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Arthropods Diversity and Incidence Variation Due to *Macrosiphum euphorbiae* (Aphididae) and *Bemisia tabaci* (Aleyrodidae) on Leaves of *Lycopersicon esculentum* Mill (Solanaceae) at Yaoundé

[1] Pierre Stephan Elono Azang, [2] Cyril Romeo Heumou, [3] Désirée Chantal Alene, [4] Edoua Veronique Kesseng, [5] Pierre Ngassam, [6] Joseph Lebel Tamesse, [7] Champlain Djiéto-Lordon

[1, 4, 6] Department of Biological Sciences, Higher Teacher Training College, University of Yaoundé I, Yaoundé, Cameroon
[2] Department of Biology, Higher Teacher Training College, University of Bamenda, Bamenda, Cameroon
[3, 5, 7] Department of Animal Biology and Physiology, Faculty of Science, University of Yaoundé I, Yaoundé, Cameroon

Corresponding Author: **Pierre Stephan Elono Azang**

Abstract

Vegetable crops in general and *Lycopersicon esculentum* in particular are subject to many constraints, among which are suckers. These insect pests usually constitute an important limiting factor for the yield of tomato crops (*Lycopersicon esculentum* Mill.). This study was conducted to contribute to the knowledge of arthropods associated with tomato cultivation. It was carried out from March 14 to August 14, 2018 within the campus of the Higher Teacher Training College, urban area of Yaoundé. For this, the number of leaves attacked in the field was evaluated each week according to the phenology and the sampling periods in order to determine the population fluctuation of the pests. The insects were captured, then identified; the diversity of the arthropod fauna associated with *L. esculentum* has been assessed. The results obtained showed that the diversity of the arthropod fauna associated with tomato is rich and varied. A total of 661 individuals belonging to 08 orders, 24 families and 44 species were inventoried. This community includes insects that are harmful and useful to the plant. On the ordinal level, the Hemiptera presented the highest abundance, with 80.18% of the total population, in this order, the Aphididae family, strongly represented by the species *Macrosiphum euphorbiae* (48.26%) presented highest abundance followed by that of the Aleyrodidae mainly represented by the species *Bemisia tabaci* (15.58%). The average number/5 leaves/plant of *M. euphorbiae* (aphids) and *B. tabaci* (whiteflies) during the study did not vary according to the phenology of *L. esculentum* ($P>0.05$) with values slightly higher during fruiting period for aphids (4.34 ± 0.58 individuals) and pre-flowering period (2.30 ± 0.40 individuals) for whiteflies. Analysis of the attack rate on leaves due to aphids and whiteflies showed that it varies significantly ($P<0.05$) depending on the sampling periods (with a higher value of 46.99 ± 2.82% attack in the first week of sampling) and depending on the phenology of the plant (with a maximum value of 23.24 ± 1.63% in the pre-flowering period). All this information collected constitutes a first step for the implementation of integrated pest's management on *L. esculentum*.

Keywords: Arthropods Diversity, Infestation, *Macrosiphum euphorbiae*, *Bemisia tabaci*, Phenology, Correlation

1. Introduction

Agriculture is one of the key factors in the economic growth of a country. It is the main source of income for 80% of the world poor (BM, 2016) [8]. The agricultural sector plays a key role in reducing poverty, raising incomes and improving food security (BM, 2016) [8]. In Cameroon, agriculture contributes to economic activity, because it is the main provider of jobs, since it employs 60% of the active population, mainly on family farms (INS, 2017) [26]. The presence of a varied climate from one agro-ecological zone to another has favored the development of diversified agriculture in Cameroon, mainly through market gardening. Formerly intended for self-consumption, market garden crops now occupy a prominent place in public markets because vegetables are food products with high nutritional and commercial value. Tomato (*Lycopersicon esculentum* Mill.) is one of the most widespread vegetable crops worldwide (Shankara *et al*., 2005) [33]. It is the third cultivated species in the world, after potatoes and sweet potatoes (De Broglie and Guéroult, 2005) [14]. The tomato is cultivated in more than 170 countries of the world and in various climates, including in relatively cold regions thanks to the development of crops under cover (FAO, 2014) [20]. It has become one of the most important vegetables in the world in terms of production (Shankara *et al*. 2005) [33]. According to the Statistical Agency of the Food and Agriculture Organization, total tomato production would be 182,301,395 tonnes in 2017. In Cameroon, tomatoes remain the most important vegetable in terms of production, with in 2016 an annual production of 1,182,114 tons (INS, 2017) [26]. The West region recorded the largest tomato production in Cameroon in 2016 with a production of 776,023 tons (INS, 2017) [26].

The development of market gardening in general and that of tomato in particular is faced with many constraints, including the proliferation of insect pests which, in most cases, contributes to the decline in yields of this crop (Elono Azang, 2008) [19]. To cope with this situation, producers resort to the intensive use of pesticides. According to the FAO (2014) [20], the world consumption of pesticides was estimated at 3000 million Kilos. These pesticides contribute in the majority of cases to environmental pollution and to the intoxication of populations by contaminated vegetables. The WHO estimates that approximately 20,000 people die each year from pesticide poisoning in the Third World (Anonyme, 2013) [2]. New methods of combating these pests of market garden crops are being developed, favoring economical management and preserving the environment, the multiplication of natural enemies and human health (Ryckewaert and Fabre, 2001) [32]. How to fight against insect pests of tomato crops by increasing its yield without polluting the environment and poisoning the fruits?

The objective of this study is to contribute to the improvement of the yield of tomato crops by setting up integrated control strategies based on knowledge of the arthropodofauna associated with tomato and leaf damage due to Hemiptera. Specifically, this work will involve: (i) highlighting the diversity and specific richness of the arthropodofauna associated with L. esculentum, (ii) noting the temporal fluctuation of the populations of aphids and whiteflies on the leaves of L. esculentum; (iii) and finally, to evaluate the attack rates due to aphids and whiteflies on the leaves of L. esculentum.

2. Materials and Methods

2.1 Sampling Period and Study Site

Our study site is located in the urban area of Yaoundé, precisely within the premises of the Higher Teacher Training College of Yaoundé (03°51'35.5"N; 011°30'37.1"E; asl. 729m) (Fig 1). The city of Yaoundé has a variable population density from one site to another, a very diversified habitat and a degree of urbanization which varies from one district to another. Our study was carried out during the small rainy season and extended over part of the small dry season. It began on March 7, 2018 with the transplanting of tomato plants in the field and ended on August 14 with data collection.

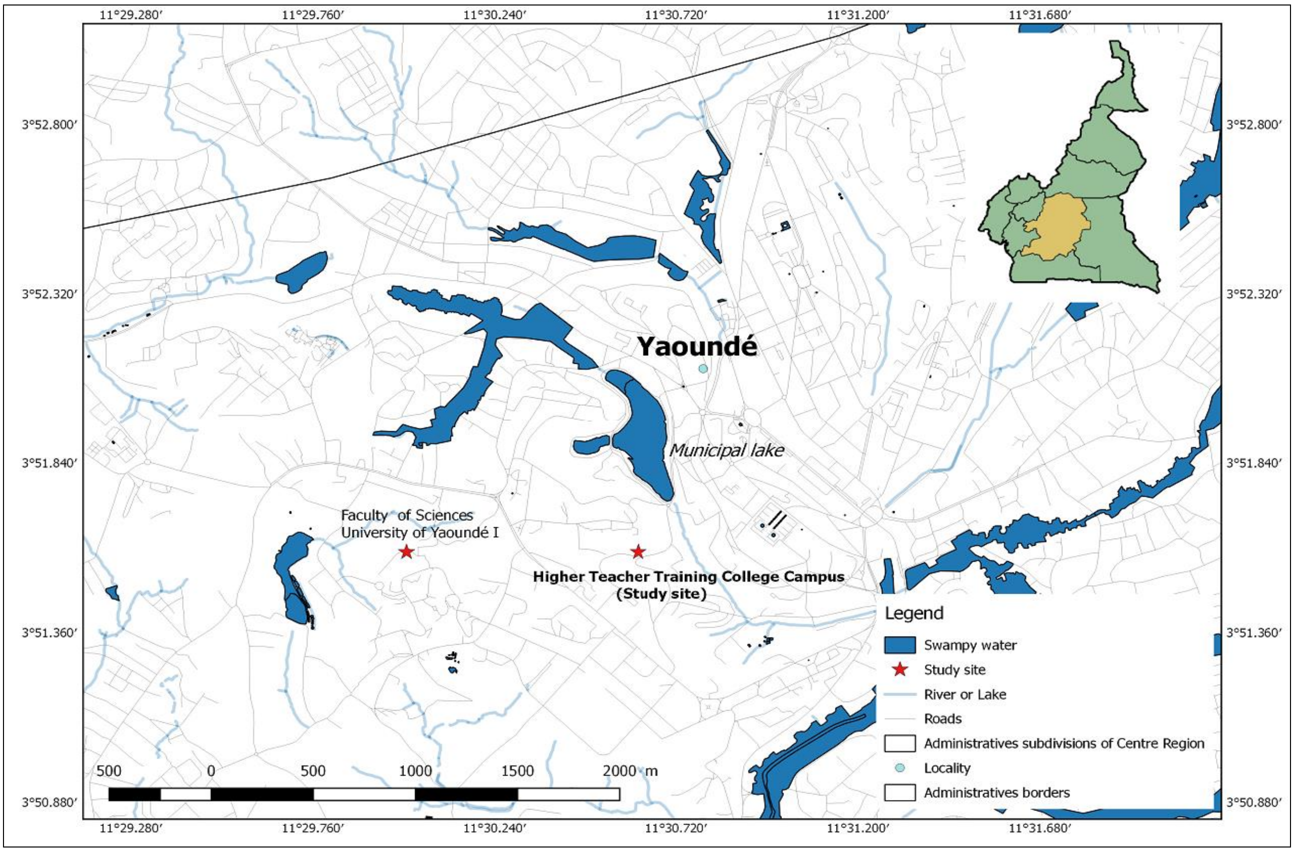

Fig 1: Study site at Higher Teacher Training College of the University of Yaoundé I

2.2 Geology and Vegetation

The relief of Yaoundé is characterized by an alternation of hills and marshy lowlands (Kekeunou, 2007) [27]. The lithological substrate is made up of metamorphic rocks of a gneissic nature and therefore the soils derived from them are red and ferralitic on the interfluves (Bachelier, 1985) [5], with a pH between 5 and 5.2 (Kekeunou, 2007) [27]. The city of Yaoundé is included in the southern Cameroonian plateau and is therefore covered with dense semi-deciduous forest (Darge, 1983; Letouzey, 1985) [13, 30]. This forest is however degraded in places by human activities, for example the case of our study site where the tree forest was destroyed for the benefit of the construction of classrooms. At our study site, the dominant vegetation was mainly made up of plants of the species Pennisetum purpureum ("Sissongo").

2.3 Climatological Data of the Study Area

The climate of the city of Yaoundé is equatorial of the Guinean type with an alternation of four seasons. Data on rainfall, humidity and relative temperature of the city of Yaoundé during the year 2018 showed that the annual average temperature was 23.3°C. The hottest month was January with an average temperature of 24.4°C and the coldest month was August with an average temperature of 22.2°C. The highest temperature in Yaoundé was recorded in April and was 35.6°C while the lowest temperature was recorded in January with a value of 12.2°C. The total annual rainfall was 1546.9mm. The month with the most rainfall was October with an average value of 299.7mm. The driest month was December with an average rainfall of 20.3mm.

2.4 Biological Material

The biological material used for our study consisted of the "Rio Grande" tomato variety produced in Italy. The seeds were purchased from a store specializing in the sale of agricultural inputs (Agrishop) at the Mfoundi market in Yaoundé. The nursery (Fig 2) was set up at the back of the building housing the offices of the Higher Teachers Training College, near the animal physiology facility on February 21, 2018. In a basin 13 cm high and 35 cm in diameter two-thirds filled with soil enriched with rat droppings, the tomato seeds were planted on lines previously drawn using a stick and then covered with a thin layer of soil and watered. The nursery was subsequently watered every other day. Seedling emergence took place one week after planting the seeds.

Fig 2: (A) Seedlings and (B) tomato plant in the field

2.5 Experimental Design

Our experimental plot was installed at the rear of classrooms 1, 2, 3 and 4. The plot was first cleaned and plowed, then 04 ridges 4 m long and 1.5 m wide were placed in place. The ridges were each separated from each other by a space of 0.5 m. The transplanting of the seedlings was carried out at the end of the afternoon when the majority of the seedlings had reached 5 to 6 leaves. The seedlings were transplanted on each ridge in two rows of 5 seedlings, i.e. a total of 10 seedlings on a ridge. The plants located on the same row were separated from each other by a distance of 0.8m and those located on the neighboring rows, separated by 1m. In total, due to 10 plants per ridge, our experimental garden consisted of 40 tomato plants. Immediately after the day of transplanting the plants, watering was done every evening from 5 p.m. during dry periods. The experimental garden was weeded manually after every two weeks in order to stir up the surface layer of soil and also eliminate weeds. During our study, our experimental plot was in no way treated with pesticides.

2.6 Data Collections

2.6.1 Biological diversity on *L. esculentum*

The study of insect diversity was based on captures of adult (mature) and immature (caterpillars) forms, then by calculating diversity indices and non-parametric estimators of specific richness. Adult insects were captured using a mouth aspirator. This method of collection with a mouth aspirator has the advantage of allowing the observation of the activity of certain insects before their capture and also of capturing living insects. The insects captured on the plants were kept in small bottles containing alcohol at 70° and bearing indications including the date of capture, the variety of the host plant, the plant code, the phenological stage and the slice and time slot. The vials containing insects were subsequently kept in the laboratory for later identification. Lepidoptera and Diptera larvae are collected with the leaf as a rearing medium. The leaves and their larvae were put in plastic bags and transported to the laboratory for breeding in petri dishes where they were regularly fed daily with fresh leaves of Lycopersicon esculentum, in order to obtain easily identifiable adult forms. The identification of the adult forms was made in the Zoology laboratory of the Faculty of Sciences of the University of Yaoundé I on the one hand using field guides from Michel and Bournier (1997) and Bordat and Arvanitakis (2004) and the identification keys of Bezzi (1913) [7], Goureau (1974) [21], Borror *et al*. 1976 [10], Delvare and Aberlenc (1989) [15], Anonymous 1998 [1], Daly *et al*. 1998 [12]; and on the other hand using the reference collection of the Zoology laboratory of the University of Yaoundé I. The insects that were identified were placed in labeled tubes and then stored in the reference collection.

2.6.2 Species Richness and Diversity of Insects on *L. esculentum*

Biological diversity was established after identification of captured insects. These arthropods have been classified into orders, families and species according to their abundance. The sampling effort was evaluated using non-parametric estimators of species richness, namely: ACE, ICE, Chao 1, Chao 2, Jack-Knife 1, Jack-Knife 2, Bootstrap, MMSMean and Mean, then from the rarefaction curves. Species diversity was calculated from the Shannon-Wiener (H') and Simpson (E) diversity index. Diversity is the function of the probability Pi of presence of each species 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 species numbers;
ni = Population size of species i.

2.6.3 Temporal Fluctuation of Aphid and Whitefly Populations/5 leaves/Plant

Aphids and whiteflies were counted in the field each week on 5 leaves and per tomato plant and on 5 plants per ridge chosen at random, for a total of 100 leaves per 20 plants sampled until the end of the study. Then at the end of the sampling, the average abundance of aphids and whiteflies was noted according to the sampling records, corresponding to one week of data collection. The average number of aphids and whiteflies per 5 leaves and per tomato plant was also evaluated according to the phenology of the tomato plants in order to see the influence of the different phases of development of the plants on the temporal fluctuation of their populations.

2.6.4 Assessment of Attack Rates on Leaves Due to Aphids and Whiteflies

The attack rate on leaves was evaluated according to the weeks of sampling and the phenology of the tomato plants. The attacked leaves showed characteristic deformations due to various bites from aphids and whiteflies. The attack rates (the two associated pests) were calculated from the ratios: number of leaves attacked by aphids and whiteflies (ni) over the total number of leaves on the plant (N) x 100 according to the following formula:

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

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

2.7 Data Analysis

The means abundance and attack rate due to aphids and whitefly were compared using the Analysis of Variance test (ANOVA) contained in the GLM procedure of the "Statistica" software version 8.0 (2007), followed by a multiple comparison of the means 2 to 2 by an LSD test of Fisher in case of significant differences. All results were assessed at the 5% significance level.

3. Result

3.1 Insects Diversity on *L. esculentum*

3.1.1 Biological Diversity

During the study, 661 individuals belonging to 08 orders, 24 families and 45 species were counted on L. esculentum. On the ordinal level, the Hemiptera presented the highest abundances on the total fauna identified (with 80.18% of all individuals). Coleoptera (1.81%), Diptera (1.81%), Lepidoptera (1.81%), Orthoptera (1.11%), Hymenoptera (1.05%), Araneae (1. 05%) and Dictyoptera (0.31%) presented the lowest abundances (Fig 3).

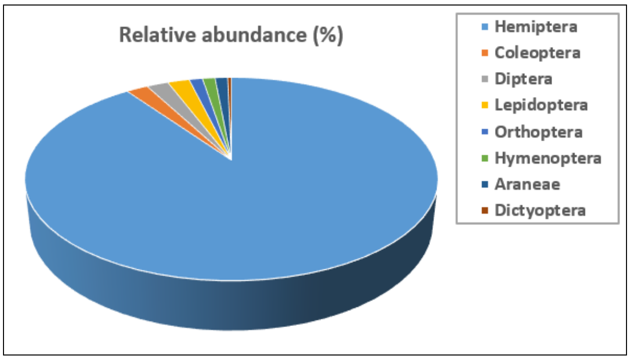

Fig 3: Relative abundances of different orders of arthropods associated with L. esculentum

On the family level, Aphididae were the most abundant (56.58%) of all individuals captured), followed by Aleyrodidae (15.58%), Pseudococcidae (7.26%) and Tetrigidae (3.33 %). All the other families showed low abundances (< 2%) (Fig 4).

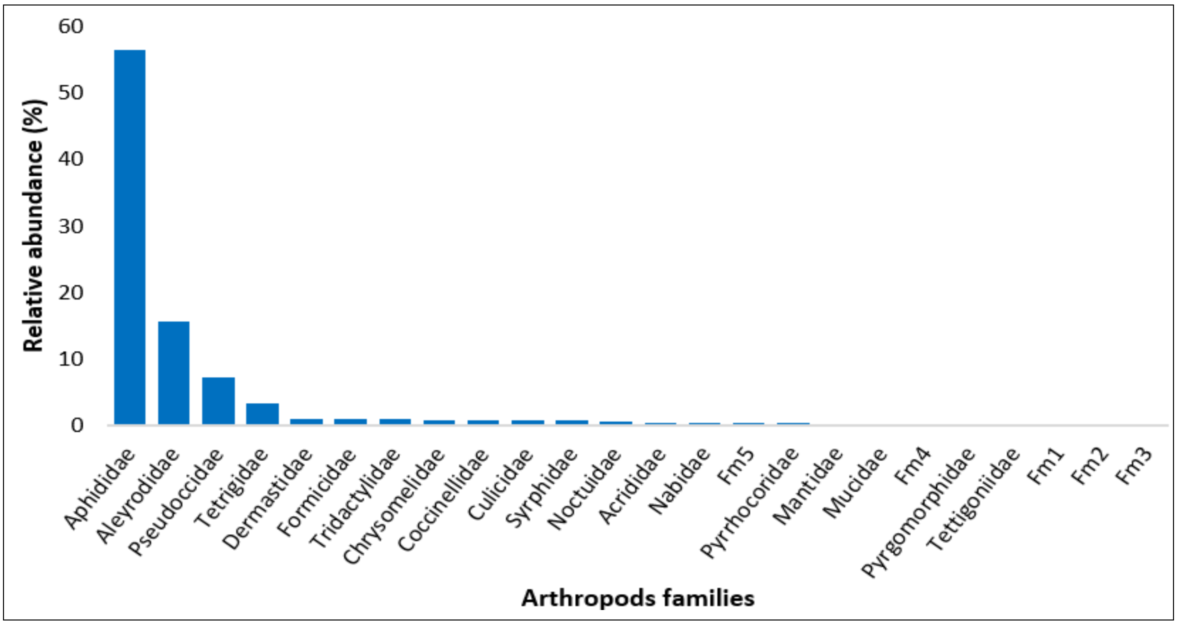

Fig 4: Relative abundances of different arthropods families associated with *L. esculentum*

On the specific level, 03 species were economically important on the basis of their abundances and the actions caused on the leaves of L. esculentum. These are: Macrosiphum euphorbiae (48.26% of all individuals surveyed), which presented the highest abundances, followed by Bemisia tabaci (15.58%) and Aphis fabae (8.32%). The other species presented very low abundances, among these species we can mention respectively Pseu. Gn.1 sp.1 (4.84%), Pseu. Gn.2 sp.1 (2.42%), Paratetrix meridionalis (1.66%), Pheidole sp. 1 (1.06%), Tetrix ondulata (1.06%), Culex sp. 1 (0.62%), Helicoverpa armigera (0.62%), Syr. Gn.1 sp.1 (0.62%), and Trid. Gn.1 sp.1 (0.62%) (Table 1).

Table 1: Relative and absolute abundance of economically important arthropod species on *L. esculentum*

Orders	Families	Species	Absolute and relative abundances (%)	Trophic Groups
Hemiptera	Aphididae	*M. euphorbiae*	329 (48, 26 %)	Sap-sucker
Hemiptera	Aleyrodidae	*B. tabaci*	103 (15, 58 %)	Sap-sucker
Hemiptera	Aphididae	*A. fabae*	55 (8, 32 %)	Sap-sucker
Hemiptera	Pseudococcidae	Pseu. Gn.1 sp.1	32 (4, 84 %)	Sap-sucker
Hemiptera	Pseudococcidae	Pseu. Gn.2 sp.1	16 (2, 42 %)	Sap-sucker
Orthoptère	Tetrigidae	*P. meridionalis*	11 (1, 66 %)	Leaf-eating
Hymenoptera	Formicidae	*Pheidole* sp.1	7 (1, 06 %)	Predator
Orthoptera	Tetrigidae	*T. ondulata*	7 (1, 06 %)	Leaf-eating
Diptera	Culicidae	*Culex* sp.1	4 (0, 62 %)	Leaf-eating
Lepidoptera	Noctuidae	*H. armigera*	4 (0, 62 %)	Fruit pest
Diptera	Syrphidae	Syrp. Gn.1 sp.1	4 (0, 62 %)	Predator
Orthoptera	Tridactilidae	Trid. Gn.1 sp.1	4 (0, 62 %)	Leaf-eating

Note: The values in parentheses represent the relative abundances of the different arthropod species of economic importance on *L. esculentum.*

3.1.2 Sampling Effort

The results show that on L. esculentum, the specific richness increases according to the cumulative number of samples. The global rarefaction curve tends towards a plateau; which shows a globally satisfactory sampling effort on L. esculentum (Fig 5).

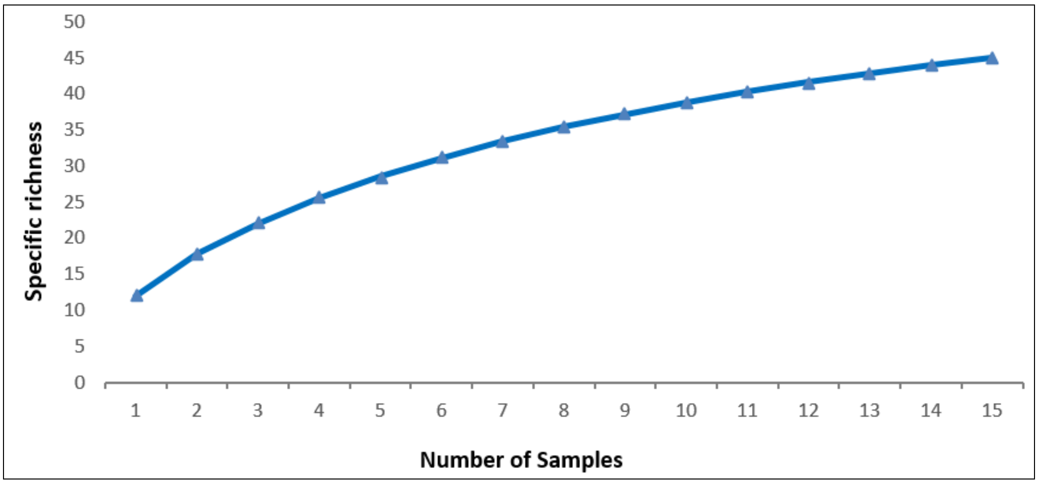

Fig 5: Sampling effort of arthropod species associated with *L. esculentum*

3.1.3 Specific and Richness Diversity

The non-parametric estimators of species richness (Table 2) used to assess the sampling effort presented values between 64.71% and 84.41% (ACE=74.26%, ICE=68, 13%, Chao1=79.41%, Chao2=78.56%, Jack-Knife 1= 71.74%, Jack-Knife 2= 64.71%, Bootstrap=84.41%, MMS Means=65.44 %, Means=73.33%) satisfactory values for a representative sample of the arthropod community on L. esculentum (Table 2). The results show that on L. esculentum, the specific diversity is high (Shannon index (H') = 2.08; Simpson index (D) = 3.73). The total number of species was 45 with a total abundance of 661 individuals. This shows that the specific diversity was representative during the study (Table 3).

Table 2: Non-parametric estimators of arthropod species richness associated with L. esculentum

Non-parametric estimators	Specific richness
ACE	60, 6 (74, 26%)
ICE	66, 05 (68, 13%)
Chao 1	56, 67 (79, 41%)
Chao 2	57, 28 (78, 56%)
Jack-Knife 1	62, 73 (71, 74%)
Jack-Knife 2	69, 54 (64, 71%)
Bootstrap	53, 31(84, 41%)
MMSMeans	68, 77(65, 44%)
Means	61, 87 (73, 33%)
Samples	15
Observed Species	45

Note: Values in parentheses represent sampling effort

Table 3: Species diversity of arthropods associated with *L. esculentum*

Specific diversity index	Values
Shannon index (H')	2,08
Simpson index (D)	3,73
Observed Species (S)	45
Abundance (A)	661

3.2 Population Variation of Aphids and Whitefly on *L. esculentum*

3.2.1 Population Variation Based on Sampling Surveys

The average number of aphids/5 leaves/plant presented a significant variation according to the surveys (ddl = 7; F = 7.17; P < 0.05) and evolved in four phases:

- In the first phase, the number of aphids decreases from the first to the second week to reach the value of 3.7 ± 0.54 aphids/5 leaves; min = 2.56; max=4.83 (N=20).
- In the second phase, the number of aphids increases from the second week to take in the fifth week, a maximum value of 5.05 ± 0.52 aphids/5 leaves; min=3.95; max=6.14 (N=20).
- Then, in the third phase, the average number of aphids per 5 leaves per plant decreases from the fifth week to take in the sixth week, the minimum value of 1.6 ± 0.35 aphids/5 leaves; min=0.86; max=2.33 (N=20).
- Finally, in the fourth phase, the number of aphids increases from the sixth week to the eighth week to reach a maximum value of 6.47 ± 0.58 aphids/5 leaves; min=5.24; max=7.70 (N=19) (Table 4).

The fluctuation of whiteflies per 5 leaves per plant shows a significant difference according to the sampling surveys (ddl = 7, F = 3.27 and P< 0.05). The analysis of the number of whiteflies / 5 leaves / plant according to the weeks of sampling shows that the number of whiteflies evolved in five respective phases:

- In the first phase, the average number of whiteflies increases from the first to the second week of sampling and takes the value of 5.35 ± 1.84 whiteflies/5 leaves; min = 1.49; max=9.20 (N=20).
- From the second to the fifth week (second phase), the average number of whiteflies drops to the minimum value of 0.70 ± 0.21 whiteflies/5 leaves; min = 0.24; max=1.15 (N=20).
- In the third phase, this number increases from the fifth to the sixth week for a value of 1.10 ± 0.36 whiteflies/5 leaves; min=0.32; max=1.87 (N=20).
- At the fourth phase, the number of whiteflies drops until the seventh week to reach the average value of 0.35 ± 0.13 whiteflies/5 leaves; min = 0.07; max=0.62 (N=20).
- Finally in the fifth phase, the average number of whiteflies/5 leaves/plant increases in the eighth week to a value of 2.26 ± 1.46; min=-0.81; max=5.34 (N=19) (Table 4).

Table 4: Mean number of M. euphorbiae and B. tabaci per 5 leaves of *L. esculentum*

Number of sampling	Mean number (± Std. Err.) of *M. euphorbiae* per 5 leaves	Mean number (± Std. Err.) of *B. tabaci* per 5 leaves/plant	N
1	5.0±0.98 (2.92-7.07)	3.25±0.74 (1.69-4.80)	20
2	3.70±0.54 (2.56-4.83)	5.35±0.84 (1.49-9.20)	20
3	3.95±0.37 (3.16-4.73)	1.40±0.49 (0.36-2.43)	20
4	4.85±0.43 (3.94-5.75)	1.70±0.30 (1.05-2.34)	20
5	5.05±0.52 (3.95-6.14)	0.70±0.21 (0.24-1.15)	20
6	1.60±0.35 (0.86-2.33)	1.10±0.36 (0.32-1.87)	20
7	2.85±0.39 (2.01-3.68)	0.35±0.13 (0.07-0.62)	20
8	6.47±0.58 (5.24-7.70)	2.26±1.46 (0.81-5.34)	19
Means ± SD	4.18±1.45 (1.6-6.47)	2.01±1.57 (0.35-5.35)	
Probability values	**ddl=7; F=7.17; p=0.000 MS=6.203; df=151.00**	**ddl=7; F=3.27; p=0.0028 MS=16.143; df=151.00**	

Note: The values in parentheses represent the minimum and maximum values of the mean (Fisher's LSD test)

3.2.2 Populations Variation According to the Phenological Stage of *L. esculentum*

The evolution of aphids per 5 leaves per plant depending on the phenology of the plant does not show a significant difference (ddl = 2, F = 0.11 with P > 0.05), because the temporal fluctuation of aphids varies very little from preflowering to fruiting through flowering, however the average number of aphids per 5 leaves per plant is significantly higher at fruiting with an average value of 4.34 ± 0.58 aphids / 5 leaves; min=3.14; max=5.55 (N=23).

The analysis of the fluctuation of whiteflies/5 leaves/plant does not show a significant variation according to the phenology of the plant (ddl=2; F=1.62 and P>0.05). The study of the variation in the number of whiteflies/5leaves/plant shows that the number of whiteflies is slightly higher at preflowering, i.e. 2.30 ± 0.40 whiteflies/5leaves; min = 1.49; max = 3.11 (N = 109), then decreases at flowering to reach a minimum value at fruiting, i.e. 0.56 ± 0.24 aphids/5 leaves; min = 0.06; max = 1.06 (N = 23) (Fig 6).

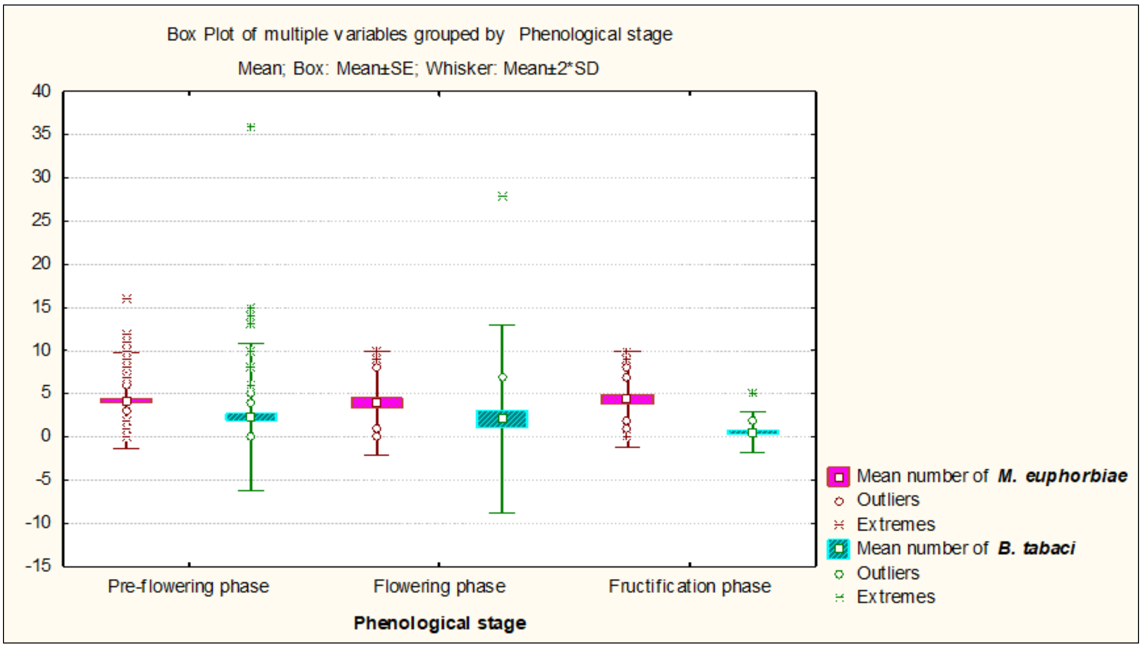

Fig 6: Mean number of aphids and whitefly per phenological stage on leaves of L. esculentum (Fisher's LSD test)

3.3 Attack rate (%) Due to the Aphid/Whitefly Complex on *L. esculentum* Leaves

3.3.1 Attack Rate Based on Sampling Survey

The analysis of variances of the temporal fluctuation of the number of leaves attacked per plant showed a significant evolution according to the surveys (ddl= 7; F= 2.56 and p=0.016). Indeed, the observation of the evolution of the number of leaves attacked per plant shows an increasing evolution according to the readings from a minimum value of 7.70 ± 0.44 leaves per plant; min=6.77; max = 8.62 (N = 20) at survey 1 up to a maximum value of 17.15 ± 3.5 leaves per plant; min = 9.80; max = 24.51 (N = 19) at survey 8 (Table 5). The attack rate on leaves due to the M. euphorbiae / B. tabaci complex showed a significant variation depending on the readings (ddl=7; F= 72.82; P<0.05). Indeed, at the first survey, the attack rate is maximum with an average value of 46.99 ± 2.82%; min = 41.08%; max = 52.90% (N = 20), then decreases gradually until the last survey (survey 8) where it reaches the average minimum value of 4.55 ± 0.90%; min = 2.64%; max = 6.46% (N = 19) (Table 5).

Table 5: Attack rate (%) due to M. euphorbiae and B. tabaci on the leaves of L. esculentum by sampling survey

Sampling Survey	Average total number (N) of leaves / plant	Average number (ni) of attacked leaves / plant	Attack rate (%) on leaves	N
1	17.05±1.17 (14.59-19.51)	7.70±0.44 (6.77-8.62)	46.99±2.82 (41.08-52.9)	20
2	31.65±2.66 (26.08-37.21)	9.85±0.74 (8.28-11.41)	32.38±1.92 (28.35-36.42)	20
3	54.15±7.46 (38.52-69.77)	9.40±0.82 (7.67-11.12)	21.42±2.29 (16.61-26.23)	20
4	98.10±15.54 (65.55-130.64)	9.70±1.15 (7.27-12.12)	13.61±2.32 (8.74-18.49)	20
5	166.8±27.21 (109.83-223.76)	12.55±1.85 (8.66-16.43)	8.91±1.00 (6.80-11.02)	20
6	252..8±40.88 (167.23-338.36)	12.45±2.66 (6.86-18.03)	5.57±0.93 (3.62-7.52)	20
7	318.1±46.8 (220.13-416.06)	14.50±2.22 (9.83-19.16)	5.07±0.69 (3.61-6.54)	20
8	419.1±61.48 (289.93-548.27)	17.15±3.50 (9.80-24.51)	4.55±0.90 (2.64-6.46)	19
Means ± SD	157.85±148.88	11.66±3.00	17.31±14.87	
Probability values	**ddl=7; F=20.33; p=0.00 MS=20916; df=151.00**	**ddl=7; F=2.56; p=0.016 MS=73.76; df=151.0**	**ddl=7; F=72.83; p=0.00 MS=64.48; df=151.00**	

Note: The values in parentheses represent the minimum and maximum values of the mean (Fisher's LSD test)

3.3.2 Attack Rate According to the Phenology of *L. esculentum*

The observation of the temporal fluctuation of the attacked leaves per plant according to the phenology shows a significant evolution (ddl=2; F =44.73 and P<0.05). According to the data obtained, the number of attacked leaves increases with the phenology of the plant to reach at fruiting, the maximum value of 24.26 ± 2.98 leaves per plant; min=18.06; max=30.45 (N=23) (Table 6).

The attack rate on leaves according to phenology shows a significant variation (ddl = 2; F= 28.24; P< 0.05). It decreases during the pre-flowering period from the maximum value of 23.24 ± 1.63%; min = 20%; max = 26.47% (N = 108) until flowering with a minimum value of 4.8 ± 0.49%; min=3.86%; max = 5.90% (N = 27), then it increases slightly from flowering to fruiting up to the average value of 5.16 ± 0.77%; min=3.84%; max = 6.77% (N = 23) (Table 6).

Table 6: Attacks rate (%) due to *M. euphorbiae* and *B. tabaci* on leaves according to the phenological stage of *L. esculentum*

Phenological stage	Average total number (N) of leaves / plant	Average number (ni) of leaves attacked / plant	Attack rate (%) on leaves	N
Pre-flowering phase	71.03±6.60 (57.93-84.13)	8.81±0.39 (8.03-9.59)	23.24±1.63 (20.01-26.47)	109
Flowering phase	259.44±18.87 (220.64-298.24)	12.22±1.49 (9.14-15.30)	4.88±0.49 (3.86-5.90)	27
Fructification phase	521.21±49.71 (418.11-624.32)	24.26±2.98 (18.06-30.45)	5.16±0.77 (3.54-6.77)	23
Means ± SD	283.89±202.21	15.09±7.25	11.09±9.40	
Probability values	**ddl=2; F=159.48; p=0.00 MS=12918; df=156.00**	**ddl=2; F=44.73; p=0.00 MS=50.76; df=156.00**	**ddl=7; F=28.24; p=0.00 MS=201.19; df=156.00**	

Note: The values in parentheses represent the minimum and maximum values of the mean (Fisher's LSD test)

4. Discussion

4.1 Arthropods diversity on *L. esculentum*

The diversity of Arthropods associated with Lycopersicon esculentum within the Higher Teacher Training College campus was made up of 661 individuals belonging to 08 orders, 24 families and 45 species of Arthropods. Similar results were obtained by Heumou *et al*, (2015) [24] at the University of Yaoundé I campus where 45 species of Arthropods belonging to 31 families and 10 orders were identified on some vegetable crops. Chougourou *et al*. (2012) [11] also obtained similar results on tomato plots in the commune of Djakatomey. The main orders of species identified during the study were more diverse than those obtained by Chougourou *et al*. (2012) [11]; Djiéto-Lordon and Alene (2006) [16] who identified only 06 orders. This difference observed on the ordinal level could be explained on the one hand by the fact that the experimental plot was located near a bush and on the other hand by the fact that this plot had previously been used for the cultivation of other plants like corn. The inventory of the different species shows that the pests associated with tomato crops are numerous and diversified, which has also been demonstrated by the work of Atachi *et al*. (1989) [4], by Djiéto-Lordon *et al*. (2007) [17] and Heumou (2008) [23].

Hemiptera showed the highest abundances on leaves of L. esculentum. Hemiptera are sucking that take sap from certain plant organs. The bites of these insects are responsible for direct damage which deteriorates the various organs of the plant (Appert and Deuse 1988) [3] and indirect damage resulting from the vector action of various germs which they inject into the vessels of the plant (Betbeder-Matibet 1989) [6]. Hemiptera were mainly represented respectively by the Aphididae and Aleyrodidae families, these results show similarities with those obtained by Kengne (2015) [28] on the cultures of Solanum melongena and Solanum aethiopicum in the same study site.

Species diversity was high during the study. The work of Heumou *et al*. (2015) [24] on the same crop rather showed low specific diversities in Koutaba (H'=0.992) and Okola (H'=0.666). This difference could be explained by different climatic conditions present in the different study sites in Southern Cameroon.

4.2 Population variation of *M. euphorbiae* and *B. tabaci* per 5 leaves on *L. esculentum*

During the study, the fluctuation of aphid populations (M. euphorbiae) depending on the phenology of the plant did not show any significant difference. Keudem (2016) [29] also noted during his work on the cultivation of Solanum macrocarpon that phenology does not influence the abundance of these pests. The fluctuation of aphids was however a little higher at fruiting compared to the other phenological stages. These results are different from those obtained by Soro *et al*. (2015) [34] on the cultivation of Solanum melongena, who found during his work that the fall of aphids is linked to the decrease in the quantity of sap produced by the plant during the last part of its cycle. The difference observed in the results could be explained by the fact that the experimental plot, being located near other Solanaceae crops, was continuously visited by aphids from other crops.

The abundance of Bemisia tabaci whiteflies did not show any significant difference depending on the phenology of the plant. Indeed, the whitefly population varied little during the different phenological phases, but it remained a little higher during pre-flowering. These results are not similar to those obtained by Djieto-Lordon *et al*. (2014) [17] on Capsicum annuum crops who rather noted that the whitefly population is not important during pre-flowering, it gradually increases until it reaches a maximum at the end of the plant's life cycle. This can be explained by the fact that during the works the tomato plants were attacked by a virus which caused the progressive drying up and the cessation of the growth of certain plants and therefore of the sap, the whiteflies n no longer have enough sap to feed themselves, went to colonize neighboring plants.

4.3 Attack Rate Due to Aphids and Whiteflies on *L. esculentum* leaves

The attack rate on leaves due to pests varied significantly depending on the phenology of the plant. It was maximum during pre-flowering, i.e., 23.24%. These results are consistent with those obtained by Keudem (2016) [29] on eggplant leaves.

5. Conclusion

The results obtained during the study highlighted a rich and varied specific diversity. Several families of insects, including harmful and useful insects, were found on the different plants. Among the different families of harmful insects, the Aphididae and in particular the species Macrosiphum euphorbiae and that of the Aleyrodidae represented by the species Bemisia tabaci have been identified as the greatest pests on leaves of agronomic importance in tomato cultivation. Work on the fluctuation of aphids and whiteflies according to tomato phenology showed that the population of aphids and whiteflies is not influenced by the phenology of the plant, however, the populations of aphids remained slightly higher during fruiting, while those of whiteflies slightly higher during pre-flowering. However, the fluctuation of aphids and whiteflies varied greatly depending on the sampling records. The results relating to the attack rates of the various pests on leaves made it possible to highlight a significant variation according to the phenology of the plant and the various surveys.

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