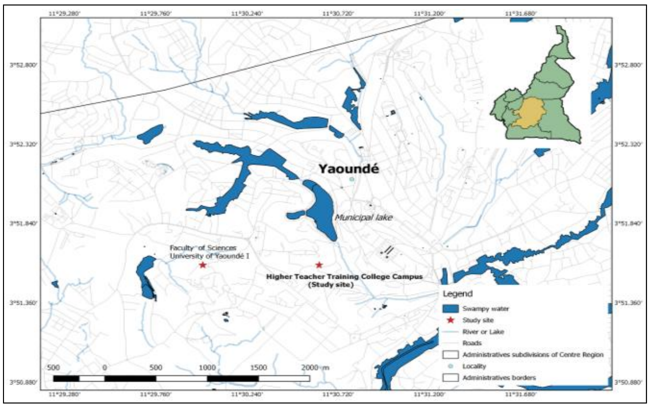

Fig 1: Study site at Higher Teacher Training College of the University of Yaoundé I

2.2 Geology and Vegetation

The soil of Yaoundé is a classic lateritic and forest soil, more or less superficially leached red horizon which can reach a depth of 4 to 10m under favorable conditions, then, gravelly horizon, mottled horizon and horizon of alteration of the bedrock. In addition to marshy areas, this soil is chemically poor but can nevertheless support rich crops in semi-rural areas, if it is enriched or as long as a significant forest cover protects it from erosion (Bachelier 1985) [1]. The vegetation is of the intertropical type with predominance of southern forest (Wéthé 1999) [17]. It is strongly degraded following a strong urbanization.

2.3 Biological Material

The plant material used during our study consisted of plants of the species *Capsicum annuum* of local red and yellow varieties, whose seeds were extracted from fruits purchased at the Mfoundi market in Yaoundé (Fig 2).

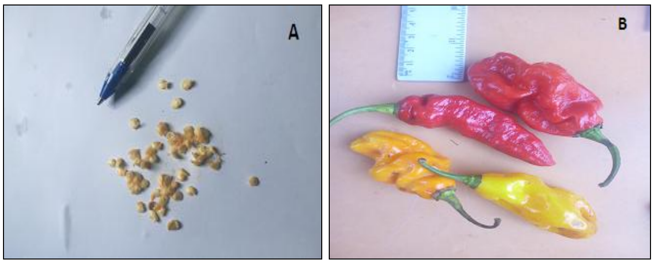

Fig 2: Seeds (A) and Fruits (B) of local varieties of red and yellow peppers

2.4 Seeds Nursery

The seeds were planted on March 23, 2019 at the Higher Teacher Training College (HTTC) campus in a rectangular tray (dimensions: 20*30cm) containing black soil that we purchased from a botanical garden at the ENAM crossroads. The seeds were put in rows spaced horizontally, 1cm deep and covered with soil. We then watered regularly and emergence took place after 8 days.

2.5 Experimental Design

Left fallow for 2 years, the experimental space (11.5m long and 8.5m wide) was cleared, cleaned, plowed and we put in place 4 ridges 4.6m long and 1.5m wide each, spaced 0.5m apart (Fig 3). The ridges were enriched with organic fertilizer (rat waste from the animal facility of the Animal

Physiology Laboratory). The seedlings (4 to 5 leaves) were transplanted in the evening to avoid water stress caused by the high temperatures of the experimental site. Each ridge had 10 young pepper plants at the rate of 5 plants per row or line. Each plant was separated from the other by 1 m on the same line and 0.8 m on the neighboring line. After transplanting (May 14, 2019), the plants were watered and freed of weeds by weeding to avoid competition between plants. It should be noted that no insecticide treatment was carried out.

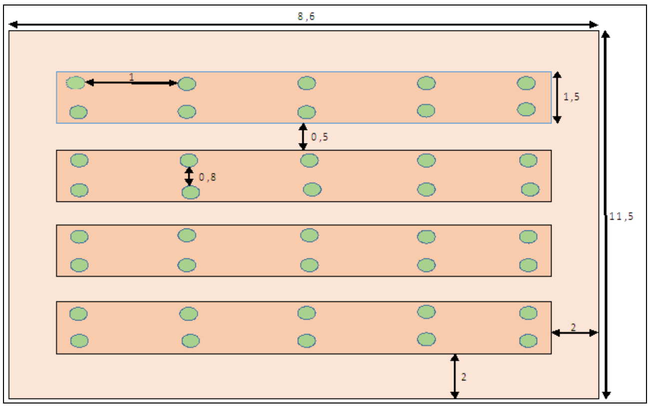

Fig 3: Experimental device on the HTTC campus (Unit of measurement = meter (m), the circles represent the pepper plants)

2.6 Data collection

2.6.1 Sampling survey

The sampling effort was evaluated using nonparametric estimators of species richness, namely: ACE, ICE, Chao 1, Chao 2, Jack-Knife 1, Jack-Knife 2, Bootstrap, Effort MMSMean and Mean, and then rarefaction curves.

2.6.2 Ordinal biological richness

Biological diversity was highlighted through observations and captures of insects in the field on all parts of the plant (stems, leaves, flowers, fruits). These captures were made using a locally manufactured mouth aspirator, constituting the only means of capture used (Elono *et al*. 2016) [5], once a week from 8 a.m. to 12 p.m. from the start of sampling until at the end. The captured insects were introduced into a box containing 70% alcohol for better preservation and labeled with the following information: (i) date of sampling; (ii) current season; (iii) variety of pepper; (iv) ridge and plant numbers and, (v) phenological state of the plant. These boxes were brought back to the laboratory for counting, sorting and identification using the identification keys and their conservation.

2.6.3 Ordinal diversity

Ordinal diversity was calculated from Shannon's (H') and Simpson's (S) diversity index. Diversity is the function of the probability Pi of presence of each species (order in our case) i, in relation to the total number of individuals. It is calculated from the following formula:

$$H' = -\sum ni/N \log_2 ni/N$$

$$D = \sum ni\,(ni-1) / N\,(N-1)$$

Where:

H' = Shannon index;
D = Simpson's index;
N = Sum of ordinal numbers;
ni = Population size of ordinal i.

2.6.4 Phenological influence on ordinal's abundance

The captured insects were arranged in order, allowing us to assess their abundance according to the phenology of each pepper variety.

2.6.5 Index damage due to *Cryptophlebia leucotreta* on fruits

Losses were assessed from fruit harvests in the field throughout the fruiting period. Thus, of the harvested fruits, the fruits showing insect bites and the exit holes of the larvae of *Cryptophlebia leucotreta* were considered as attacked and those showing no sign caused by an insect, were considered as healthy fruits. The attack rates were evaluated by the proportion of attacked fruits out of all the fruits harvested according to the following formula (Heumou *et al*. 2015, Elono *et al*. 2016) [8, 5]:

$$\textbf{AR (\%)} = ni / N \times 100$$

Where:

AR (%) = Attack rate (%) due to aphids and whiteflies**;**
ni = Number of fruits attacked**;**
N = Total number of fruits per plant**.**

2.7 Data Analysis

The data was entered into Excel software. After a logarithmic transformation of the numbers, we compared the means of the different orders of insects on the two varieties of pepper using the ANOVA test contained in the GLM procedure of the "Statistica" software version 8.0. (2007), followed by a multiple comparison of means 2 to 2 by Fisher's LSD test in case of significant differences. Sampling effort was extracted using "Estimate S" software version 8.2.0 (2009). All the results were assessed at the significance level of 5% ($p < 0.05$).

3. Result

3.1 Sampling effort

At the end of the study, a gradual evolution in the number of insect orders was observed (6 orders on the yellow pepper and 5 on the red pepper). We can therefore say that the sampling was representative in this insect community associated with these two pepper varieties because, as we progressed, more orders were added until saturation was reached (Fig 4).

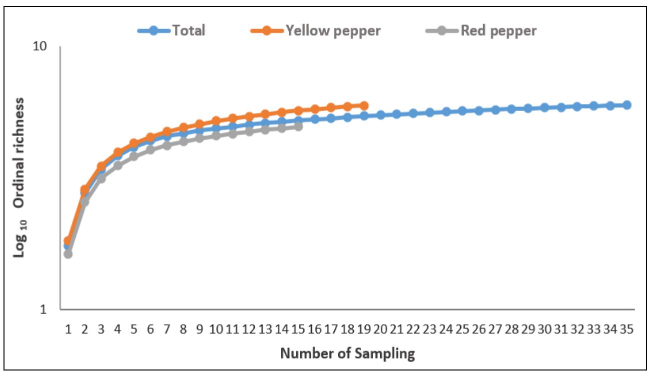

Fig 4: Experimental device on the HTTC campus (Unit of measurement = meter (m), the circles represent the pepper plants)

The non-parametric estimators of ordinal richness, namely ACE (86.95% on yellow pepper and 88.02% on red pepper), ICE (89.55% on yellow pepper and 91.74% on red pepper), Chao 1 (100% on yellow and red pepper), Chao 2 (100% on both pepper varieties), Jack knife 1 (86.33% on yellow pepper and 84.17% on red pepper), Jack knife 2 (85.71% on yellow pepper and 73.42% on red pepper), Bootstrap (92.02% on yellow pepper and 92.59% on red pepper), Means (89.68% and 83.33% on yellow and red pepper respectively), and MMSMeans (88.23% and 86.2% on yellow and red pepper respectively), made it possible to evaluate the sampling effort, which presented the retained values within the interval 85.71% and 100% for yellow pepper, then 73.42% and 100% for red pepper. These values are sufficient for a representative sample of the insect community in our study site (Table 1).

Table 1: Non-parametric estimators of ordinal richness in the insect fauna of yellow and red peppers from July to September 2019 in Yaoundé

Non-parametric estimators	Values	
	Yellow pepper	Red pepper
ACE	6.9 (86.95%)	5.68 (88.02%)
ICE	6.7 (89.55%)	5.45 (91.74%)
Chao 1	6 (100%)	5 (100%)
Chao 2	6 (100%)	5 (100%)
Jack knife 1	6.95 (86.33%)	5.94 (84.17%)
Jack knife 2	7 (85.71%)	6.81 (73.42%)
Bootstrap	6.52 (92.02%)	5.4 (92.59%)
Means	6.69 (89.68%)	6 (83.33%)
MMSMeans	6.8 (88.23%)	5.8 (86.2%)
Cumulated sampling	19	15
Observed Orders	6	5
Abundance	49	35

Note: The values in parentheses represent the sampling effort.

3.2 Ordinal richness

On the yellow pepper, we captured 49 individuals belonging to 6 insect orders. These were: Coleoptera, Dermaptera, Diptera, Hemiptera, Hymenoptera, and Orthoptera. The order Coleoptera had the highest abundance, representing 42.85% of all individuals, followed by Hemiptera with 22.45%, and Orthoptera with 20.81%. The orders Diptera (8.15%), Hymenoptera (4.01%), and Dermaptera (2.05%) had the lowest abundance (Fig 5).

On the red pepper, we captured 35 individuals belonging to 5 orders: Coleoptera, Diptera, Hemiptera, Hymenoptera, and Orthoptera. The order Coleoptera exhibited the highest abundance, representing 45.71% of all individuals, followed by Diptera with 28.57%, and Orthoptera with 14.29%. The orders Hemiptera (8.57%) and Hymenoptera (2.86%) showed the lowest abundances (Fig 5).

Observations of the two varieties show an absence of the order Dermaptera on red pepper compared to yellow pepper, where this order represented 2.05% of individuals. Furthermore, a high abundance of Diptera was found on red pepper, with 28.57% of individuals compared to only 8.16% on yellow pepper; in contrast, the order Hemiptera was more abundant on yellow pepper than on red pepper (Fig 5).

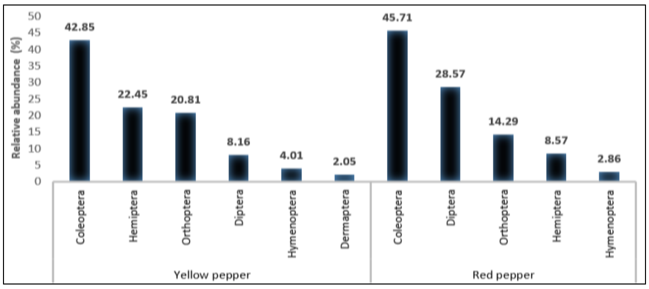

Fig 5: Relative abundances of different insect orders on red and yellow peppers

3.3 Ordinal diversity

The study showed that ordinal diversity was high in both chili pepper varieties throughout our study (Shannon index: yellow variety = 1.44 and red variety = 1.31; Simpson index: yellow variety = 3.71 and red variety = 3.34), demonstrating representative ordinal richness. It should be noted that the yellow variety exhibited higher insect diversity compared to the red variety (Table 2).

Table 2: Ordinal diversity of the insect fauna associated with yellow and red peppers

Diversity indexes	Index values	
	Yellow pepper	Red pepper
Shannon index (H')	1.44	1.31
Simpson index (D)	3.71	3.34
Abundance	49	35
Orders	6	5

3.4 Phenology influence on insect orders' abundance

3.4.1 On yellow pepper

During the pre-flowering period, the orders Hemiptera and Coleoptera were the most represented, with 4 (50%) and 3 (37.5%) individuals respectively (Table 3). During the flowering period, the order Coleoptera was the most represented, followed by Orthoptera and Hemiptera, with 13 (46.42%) individuals, 6 (21.42%) individuals, and 5 (17.85%) individuals respectively (Table 3). during the flowering-fruiting period, the orders Coleoptera and Orthoptera were the most representative with 5(38.46%) and 4(30.76%) individuals respectively (Table 3). We observed that, across the three phenological phases, the orders Coleoptera, Orthoptera, and Hemiptera were most represented during the flowering phase, accounting for 46.42%, 21.42%, and 17.85% of all individuals, respectively; the orders Hemiptera and Coleoptera were most represented during the pre-flowering phase, with 50% and 37.5% of individuals, respectively; and finally, the orders Coleoptera and Orthoptera were most represented during the flowering-fruiting phase, with 38.46% and 30.76% of individuals, respectively. The results showed that the highest number of insects (57.14%) was observed during the flowering period (cumulative insect orders).

3.4.2 On red pepper

During pre-flowering, the order Coleoptera was the most representative with 4 (57.14%) individuals. During flowering, the order Coleoptera was the most represented with 4 (40%) individuals, followed by Diptera with 2 (20%) individuals, and Orthoptera with 2 (20%) individuals. During flowering and fruit set, the orders Coleoptera and Diptera were the most represented with 8 (44.44%) and 7 (38.88%) individuals, respectively. We observed that, over the three phenological phases, the orders of Coleoptera were the most represented at the pre-flowering phase with (57.14%) of all individuals; the order of Coleoptera and Diptera were the most represented at flowering with 40%, 20% of individuals respectively and finally, the order of Coleoptera and Diptera were the most represented at the flowering-fruiting phase with 44.44%, 38.88% respectively. The results showed that it was during the flowering-fruiting period (cumulative insect orders) that the individuals were most represented (with 51.42%) of individuals (Table 3).

Table 3: Influence of yellow and red peppers phenology on the absolute and relative abundances of insect orders

Insect orders	Pepper varieties	Phenological stages			Total
		Pre-flowering	Flowering	Flowering-fruiting	
Coleoptera	Yellow pepper	3 (37.5%)	13 (46.42%)	5 (38.46%)	21 (42.85%)
	Red pepper	4 (57.14%)	4 (40%)	8 (44.44%)	16 (45.71%)
Dermaptera	Yellow pepper	0 (0%)	1 (3.57%)	0 (0%)	1 (2.04%)
	Red pepper	0 (0%)	0 (0%)	0 (0%)	0 (0%)
Diptera	Yellow pepper	1 (12.5%)	3 (10.71%)	0 (0%)	4 (8.16%)
	Red pepper	1(14.28%)	2 (20%)	7 (38.88%)	10 (28.57%)
Hemiptera	Yellow pepper	4 (50%)	5 (17.85%)	2 (15.38%)	11 (22.44%)
	Red pepper	1(14.28%)	1 (10%)	1 (5.55%)	3 (8.57%)
Hymenoptera	Yellow pepper	0 (0%)	0 (0%)	2 (15.38%)	2 (4.08%)
	Red pepper	0 (0%)	1 (10%)	0 (0%)	1 (2.85%)
Orthoptera	Yellow pepper	0 (0%)	6 (21.42%)	4 (30.76%)	10 (10%)
	Red pepper	1(14.28%)	2 (20%)	2 (11.11%)	5 (14.28)
Total	Yellow pepper	8 (16.32%)	28 (57.14%)	13 (26.53%)	49 (100%)
	Red pepper	7 (20%)	10 (28.57)	18 (51.42%)	35 (100%)

Note: The values in parentheses represent the relative abundances.

3.5 Index damage due to *Cryptophlebia leucotreta* on *Capsicum annuum* fruits

3.5.1 For harvested fruits

- At harvest 1, the total number of fruits harvested per plant, according to pepper varieties, did not show significant variation (df=1; F=2.29; P=0.15). This number was slightly higher for yellow pepper, with an average of 4.69±0.69 fruits harvested per plant (Min=3.18; Max=6.20; N=13).
- At harvest 2, the total number of fruits harvested per plant, according to pepper varieties, did not show significant variation (df=1; F=0.12; P=0.733). This value was slightly higher for red pepper, with an average of 2±0.57 fruits (Min=0.16; Max=3.83; N=4).
- At harvest 3, the total number of fruits harvested per plant according to pepper varieties did not show a significant variation (df=1; F=3.2; P=0.076). This number was slightly higher for red pepper, with an average of 13.5±0.40 fruits (Min=12.66; Max=14.33; N=24).
- At harvest 4, the total number of fruits harvested per plant, according to pepper varieties, showed a significant difference (df=1; F=9.71; P=0.004). This number was higher for red pepper, with an average of 15.85±0.63 fruits (Min=14.58; Max=17.12; N=110).
- At harvest 5, the total number of fruits harvested per plant varied significantly among pepper varieties (df=1; F=6.84; P=0.011). This number was highest for red pepper, with an average of 11.37 ± 1.36 fruits (Min=8.61; Max=14.13; N=40).
- At harvest 6, the total number of fruits harvested per plant varied significantly among pepper varieties (df=1; F=74.30; P=0.000). This value was higher for red pepper, with an average of 31.07 ± 1.83 fruits (Min=27.35; Max=34.79; N=40).

3.5.2 For attacked fruits

- At harvest 1, the total number of fruits attacked by *C. leucotreta* was not significantly different among pepper varieties (df=1; F=3.04; P=0.101). This number was slightly higher for yellow pepper, with an average of 2.92 ± 0.82 attacked fruits (Min=1.11; Max=4.72; N=13).
- At harvest 2, the total number of fruits attacked by *C. leucotreta* was not significantly different among pepper varieties (df=1; F=0.31; P=0.58). This number was slightly higher for yellow pepper, with an average of 0.41 ± 0.14 attacked fruits (Min=0.08; Max=0.74; N=12).
- At harvest 3, the total number of fruits attacked by *C. leucotreta* differed significantly among pepper varieties (df=1; F=7.07; P=0.009). This number was higher for yellow pepper, with an average of 2.67 ± 0.65 attacked fruits (Min=1.35; Max=3.99; N=49).
- At harvest 4, the total number of fruits attacked by *C. leucotreta* differed significantly among pepper varieties (df=1; F=38.51; P=0.00). This number is slightly higher for red pepper, with an average of 6 ± 0.73 fruits attacked (Min=4.53; Max=5.46; N=110).
- At harvest 5, the total number of fruits attacked by *C. leucotreta*, according to pepper variety, did not show a significant difference (df=1; F=0.002; P=0.95). This number is slightly higher for yellow pepper, with an average of 1.30 ± 0.43 fruits attacked (Min=0.40; Max=2.20; N=23).
- At harvest 6, the total number of fruits attacked by *C. leucotreta*, according to variety, showed a significant variation (df=1; F=7.71; P=0.006). This number is higher for red pepper with an average of 9.02±1.51 fruits attacked (Min=5.95; Max=12.09; N=40) (Table 4).

3.5.3 For attack Rate (AR%)

- At harvest 1, the attack rate due to *C. leucotreta* did not differ significantly between pepper varieties (df=1; F=3.09; P=0.09). This rate was slightly higher for yellow pepper, with a mean rate of 54.94 ± 12.61% (Min=27.45; Max=82.43; N=13).
- At harvest 2, the infestation rate due to *C. leucotreta* on yellow and red peppers was not significant (df=1; F=0.89;

P=0.35). This rate was slightly higher for yellow pepper, with a mean rate of 27.77 ± 11.29% (Min=2.90; Max=52.64; N=12).

- At harvest 3, the attack rate due to *C. leucotreta* showed a significant difference depending on the pepper variety (df=1; F=6.83; P=0.010). This rate was significantly higher for yellow peppers with a mean of 13.98 ± 3.2% (Min=7.37; Max=20.59; N=49).
- At harvest 4, the attack rate due to *C. leucotreta* on yellow and red pepper was significant (df=1; F=44.67; P=0.000). This rate was significantly higher for yellow pepper, with an attack rate of 35.33 ± 3.90% (Min=27.59; Max=43.08; N=110).
- At harvest 5, the attack rate due to *C. leucotreta* on yellow and red peppers showed a significant difference (df=1; F=4.43; P=0.039). This rate was significantly higher on yellow pepper, with a mean rate of 24.76 ± 8.62% (Min=6.87; Max=42.66; N=23).
- At harvest 6, the attack rate due to *C. leucotreta* on yellow and red peppers did not show a significant difference (df=1; F=0.74; P=0.38). This rate was slightly higher on yellow pepper, with a mean of 26.24 ± 3.95% (Min=14.17; Max=28.80; N=40) (Fig 6).

Thus, the attack rate did not vary between the two pepper varieties at harvests 1, 2, 5 and 6 (P≥0.05) but showed a significant variation at harvests 3 and 4 (Table 4 and Fig 6).

Table 4: Variation in average abundance of harvested fruits attacked by *Cryptophlebia leucotreta* on yellow and red peppers according to harvests

Harvests	Variables	Pepper varieties		Probability values		
		Yellow pepper	Red pepper	ddl	F	P
1 (11/09/2019)	Harvested fruits	4,69±0,69	2,75±0,25	1	2,29	0,15
	Attacked fruits	2,92±0,82	0,25±0,25	1	3,04	0,10
	Attack rate (%)	54,94±12,61a	12.50±2,5a	1	3.09	0.09
2 (13/09/2019)	Harvested fruits	1,83±0,20	2±0,57	1	0,12	0,73
	Attacked fruits	0,41±0,14	0,25±0,25	1	0,31	0,58
	Attack rate (%)	27,77±11,29a	8.33±3.3a	1	0.89	0.35
3 (26/09/2019)	Harvested fruits	11,51±0,74	13,5±0,40	1	3,2	0,07
	Attacked fruits	2,67±0,65	0,16±0,11	1	7,07	0,009
	Attack rate (%)	13,98±3,2a	1.51±1.04b	1	6.83	0.010
4 (05/10/2019)	Harvested fruits	12,94±0,67	15,85±0,63	1	9,71	0,004
	Attacked fruits	0,73±0,18	6±0,73	1	38,51	0,00
	Attack rate (%)	35,33±3,90a	5.04±1.23b	1	44.67	0.000
5 (12/10/2019)	Harvested fruits	6,39±0,81	11,37±1,36	1	6,84	0,01
	Attacked fruits	1,30±0,43	1,27±0,34	1	0,002	0,95
	Attack rate (%)	24,76±8,62a	8.28±3.09a	1	4.43	0.039
6 (19/10/2019)	Harvested fruits	12,64±1,22	31,07±1,83	1	74,30	0,00
	Attacked fruits	4,49±0,82	9,02±1,51	1	7,71	0,006
	Attack rate (%)	26,24±3,95a	21.48±3,61a	1	0.74	0.38
Means ± SD	Harvested fruits	8.34±4.46	12.76±10.11			
	Attacked fruits	2.09±1.48	2.83±3.59			
	Attack rate (%)	30.50±13.15	9.52±6.59			

Note: SD=Standard Deviation.

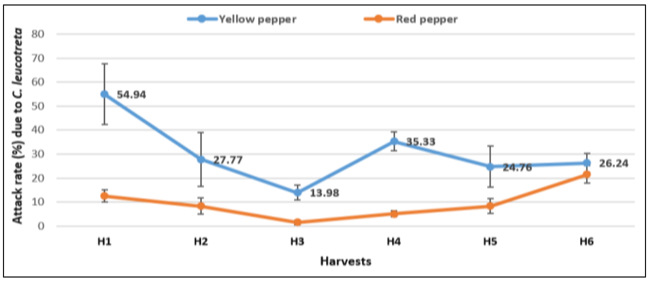

Fig 6: Variation in the attack rate (AR%) due to *C. leucotreta* on the fruits of yellow and red peppers according to harvests. Note: H1=Harvest 1

4. Discussion

4.1 Ordinal richness and insect diversity

In our experimental plot, the study of the insect fauna of *C. annuum* revealed 06 orders for the yellow variety, including: Coleoptera, Diptera, Orthoptera, Hemiptera, Hymenoptera and Dermaptera. However, for the red variety, we obtained 05 orders, including: Coleoptera, Diptera, Orthoptera, Hemiptera and Hymenoptera. This work aligns with that of Elono Azang (2007) [4] on *C. annuum* at the University of Yaoundé 1 campus, where he identified 09 orders. Mbanyé (2000) [12], also at the Yaoundé campus, identified 07 orders. Similar results were obtained by Djiéto-Lordon & Aléné (2006) [2], who counted 10 families belonging to 06 orders (Hemiptera, Coleoptera, Hymenoptera, Lepidoptera, Diptera and Thysanoptera) exclusively in peri-urban horticultural farms in the city of Yaoundé (Nkolondom). These results show that the insect fauna of *C. annuum* is quite diverse for both pepper varieties due to the fact that this same site has been home to other crops, which highlights the high susceptibility of *C. annuum* to attacks by insect pests.

4.2 Sampling effort

Our work on the Solanaceous plant *Capsicum annuum* shows that ordinal richness increases gradually with the number of orders. That is, as sampling progresses, the number of insect orders also increases. These results corroborate those obtained by Heumou *et al.* (2015) [8] working on the diversity and agronomic status of pests of tomato and pepper fruits in two agro-ecological zones of Southern Cameroon (Koutaba and Okola). Non-parametric estimators of the ordinal richness of the insect fauna associated with *C. annuum*, used to assess sampling effort, yielded values between 86.95% (ACE) and 88.23% (MMSMeans), satisfactory values for a representative sample of insect orders on *Capsicum annuum*. The same estimators were also used by Mokam *et al*. (2015) [13] and Elono Azang (2017) [4], and the values were found to be satisfactory.

4.3 Phenology influence on insect abundance

During this study, we observed that the flowering stage exhibits the highest number of orders and therefore an abundance of insects on both yellow and red peppers. Furthermore, it can be said that phenology influences pest abundance. These results are similar to those of Kemgang (2019) [10] who found that the fruiting stage or the flowering-fruiting stage has the highest number of aphids on pepper. However, it should be noted that beetles and grasshoppers colonize *Capsicum annuum* plants extensively; during flowering for yellow pepper and during flowering-fruiting in the case of red pepper. The high abundance of Coleoptera and Orthoptera observed on *C. annuum* during flowering and flowering-fruiting set shows that individuals belonging to these orders preferentially consume the flowers and, to a lesser extent, the fruits. These results corroborate those of Elono Azang (2017) [4], which revealed that Orthoptera attack pepper, perforating the flowers, and prevent fruit formation by destroying the stamens. The work of Djiéto-Lordon *et al*. (2006) [2] shows that the insects directly attack all phenological stages of peppers, with a preference for the yellow variety.

4.4 Index damage due to fruits pests

The attack rate on the fruit of the two pepper varieties varied significantly between harvests 3 and 4. The results obtained from the evaluation of the attack rate due to *C. leucotreta* on *C. annuum* revealed that the yellow variety is more susceptible to attack compared to the red variety. Indeed, yellow *Capsicum annuum* fruits showed higher rates of infestation than the red variety. This may be due to the fact that the yellow color likely has an attractive effect on fruit pest because of its low capsaicin content (Tchiegang & Kapchien 1999) [16].

5. Conclusion

The work carried out on the comparative study of the insect fauna associated with two pepper varieties showed us that the insect fauna of *C. annuum* is quite diverse for both the red and yellow pepper varieties, with higher insect populations on the yellow variety. Indeed, insects use plants as a food source or as shelter: a place for mating, refuge, or egg-laying. It has been noted that flowering and flowering-fruiting set are the two phenological stages where a greater diversity of insects appears than during pre-flowering, regardless of the pepper variety, with a preference for flowering on yellow pepper. The observed peak in insect activity is indeed linked to the appearance of flowers and fruits, which attract nectar-feeding insects on the one hand and carpophagous insects on the other. The attack rate per fruit harvest due to *C. leucotreta* on the two varieties of yellow and red pepper revealed that the yellow variety is more susceptible than the red variety. This attack rate is possibly due to the color or biochemical properties of the yellow pepper.

6. References

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