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Populations Variations and Impacts of *Bemisia tabaci* (Genn.) and *Aphis gossypii* Glov. (Hemiptera), Two Sap-sucking Insects of Pepper *Capsicum annuum* L. 1753

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Abstract: From April to August 2018, seasonal variation of the populations and the damage due to *Aphis gossypii* (Aphididae) and *Bemisia tabaci* (Aleyrodidae), two sap-sucking pests on Pepper (*Capsicum annuum* L.), was carried out in a forestry region of Cameroon with bimodal rainfall. This study focused on 133 days after transplanting (DAT). Populations were counted by 5 leaves per plant during 19 weeks, 02 seasons and 03 phenological phases of plant. Average number of individuals and attacked leaves due to these pests were correlated with total rainfall, mean temperature and mean relative humidity. The study showed that the average number of *A. gossypii* and *B. tabaci* per 5 leaves per plant varied significantly with sampling weeks (df=18, F=8.50, p<0.001 and df=18, F=4.87, p<0.001 respectively), seasons (df=1, F=2.99, p<0.01 and df=1, F=12.58, p<0.001 respectively) and with phenological phases of *C. annuum* (df=2, F=111.07, p<0.01 and df=2, F=132.74, p<0.01 respectively). The highest population were recorded at the 13th sampling week corresponding to 91 days after transplanting (91 DAT) with 5.30±0.8 individuals/5 leaves for *A. gossypii* and 2.30±0.42 individuals/5 leaves for *B. tabaci*. Average number of *A. gossypii* and *B. tabaci* were highest in the short dry season with 3.49±0.17 individuals/5 leaves and 0.83±0.07 individuals/5 leaves respectively. The study also showed that damage due to *A. gossypii* / *B. tabaci* complex varied significantly with sampling weeks (df=18, F=3.02, p<0.004), with seasons (df=1, F=9.69, p<0.001) and with phenological phases of *C. annuum* (df=2, F=20.31, p<0.005). These damage were higher in the first sampling week corresponding to 7 days after transplanting (7 DAT) with an average attack rate of 31.25±5.56%, during the short rainy season with an average attack rate of 20.57±1.48% and during the pre-flowering phase with an average attack rate of 20.85±1.10%. Average number of *A. gossypii* and *B. tabaci* individuals showed negative and non-significant correlations with total rainfall (r=-0.80, p<0.104 and r=-0.60, p<0.284 respectively) and mean temperature (r=-0.86, p<0.057 and r=-0.29, p<0.637 respectively), then positive and significant for *A. gossypii* (r=0.89, p<0.040) and positive and non-significant for *B. tabaci* (r=0.11, p<0.857) with relative humidity. Damage due to hemipteran complex showed positive and non-significant correlations with total rainfall (r=0.60, p<0.285) and mean temperatures (r=0.87, p<0.058) and negative and significant correlations with relative humidity (r=-0.86, p<0.041). The present study provided baseline data for integrated pest management strategies against *A. gossypii* and *B. tabaci* on *C. annuum* in forestry region of Southern Cameroon.

Keywords: *Aphis gossypii*, *Bemisia tabaci*, Population Variation, Damage, Correlation

1. Introduction

Pepper (*Capsicum annuum* L.), market gardening of the family of Solanaceous is considered as one of the commercial spice crop and it is the most widely used as a universal spice, named as wonder spice [1]. The pepper variety which is considered as a traditional spice is cultivated near the dwellings, and is sold in all the markets in tropical Africa [2]. In Cameroon, pepper appear among the most current spice species and it is consumed in various culinary preparations: fresh, dried, in association with other vegetables [3]. Fruits are also consumed in the form of dry powder associated with grilled meat; macerated in water or in the form of wet or oily paste [4]. Different varieties are cultivated for various uses like vegetable, pickles, spice and condiments [1]. In Cameroon and several other countries of the world, pepper is an essential component of the daily diet of humans. It is also an important source of income for producers and the State through taxes, particularly in urban and peri-urban areas of developing countries. [5, 6]. Statistics from the Food Alimentation Organization (FAO) estimate a global pepper production at 21.3 million tons in 2001 for a cultivated area of 1.6 million ha. In the year 2004, annual world production of pepper was evaluated to 23 million tons from a total of 1.54 million ha [7]. In Cameroon, the production of this crop increased from 25 987 tons for a cultivated area of 13 083 ha in 2009 to 29 910 tons for an area of 14 007 ha in 2010 [8]. This speculation has the second highest growth rate of the order of 29% and is increasingly proving to be a promising channel through trade in the sub-region [8]. China is the world's major producer of *C. annuum* with an area of 0.61 million ha and a production of 120 million tons [7]. Medicinally, pepper increases intestinal peristalsis and stimulates gastric acid production at low dose but inhibits it in high doses [9]. Although this crop is important in many ways, it is still subject to repeated attacks by several pests that significantly reduce its yield.

Among these pests, two economically important hemipterans: *Aphis gossypii* Glover (aphid) and *Bemisia tabaci* (Gennadius) (whitefly) attack the leaves of *C. annuum* [3]. Aphid are small insects often globular in form, and exist generally in large colonies on the underside of leaves, on young shoots and on flower buds [10, 11]. *Aphis gossypii* (plant lice) is a common species that infest many crops and it is serious pest of many vegetables and other crops like cotton [11]. These insects directly damage pepper by sucking the phloem, and indirectly by virus transmission and excretion of excess carbohydrates from their diet of phloem sap [12, 13]. The excretions can foster the occurrence of fungus that inhibits photosynthetic activity, resulting in chlorosis and consequent loss of yield [12, 14, 13]. On all of its many hosts, severely attacked leaves curl and young growth is stunted. As populations build up, the upper surface of leaves and fruit becomes contaminated with honeydew, leading to growth of sooty moulds, which is unsightly and interferes with photosynthesis [10].

Bemisia tabaci (whitefly) is polyphagous pest affecting a broad range of cultivated hosts including cotton and several other winter, spring, and summer crops [15]. Whitefly species currently are known to attack over 500 species of plants representing 74 plant families. The adult whitefly is very small: about 1 mm long, silvery-white in color and with wings of a waxy texture. It is found often on the underside of the foliage where it sucks the plant sap [11]. Direct crop damage occurs when whiteflies suck juices from the plant and with high populations plants may wilt, turn yellow and die. Whiteflies also excrete honeydew, a sweet sticky fluid which may cover the leaves completely. On this honeydew, mould fungi grow and the leaves may turn black in color. This reduces the capability of the leaves to produce energy from light and may lower fruit quality. In some hosts, damage can result from whitefly feeding toxins that cause plant disorders such as irregular ripening of pepper fruits [11]. *Aphis gossypii* is one of the most important insect pest in low altitude and humid areas and estimated can reduce ranged from 56 to 65% of pepper yields when no insecticides are taken [16, 13], show that [17] found that *A. gossypii* reduced the yield of cotton seed by 37% in sole cotton plots compared with 10% loss of cotton-seed yield per plant in the intercropping systems. On the other hand, the result of reduced seed cotton yield by *B. tabaci*, contamination with honeydew, sooty mould and transmission of viruses such as cotton leaf curl virus (CLCV) causing cotton leaf curl disease and the economic damages of seed-cotton yield were estimated to range between 10.6% and 92.2% [18-20].

Management of *B. Tabaci* and *A. gossypii* have been typically carried out by chemical insecticides, which are associated to pollution of the environment, attacks non-target organisms and also induce resistance of insects against several chemical classes of insecticides, including organophosphates, carbamates, pyrethroids, insect growth regulators and neonicotinoids [21]. Pesticides are regularly used to control aphids and whiteflies. The misuse and overuse of pesticides has lead to problems of pesticide resistance, resurgence and contamination of different components of the environment [22]. However, new methods of struggle these hemipterans are being developed with a focus on the rational management of pesticides and the preservation of the environment and human health [23]. This implies a good knowledge of the seasonal fluctuation of their populations and their damage. Weather parameters play a key role in determining the incidence and dominance of a particular pest or pest complex. Hence an incidence study on sap-sucking population fluctuation would give an idea about peak period of their activity and may be helpful in developing pest management strategy [1]. The population dynamics of aphids and whiteflies can be affected by seasonal changes in weather conditions, physiological characteristics of the host plant, farming methods and management practices [24, 13]. The seasonal attack rate due to *B. tabaci* (whitefly) and *A. gossypii* (aphid) and their correlations with different abiotic factors are an important study to be made to modulate the pest management strategies and to study the impact of changing climatic conditions on pest population variation [1].

The general objective of this work was to study the impact of *A. gossypii* and *B. tabaci* populations for an IPM against these two economic importance pests associated with the leaves of *C. annuum*. Specifically, it was: (1) to study the fluctuation of *A. gossypii* and *B. tabaci* populations according to the seasons and the phenological phases of *C. annuum*; (2) to evaluate the damage due to the *A. gossypii* / *B. tabaci* complex on leaves of *C. annuum* (3) to assess the relationship between *A. gossypii* and *B. tabaci* populations, the damages and abiotic factors.

2. Methodology

2.1. Study Site and Sharacteristics

The study was conducted in the forest area of Southern Cameroon (Lat., 03°51'35.5"N, Long 011°30'37.1"E, altitude 729m a.s.l.), specifically at the campus of the Higher Teacher's Training College of the University of Yaounde I, Central Region (Figure 1).

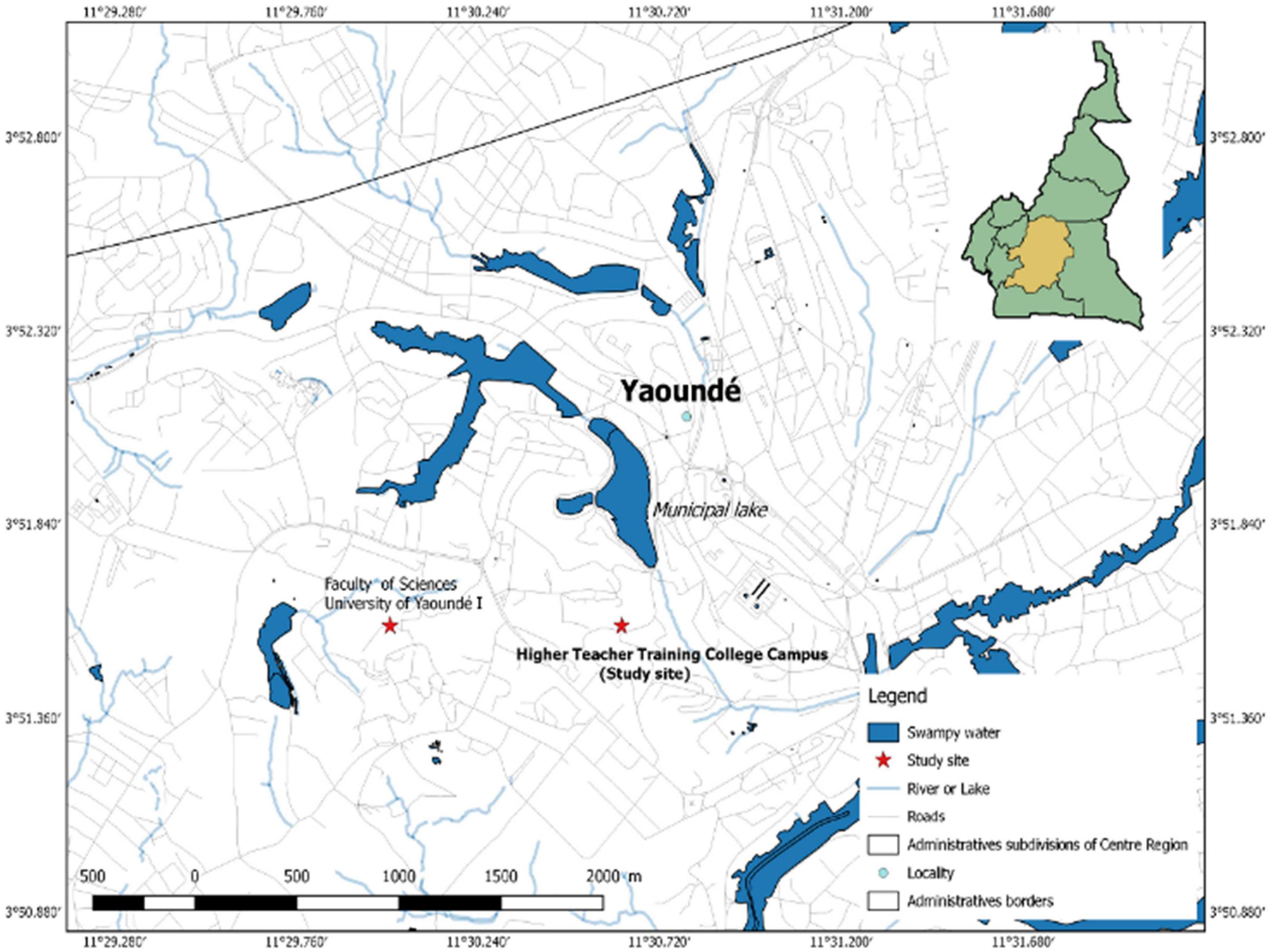


Figure 1. *Study site.*

This area is dominated by an equatorial climate of Guinean type with four seasons: (i) a long dry season that runs from mid-November to mid-March; (ii) a short rainy season beginning in mid-March and ending in late June; (iii) a short dry season that starts in July to end in August corresponding to a wet period, and (iv) a long rainy season that runs from September to mid-November [25]. Our study was conducted from April to August 2018, during 133 days corresponding to 19 weeks of sampling; which allowed us to cover two seasons namely the short rainy season (SRS) and the short dry season (SDS). The city of Yaoundé received in 2018, an annual rainfall of 1540 mm with an average annual temperature of 23.7°C (Weatherbase.com 2019). Yaoundé is characterized by alternating hills and swampy lowlands [26].

The lithological substratum of this city consists of the metamorphic rocks of gneissic nature and the soils derived therefrom are ferralitic on the interfluves [27]. Soils are red, with a pH between 4.5 and 5.5 [28]. The superficial levels of these soils are not only a support but also serve as a reserve of nutrients and water for plants [28]. The intense urbanization has led to the degradation of vegetation that was previously included in the semi-deciduous forest domain [29].

2.2. Biological Material

The biological material consisted of *Capsicum annuum* plants (Figure 2). The variety used was the "hot pepper" of the local pepper whose seeds were taken from the mature fruits from the market of Mendong (one of the districts of the city of Yaoundé). Pepper is a tropical species, but also suitable for cultivation in temperate zone. Optimum growth and production temperatures are between 18°C and 30°C. Seeds normally germinate at 25-30°C. Pepper grows on all types of soil but is suitable for light soils, deep, rich in organic matter with a slightly acid pH (6.5 to 7) and well irrigated [30, 31]. The development cycle of this plant is carried out in 03 distinct phenological phases: (i) the pre-flowering phase (extends from 60 to 65 days); (ii) the flowering phase (30 to 45 days with the appearance of flowers) and (iii) the fructification phase (extends from 30 to 40 days with appearance of the fruits and varying according to the varieties) [30].

Figure 2. *Capsicum annuum plant during the fructification phase with leaves and fruits.*

2.3. Experimental Design

The experimental space, left fallow for a very long time, was weeded, plowed and cleaned a week before transplanting the seedlings. On this plot, four ridges were made (Figure 3). Each ridge was 4 m long and 1.5 m wide and contained 10 feet of pepper spread over two lines. Neighboring feet side by side on the same line were separated by a distance of 0.8 m. The plants between the two neighboring lines were separated by 1 m. The spacing between two ridges was 0.5 m. We got a total of 40 pepper plants to sample (Figure 3). No insecticide treatment was carried out throughout the sampling period.

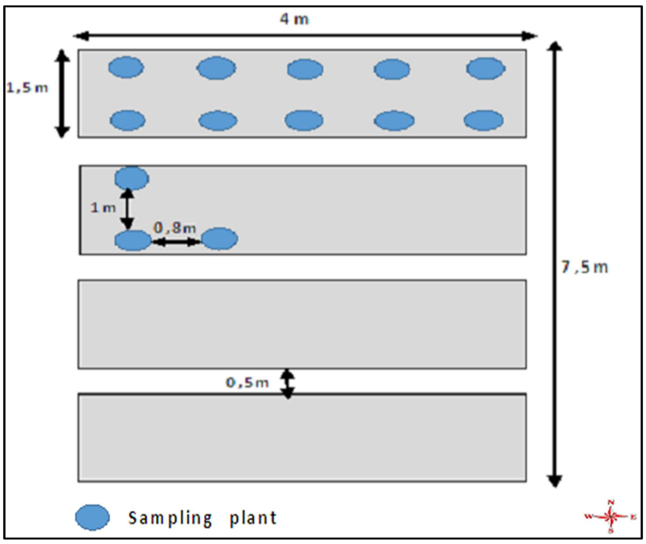


Figure 3. *Experimental set of ridges and pepper plants.*

2.4. Data Collections

2.4.1. Seasonal Variation of A. gossypii and B. tabaci Population on C. annuum

Direct counting was used to estimate weekly number of *A. gossypii* (aphids) and *B. tabaci* (whitefly) adults after transplanting. Individuals were counted on 5 leaves per plant in the field each week until the end of sampling. We randomly selected 5 plants per ridge on which sampling was repeated, for a total of 100 leaves out of 20 sampled plants. Thus, at the end of the sampling, the average number of aphids and whiteflies was recorded in a sampling survey corresponding to one week of data collection (one day chosen at random and maintained until the end of the sampling period). The average number of aphids and whiteflies per 5 leaves per plant was also determined by the phenology of pepper plants to see how these developmental phases affect the temporal fluctuation of their populations. In addition, the average number of aphids and whiteflies per 5 leaves per plant was also seasonally determined to see how these seasons affect their population fluctuations.

2.4.2. Evaluation of Percent Damage Index Due to A. gossypii / B. tabaci (Hemipterans Complex) on Leaves of C. annuum

The leaves attacked by the *A. gossypii* / *B. tabaci* complex showed characteristic discolorations and deformations on the underside (Leaf Curl Virus). Healthy leaves were those that showed no discoloration or deformation. The attack rate (Txi) or percent damage index (PDI) due to the two (cumulative) pests was calculated from the ratio: number of leaves attacked and deformed (ni) by the two pests on the total number of leaves on the plant (N) x 100 [2, 32, 33], following the formula:

$$PDI\ (AR.\ \%)=(ni/N)*100$$

Where:
PDI (AR. %)=Percent damage index (%);
ni=Total number of attacked leaves;
N=Total number of leaves.

Attack rates on leaves due to *A. gossypii* / *B. tabaci* complex were assessed based on sampling weeks, seasons of the year and the phenology of pepper seedlings.

2.4.3. Relationship Between Seasonal Abundance of A. gossypii and B. tabaci / 5 Leaves / Plant and Attack Rate and Abiotic Factors

The average number of *A. gossypii* and *B. tabaci* populations per 5 leaves, as well as the damage due to these two pests were correlated with total rainfall, mean temperature and relative humidity of the 2018 year between April and August (periods covering the short rainy season and the short dry season) to note the influence of these abiotic factors on the monthly fluctuation of their populations and their damage on the leaves of *C. annuum*.

2.5. Statistical Analysis

The data was encoded using Excel software to calculate the averages and proportions of the different individuals of aphids and whiteflies sampled and then the average attack rates calculated. After a logarithmic conversion of the numbers and attacks, we compared the averages by survey, season and phenological phase using the Analysis Of Variances (ANOVA) test contained in the GLM procedure of the "Statistica" software version 8.0 (2007), followed by a multiple comparison of the 2 to 2 means by a Tukey HSD test in case of significant differences. The Spearman correlation coefficient r between two variables was calculated for monthly variables of mean number of aphid and whitefly, mean attack rates due to the *A. gossypii* / *B. tabaci* complex and the amounts total rainfall and mean temperature. Multiple regression equations were also released. All results were appreciated at the significance level of 5%.

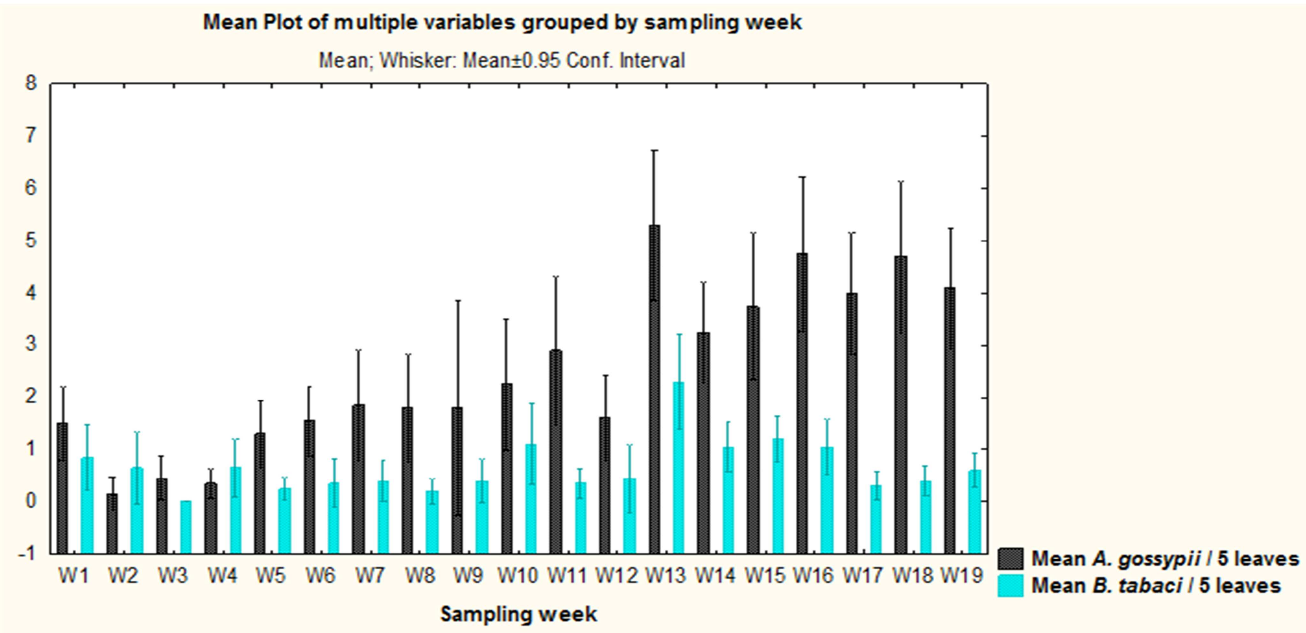
3. Results and Discussion

3.1. Seasonal Variation of A. gossypii and B. tabaci Populations Per 5 Leaves on C. Annuum

3.1.1. Abundance Per 5 Leaves Per Plant of A. gossypii in Function of Sampling Week (DAT)

The average abundance of *A. gossypii* per 5 leaves per plant showed a significant difference depending on the weeks study (df=18, F=8.50, p<0.001). This variation in abundance evolved in 07 phases from transplanting to the last week in the following manner:

1) phase 1: from week 1 (seven days after transplantation: 7 DAT), to week 4 (28 DAT), the average number of individuals decreased gradually starting from 1.50±0.33 individuals / 5 leaves / plant (Min=0.79, Max=2.20, N=20) at 0.35±0.13 individuals / 5 leaves / plant (Min=0.07, Max=0.62, N=20) from April to May (Figure 4);
2) phase 2: from week 4 to week 11 (77 DAT), the average number of individuals increases to a value of 2.90±0.67 individuals / 5 leaves / plant (Min=1.48, Max=4.31, N=20) corresponding to the months of May to June;
3) phase 3: from week 11 to week 12 (84 DAT), the average number of individuals decreased to an average value of 1.6±0.38 individuals / 5 leaves / plant (Min=0.79, Max=2.41, N=20) from the end of June to the beginning of July;
4) phase 4: from week 12 to week 13 (91 DAT), the average number of individuals increases again for a higher mean value of 5.30±0.68 individuals / 5 leaves / plant (Min=3.85, Max=6.74, N=20) during the month of July;
5) phase 5: We observe a further decrease from week 13 to week 14 (98 DAT), with a mean low value of 3.25±0.46 individuals / 5 leaves / plant (Min=2.27, Max=4.22, N=20) during the same month;
6) phase 6: from week 14 to week 16 (112 DAT), the average number of individuals increases further to reach an average value of 4.75±0.70 individuals / 5 leaves / plant (Min=3.27, Max=6.22, N=20) from the end of July to the beginning of August;
7) phase 7: from week 16 to week 19 (133 DAT) the number of individuals remains constant and ends up decreasing to reach the average value of 4.1±0.55 individuals / 5 leaves / plant (Min=2.94 Max=5.25, N=20) corresponding to August (Figure 4).



Note: W=Week; W1 to W19=Period running from April 2018 to August 2018 (Total sampling period).

Figure 4. *Mean (±0.95 Conf. Interval) numbers of A. gossypii and B. tabaci per 5 leaves per plant by sampling weeks from April to August 2018.*

3.1.2. Abundance Per 5 Leaves Per Plant of B. tabaci in Function of Sampling Week (DAT)

During the study, the average number of *B. tabaci* / 5 leaves / plant population showed significant variation depending on the weeks of study (df=18, F=4.87, p<0.001). It has also evolved into 07 phases:

1) phase 1: from week 1 (7 DAT) to sampling week 3 (21 DAT), the average number of individuals decreases from 0.85±0.29 individuals / 5 leaves / plant (Min=0.23 Max=1.46, N=20) at a value of zero (Figure 4) corresponding to the months of April then beginning of May;
2) phase 2: from week 3 to week 10 (70 DAT), the number of individuals increases and reaches an average value of 1.10±0.36 individuals / 5 leaves / plant (Min=0.32, Max=1.87, N=20) corresponding to the months of May to June;
3) phase 3: from week 10 to week 11 (77 DAT), the average number of individuals decreases to an average value of 0.35±0.13 individual / 5 leaves / plant (Min=0.07, Max=0.62, N=20) corresponding to the month of June;
4) phase 4: from week 11 to week 13 (91 DAT), we see that the average number of individuals increases considerably to reach a higher value of 2.30±0.42 individuals / 5 leaves / plant (Min=1.40, Max=3.19, N=20) during the months of late June and early July;
5) phase 5: from week 13 to week 14 (98 DAT), we observe a new decrease with an average value of 1.05±0.22 individuals / 5 leaves / plant (Min=0.58, Max=1.52, N=20) during the month of July;
6) phase 6: starting from week 14, the average number of individuals remains constant before reaching a mean low value of 0.30±0.12 individuals / 5 leaves / plant (Min=0.03, Max=0.57, N=20) at the sampling week 17 (119 DAT) during the months of July and August;
7) phase 7: from week 17, there was an increase in the number of individuals for an average value of 0.60±0.15 individuals / 5 leaves / plant (Min=0.28, Max=0.91, N=20) at the sampling week 19 (133 DAT) during the month of August (Figure 4).

The species *A. gossypii* and *B. tabaci* remain the economically important pests associated with market gardening in the urban and peri-urban zone of Yaoundé [34, 35, 33, 36]. *Aphis gossypii* and *B. tabaci* populations per 5 leaves per plant varied significantly with sampling weeks with higher populations at the 13th week corresponding to the 4th sampling month (July), ie 91 days after transplantation, and a lower average number at the 3rd week corresponding to the 2nd sampling month (May), ie 21 days after transplantation. [37] on the cucumber in Brazil shows that, the higher number of whitefly adults per leaf was observed on the third month (June) with 22.02 individual/leaf/plant, than on the second (May), 2.09 individual/leaf/plant, as well as in the first month (April) of evaluation, 0.35 individual/leaf/plant. [2] find in Yaoundé that during phase 2 (week 3 to 9 after transplanting) on red pepper, the average number of aphids increased exponentially, until a maximum of abundance around week 9 (56.34±5.69 aphids/plant) and around week 1 to 3, the average number of aphids were low with 3±1.13 aphids/plant. From week 13 to 22, the average number of whitefly increased gradually until a maximum at the end of the plant's life cycle (16.5±3.6 whitefly/plant). On yellow pepper, the same authors showed that during the phase of week 9 to 15, population of aphids was highly maintained with 48±6.34 aphids/plant and the number of whitefly population were greater than 10 individual/plant until a maximum was attained at the end of the plant's cycle at week 22. [1] in India showed that the incidence of *B. tabaci* on chili pepper was started from the 45^{th} standard week of observations (2.07 adults/three leaves), and reached its peak in the 48^{th} standard week of observations (7.07adult/three leaves) and again declined subsequently up to 1^{st} standard week of observations with a population of 1.80 adult/three leaves. The works of [20] on chili pepper in monoculture in Malaysia resulted in a higher *B. tabaci* adult number of 4.73±0.17 individuals / plant, lower than 0.16±0.019 adults / plant and an average value of 1.49±0.089 individuals / plant. The work done by [13] on cotton in Brazil show that in sole cotton (t4) (3.599 aphids) cotton aphids reached a higher population peak than in crop system t1 (2.208 aphids), crop system t2 (1.756 aphids), and crop system t3 (2.298 aphids). The lowest peak for the cotton aphid population was found in crop system t2 (1.756 aphids). These authors also show that *A. gossypii* population peaked at 42 days in sole cotton (t4) and also in crop system t1, while in crop systems t2 and t3, the cotton aphid population peaked 35 days after the plant infestations.

3.1.3. Abundance of A. gossypii and B. tabaci Populations Per Seasons

The Mean abundance of *A. gossypii* populations varied significantly by study season (df=1, F=2.99, p=0.005).

During the short rainy season, the average value of individuals increased slightly from 0 to 1.11±0.20 individuals / 5 leaves / plant (Min=0.71, Max=1.51, N=160).

During the short dry season it was found that the average number of *A. gossypii* increased again to a value of 3.49±0.17 individuals / 5 leaves / plant (Min=3.15, Max=3.83 N=220) (Figure 5).

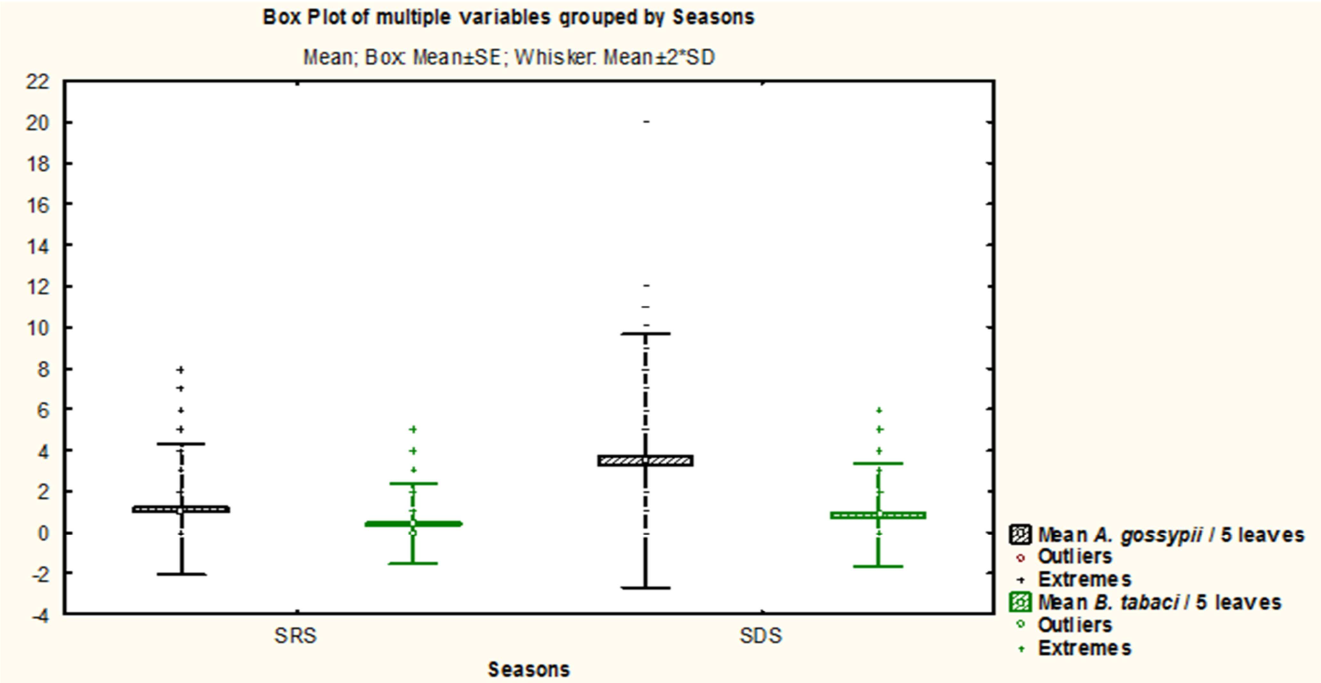
In addition, mean abundances of *B. tabaci* populations also varied significantly from season to season (df=1, F=12.58, p<0.0004).

The average of the individuals increased slightly during the short rainy season until reaching the average value of 0.41±0.08 individual / 5 leaves / plant (Min=0.24, Max=0.59, N=160).

During the short dry season, the number of individuals reached a higher mean value of 0.83±0.07 individual / 5 leaves / plant (Min=0.68, Max=0.98, N=220) (Figure 5).

In our study, the average abundances of *A. gossypii* and *B. tabaci* populations on leaves varied significantly with the seasons. These results corroborate those of [22] in West Bengal (India), and show that populations of *Aphis gossypii* on *L. esculentum* vary with the seasons of the year and that the low level of aphid population (0.19 to 0.50/leaf) was counted on 38th to 40th standard week of September to October, 52nd to 5th standard week of December to January and 18th to 22nd week that is 1st week May to 4th week of June when average temperature, relative humidity and weekly rainfall ranged from 15.71°C-28.86°C, 70.42%-92.93% and 0.00mm-240.20mm respectively. The same author shows that, persistent high population (0.62-2.69/leaf) was maintained on 41st standard week to 51st standard week that is during 2nd week of October to 3rd week of December and 6th to 17th week that is during 2nd week February to 4th week of April when average temperature, relative humidity and weekly rainfall ranged from 18.33°C-27.83°C, 47.85%-92.39% and 0.00mm-63.40mm respectively.

The short dry season (July and August) during the study was favorable for the high abundances of *A. gossypii* and *B. tabaci* populations. These abundances remain low during periods of rainfall due to heavy showers in April, May and June, which considerably reduce the level of their populations by leaching and probably the high presence of natural enemies. (e.g. ladybird beetle and green lacewing).



Note: SRS=Short rainy season; SRS=Short dry season.

Figure 5. *Mean (±SE) numbers of A. gossypii and B. tabaci populations per 5 leaves per plant by seasons during the period running from April to August 2018.*

3.1.4. Abundance of A. gossypii and B. tabaci Populations Per Phenological Stage of C. annuum

The mean abundances of *A. gossypii* and *B. tabaci* / 5 leaves / plant showed a significant difference between the phenological stages of the plant (df=2, F=111.07, P <0.005 and df=2, F=132.74, p <0.005 respectively for both pests).

During the pre-flowering phase, the average number of individuals increases from 0 to 1.42±0.13 individuals / 5 leaves / plant (Min=1.15, Max=1.69, N=269) for *A. gossypii* and from 0 to 0.50±0.06 individual / 5 leaves / plant (Min=0.36, Max=0.63, N=269) for *B. tabaci*.

During the flowering stage, the number of individuals continues to increase until reaching an average value of 3.88±0.37 individual / 5 leaves / plant (Min=3.14, Max=4.63;=35) for *A. gossypii* and an average value of 1.34±0.18 individual / 5 leaves / plant (Min=0.97, Max=1.71, N=35) for *B. tabaci*.

During the fruiting phase, the number of individuals reaches a maximum value of 5.61±0.25 individual / 5 leaves / plant (Min=5.11, Max=6.12, N=76) (Figure 6) for *A. gossypii* and a decrease in the mean number of individuals / 5 leaves / plant of 0.91±0.12 (Min=0.65, Max=1.16, N=76) for *B. tabaci* (Figure 6).

Populations of *A. gossypii* and *B. tabaci* per 5 leaves per plant varied significantly depending on the phenology stage of *C. annuum* plants. The flowering and fruiting phases showed suitable habitats for the outbreaks of populations of *B. tabaci* and *A. gossypii* respectively. The work of [2] reported that the absolute abundances of *B. tabaci* populations on red and yellow peppers in Yaoundé were higher during the flowering phase with 74066 and 73782 individuals respectively and that those of *M. euphorbiae* were higher during the fruiting phase with absolute abundance of 176 individuals on sweet pepper.

They also show that *B. tabaci* populations on red pepper was not important during the first cycle of the plant at the preflowering period and it was lower than 10 individuals (0.5±0.49 whitefly/plant) and increase population appears at the beginning of the flowering phase. [36] also points out that *B. tabaci* populations on *Solanum* spp. in Okola (Central Region) had a higher average abundance of 15.08±5.33 individuals / plant during the flowering phase. Abundances of *A. gossypii* and *B. tabaci* were lower in the pre-flowering phase. The plants at this stage will not have sufficient nutritional juice that insects can extract. In contrast to this phase, the flowering and fruiting phases were those that hosted the highest hemipterans populations. During the phase around the 10th to 19th weeks after transplanting, the population of *A. gossypii* and *B. tabaci* grew up exponentially.

This can be explained by the fact that at this stage of the life cycle, the plant's roots are well developed, the number of leaves is important for photosynthesis. As such, the youngest plants accumulate enough reserves for their flowering and fructification [2].

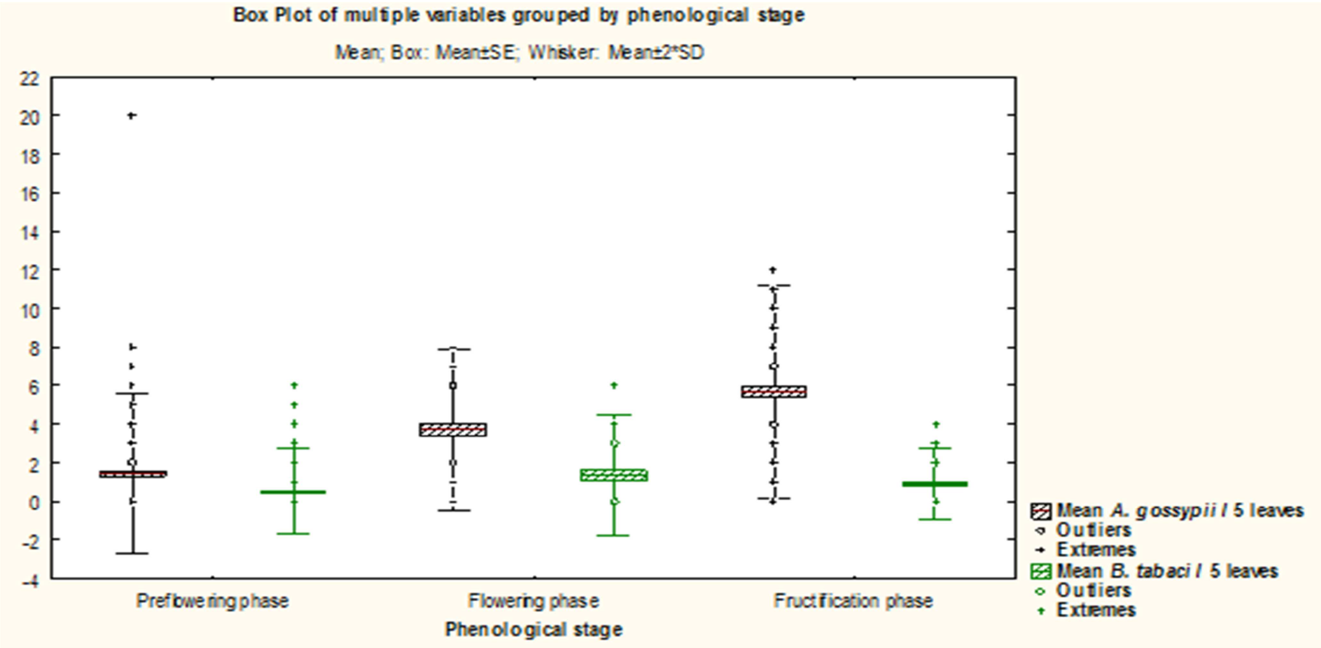


Figure 6. *Mean (±SE) number of A. gossypii and B. tabaci populations per 5 leaves on C. annuum during Phenological stages from April to August 2018.*

3.2. Percent Index Damage (PDI) Due to Hemipterans Complex on Leaves of C. annuum

3.2.1. Damage Per Sampling Week (DAT)

The damage due to the hemipterans complex showed a significant variation according to the sampling weeks (df=18, F=3.02, p<0.004). The evolution of this damage presented 4 distinct phases (Table 1):

Phase 1: From Week 1 (7 DAT) to Week 8 (56 DAT), the attack rate decreased from the higher average value of 31.25±5.56% (Min=19.59, Max=42.90, N=20) corresponding to the short rainy season to the mean lower value of 7.96±2.05% (Min=3.65, Max=12.27, N=20);

Phase 2: In the week 9 (63 DAT), the attack rate increases again, from an average value of 15.15±3.17% (Min=17.60, Max=32.48, N=20) to an average value highest of 24.14±7.39 (Min=8.70, Max=39.63, N=20) at sampling week 12 (84 DAT) corresponding to the short rainy season and the beginning of the short dry season;

Phase 3: from week 13 (91 DAT) to week 15 (105 DAT) the attack rate remained almost stable from an average value of 15.59±3.31% (Min=8.66, Max=22.52, N=20) to that of 15.18±2.90% (Min=9.11, Max=21.26, N=20) corresponding to the short dry season;

Phase 4: from week 16 (112 DAT) to week 19, the attack rate drops again from an average value of 9.44±1.96% (Min=5.32, Max=13.56, N=20) to a lower mean value of 7.93±1.87% (Min=4.02,

Max=11.85, N=20) corresponding to the short dry season (Table 1).

It should be noted that the average values of the highest damage were noted during the short rainy season. During this period, the leaves remain susceptible to repeated attacks of the *A. gossypii* / *B. tabaci* complex.

3.2.2. Percent Damage Index (PDI) Per Phenological Stage of C. annuum

The attack rate varied significantly according to the phenological stage of the plant (df=2, F=20.31, p <0.005).

During the preflowering stage, for an average total number of 17.41 leaves / plant and an average total of 2.84 attacked leaves / plant, the attack rate is higher with an average value of 20.85±1.10% (Min=18.68, Max=23.02, N=269) (Figure 7).

During the flowering stage, the attack rate drops to an average value of 8.40±3.66% (Min=2.37, Max=14.42, N=35) for an average total number of 128.6 leaves / plant and a total average of 9.17 attacked leaves / plant.

During the fructification stage, the attack rate drops further to a lower mean value of 7.57±2.07% (Min=3.48, Max=11.65, N=76) for an average total number of 272.59 leaves / plant and an average total of 16.14 attacked leaves / plant (Figure 7).

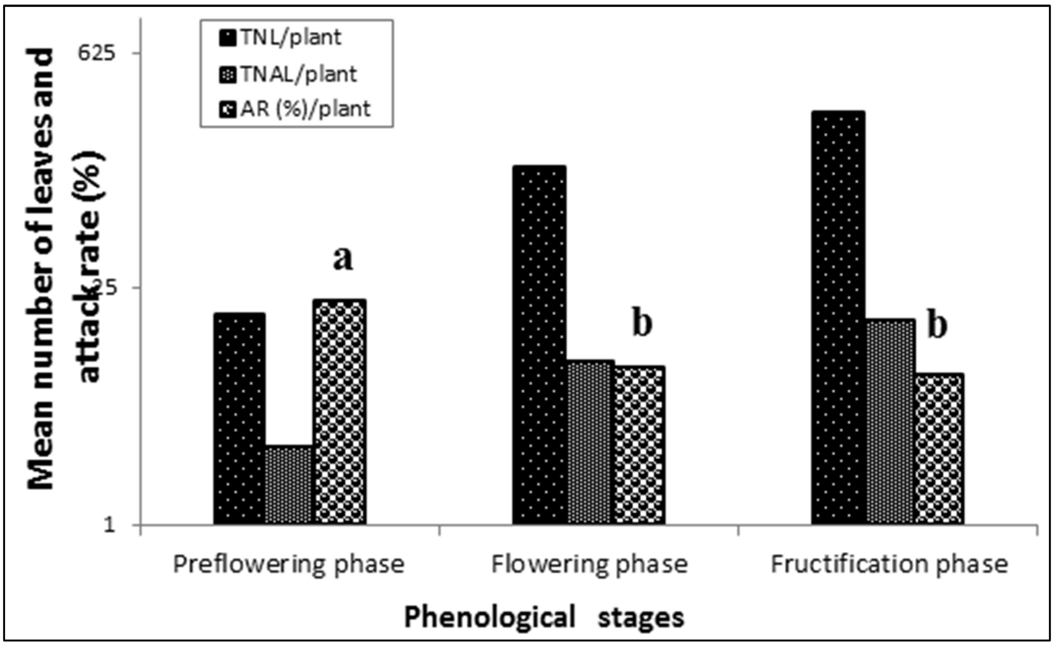


Figure 7. *Mean total number of leaves and attack rate (%) due to H. complex on leaves of C. annuum during phenological stages from April to August 2018.*

Note: TNL=Total number of leaves; TNAL=Total number of attacked leaves; AR=Attack rate; H. complex=hemipterans complex (includes *A. gossypii* and *B. tabaci*). Mean number followed by the different letter (s) differ significantly at p<0.05 (using HSD Tukey test) and mean number followed by the common letter (s) do not differ significantly at p≥0.05 (using HSD Tukey test).

The leaves are more prized by the hemipterans ones at the beginning of the vegetative cycle (preflowering phase) of the plant in field same although being less numerous in term of individuals. At this stage, the young leaves are more susceptible to hemipterans and tenderer so that the sap is easily removed by the pests.

3.2.3. Percent Damage Index (PDI) per Season

Throughout the study period, the attack rate also varied significantly with the seasons (df=1, F=9.69, p <0.001).

During the short rainy season, for an average total number of 10.13 leaves / plant and a total average of 1.97 attacked leaves / plant, the attack rate averaged 20.57±1.48%. (Min=17.65, Max=23.49, N=160).

During the short dry season, for an average total number of 128.55 leaves / plant and an average total of 9.08 leaves attacked / plant, this attack rate decreased to an average value of 14.48±1.26% (Min=11.99, Max=16.98, N=220) (Figure 8).

The short rainy season allows the development of young leaves by an almost constant rainfall regime, favoring their susceptibility to attack by the *A. gossypii* / *B. tabaci* complex.

Damage to the *A. gossypii* / *B. tabaci* complex on *C. annuum* leaves varied significantly from one study week to another after seedling transplantation with higher rates during the short rainy season and less high in the dry season. During the rainy periods, the fresh leaves remain tender to allow the sucking-stickers to take the sap, hence their susceptibility to the repeated attacks of *A. gossypii* and *B. tabaci*. Attack rates remain high given the almost permanent presence of these pests, which indirectly transmit virus that affects the quality of the leaves. The toxins injected by *A. gossypii* and *B. tabaci* make the leaves dry and thus have a castellated appearance. The works of [20] show that the result of action of *B. tabaci* reduced seed cotton yield, contamination with honeydew, sooty mould and transmission of viruses such as cotton leaf curl virus causing cotton leaf curl disease and the economic damages of seed-cotton yield were estimated to range between 10.6% and 92.2%. [17] Found that *A. gossypii* reduced the yield of cotton seed.

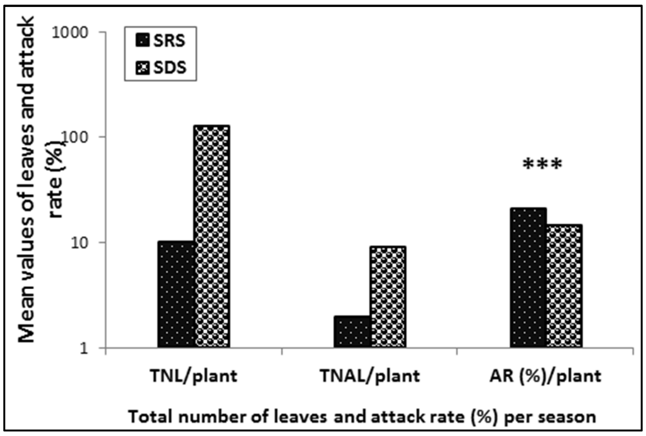


Figure 8. *Total number of leaves and attack rate (%) due to H. complex on leaves of C. annuum during seasons from April to August 2018.*

Note: SRS=Short rainy season; SDS=Short dry season; TNL=Total number of leaves; TNAL=Total number of attacked leaves; AR=Attack rate; H. complex=hemipterans complex (includes A. gossypii and B. tabaci). ***=significant at p<0.001 level.

Table 1. *Mean (±SE) attack rate (%) (Percent index damage) due to hemipterans complex (includes A. gossypii and B. tabaci) on leaves of C. annuum during sampling period from April to August 2018 (From W1 to W19).*

Sampling WAT	Sampling Months	Sampling DAT	Mean of TNL/plant	Mean of TNAL/plant	Mean of AR/plant	N
1WAT	April	07DAT	3.45±0.30a	1.20±0.21a	31.25±5.53a	20
2WAT	April	14DAT	2.70±0.52a	1.15±0.27a	25.91±6.49a	20
3WAT	May	21DAT	4.20±0.60a	1.55±0.32ab	27.53±5.78a	20
4WAT	May	28DAT	5.50±0.85a	1.75±0.48ab	21.95±4.58a	20
5WAT	May	35DAT	9.10±1.45a	2.40±0.44abc	25.04±3.55a	20
6WAT	May	42DAT	12.35±2.69a	2.00±0.47abc	11.65±3.08a	20
7WAT	June	49DAT	17.95±4.52a	2.95±0.66abc	13.27±3.47a	20
8WAT	June	56DAT	25.85±7.53ab	2.80±0.72abc	7.96±2.05b	20
9WAT	June	63DAT	41.05±10.36ab	3.45±0.62abc	15.15±3.17a	20
10WAT	June	70DAT	50.05±12.23abc	3.75±0.74abc	14.15±3.77a	20
11WAT	June	77DAT	75.65±19.31abc	4.80±0.78abc	19.69±4.58a	20
12WAT	July	84DAT	81.90±20.67abc	7.00±1.44abc	24.14±7.39a	20
13WAT	July	91DAT	98.00±23.99abc	7.70±1.57abc	15.59±3.31a	20
14WAT	July	98DAT	101.30±24.56abc	8.55±1.67abce	16.18±3.25a	20
15WAT	July	105DAT	107.15±27.42abc	9.25±1.72abce	15.18±2.90a	20
16WAT	August	112DAT	139.85±27.43bcd	9.55±1.89bce	9.44±1.96c	20
17WAT	August	119DAT	161.20±31.20cd	10.10±1.94ce	9.46±2.04c	20
18WAT	August	126DAT	232.50±47.44de	19.45±4.03de	12.42±2.38a	20
19WAT	August	133DAT	325.30±63.41e	16.30±3.84e	7.93±1.87b	20
Mean±SD			78.69±86.07	6.09±5.11	17.05±6.97	20

Note: TNL=Total number of leaves; TNAL=Total number of attacked leaves; AR=Attack rate; SD=Standard deviation; WAT=Week after transplanting; DAT=Day after transplantation; W1 to W19=Period running from April 2018 to august 2018. Mean number followed by the different letter (s) differ significantly at p<0.05 (using HSD Tukey *test*) and mean number followed by the common letter (s) do not differ significantly at p≥0.05 (using HSD Tukey *test*).

(*Gossypium hirsutum* L.) by 37% in sole cotton plots compared with 10% loss of cotton-seed yield per plant in the intercropping systems. If not controlled, *A. gossypii* can cause a significant drop in yield, reducing production by 44% taking both quantitative and qualitative losses into account, thus resulting in economic losses associated with virus attacks. Some varieties of pepper remain susceptible to repeated attacks of the *A. gossypii* / *B. tabaci* complex. The damage due to *B. tabaci* in India has been investigated on some chili pepper varieties by [1] who reported that susceptible varieties (Kashi Anmol and LCA 334) had high attack rates in the range of 14.67% and 25.33%, 27.67% and 46.67%, 62.67% and 81.33%, 86.66% and 92.00% respectively at 30, 60, 90 and 120 days after transplantation. The varieties resistant to Chili Leaf Curl Virus (CLCV) (13 / CHVar.2 and 13 / CHVar.4), presented the damage of the order of 9.33% and 1.33%, 22.67% and 9.35%, 40.00% and 29.33%, 44.00% and 40.00% respectively at 30, 60, 90 and 120 days after transplantation.

3.3. Relationship Between Mean Monthly Abundance Per 5 Leaves Populations and Abiotic Factors

3.3.1. Abiotic Factors and A. gossypii and B. tabaci Populations Followed by Average Attack Rates Due to A. gossypii / B. tabaci Complex

The results show that the average number of *A. gossypii* per 5 leaves per plant varies from month to month ($F (4, 375)=27.859$, $p <0.001$). This number increases from April to August with a maximum value of 4.26±0.21 individuals / 5 leaves / plant (Min=3.76, Max=5.08, N=80) in August at 22°C of average temperature, 86% of average relative humidity and 70 mm of total rainfall corresponding to the short dry season, and a minimum value of 0.82±0.21 individuals / 5 leaves / plant (Min=0.39, Max=1.25, N=40) in April at 23°C of average temperature, 82% of average relative humidity and 180 mm of total rainfall corresponding to the short rainy season (Table 2).

For *B. tabaci*, the mean number of individuals / 5 leaves also varies from month to month ($F (4,375)=8.38$, $p<0.001$) with a maximum value of 1.21±0.16 individuals / 5 leaves / plant (Min=0.91, Max=1.58, N=80) in July at 22°C of average temperature, 86% of average relative humidity and 50 mm of total rainfall corresponding to the short dry season, and a minimum value of 0.31±0.09 individuals / 5 leaves / plant (Min=0.91, Max=1.58, N=80) in May corresponding to the short rainy season (Table 2).

Attack rates due to *A. gossypii* / *B. tabaci* complex leave the highest mean value of 28.58±4.24% (Min=19.99, Max=37.17, N=40) in April at 23°C average temperature, 82% average relative humidity and 180 mm total rainfall corresponding to the short rainy season, to the lowest average value of 09.82±1.03% (Min=7.75, Max=11.87, N=80) in August at 22°C average temperature, 86% average relative humidity and 70 mm total rainfall corresponding to the short dry season. These results show that during the study period, the highest populations of both pests are influenced by the relative humidity during the short dry season and the lower populations by rainfall and average temperature during the short rainy season. In return, attack rates are higher during the short rainy season (Table 2).

3.3.2. Relationship Between Abiotic Factors and Populations Per 5 Leaves Per Plant of A. gossypii and B. tabaci and Damage Due to Hemipterans Complex

The study presented a positive and non-significant correlation between rainfall and mean temperature (r=0.86, p <0.058), a positive and non-significant correlation between attack rate due to the hemipterans complex (*A. gossypii* / *B. tabaci*) and precipitation (r=0.60, p <0.285), a positive and non-significant correlation between attack rate due to the hemipterans complex and mean temperature (r=0.87, p <0.057), a positive and significant correlation between mean number of individuals / 5 leaves of *A. gossypii* and relative humidity (r=0.89, p <0.040), a positive and non-significant correlation between mean number of individuals / 5 leaves of *B. tabaci* and relative humidity (r=0.11, p <0.857) and a positive and non-significant correlation between attack rate due to hemipterans complex and mean number of individuals / 5 leaves of *B. tabaci* (r=0.20, p<0.747) (Table 3).

These results show that precipitation and average temperature negatively affect the level of *A. gossypii* and *B. tabaci* populations and positively the level of damage due to the hemipterans complex of two pests. On the other hand, the relative humidity positively affects the level of *A. gossypii* and *B. tabaci* populations, but negatively the attack rates due to the *A. gossypii* / *B. tabaci* complex on leaves of *C. annuum* (Table 3).

Populations of *A. gossypii* and *B. tabaci* had negative and non-significant correlations with rainfall and mean temperature, followed by a positive and significant correlation (for *A. gossypii*) and a positive and non-significant correlation (for *B. tabaci*) with relative humidity. Rainfall has indeed lowered the level of *A. gossypii* and *B. tabaci* populations. These results follow the same logic (for precipitation and relative humidity) as those provided by [22] in West Bengal (India) on *Lycopersicon esculentum* who shows that correlation studies between aphid population and environmental parameters revealed that the aphid population had a non-significant positive correlation with mean temperature (r=0.003), while non-significant negative correlation with total rainfall (p≥0.05) and on the other hand, significant positive correlation was found between aphid population and relative humidity (r=0.757**). This indicates that activity of aphid population increases with the rise of temperature and average relative humidity. The aphid population more level under warm humid condition. In case of heavy rainfall, the pest population decreases [22].

Attack rates due to the *A. gossypii* / *B. tabaci* complex showed positive and non-significant correlations with precipitation and mean temperature and then a significant and negative correlation with mean relative humidity. In fact, rainfall favored leaf attacks due to hemipterans. Precipitation, temperature and relative humidity play a key role in the seasonal variation of populations and pest damage in a market gardening agro system. [1] show that, damage due to *B. tabaci* was found to be significantly negatively correlated with maximum temperature (r=-0.179*) and only negatively correlated with minimum temperature (r=-0.062) while negatively correlated with rainfall with (r=-0.253*). [32] report that, the main factor determining fruit losses in a study conducted at Koutaba (Western Region of Cameroon) on some varieties of pepper appeared to be the rainfall and temperature. These authors show the actions of *Ceratitis capitata* (main pest of chili fruits), which showed rather negative and non-significant correlations between the damage caused by this pest and the precipitations (r=-0.366, p=0.29) then the temperature (r=-0.067, p=0.83). This difference is due to the climatic variability of the two study areas with a single rainy season at Koutaba and two rainy seasons at Yaoundé.

Table 2. *Abiotic factors and average number /5 leaves / plant of A. gossypii and B. tabaci individuals and attack rate (%) due to hemipterans complex (A. gossypii / B. tabaci) from April to August 2018.*

Seasons	Months	Total Rainfall (mm)	Mean Temperature (°C)	Relative Humidity (%)	MN of *A. gossypii* / 5 leaves/plant	MN of *B. tabaci* / 5 leaves/plant	MAR (%) due to *H. complex*
SRS	April	180	23	82	0.82±0.21a	0.75±0.21ad	28.58a
SRS	May	200	23	85	0.91±0.13a	0.31±0.09acd	21.55ab
SRS	June	150	22	86	2.08±0.29b	0.50±0.10acd	14.05bc
SDS	July	50	22	86	3.73±0.32c	1.21±0.16ab	17.77ab
SDS	August	70	22	86	4.26±0.31c	0.43±0.08ad	09.82bc
Mean±SD		130±62.8	22.4±0.52	85±1.62	2.36±1.49	0.64±0.34	18.35±6.77

Note: MN=Mean number, MAR=Mean attack rate, SRS=Short rainy season, SDS=Short dry season, SD=Standard deviation; H. complex=hemipterans complex. Mean number followed by the different letter (s) differ significantly at p<0.05 (HSD Tukey test) and mean number followed by the common letter (s) do not differ significantly (p≥0.05, HSD Tukey test).

Table 3. *Correlation co-efficient (r) between pairs of variables and mean number/5 leaves/plant of A. gossypii and B. tabaci and attack rate due to H. complex from April to August 2018.*

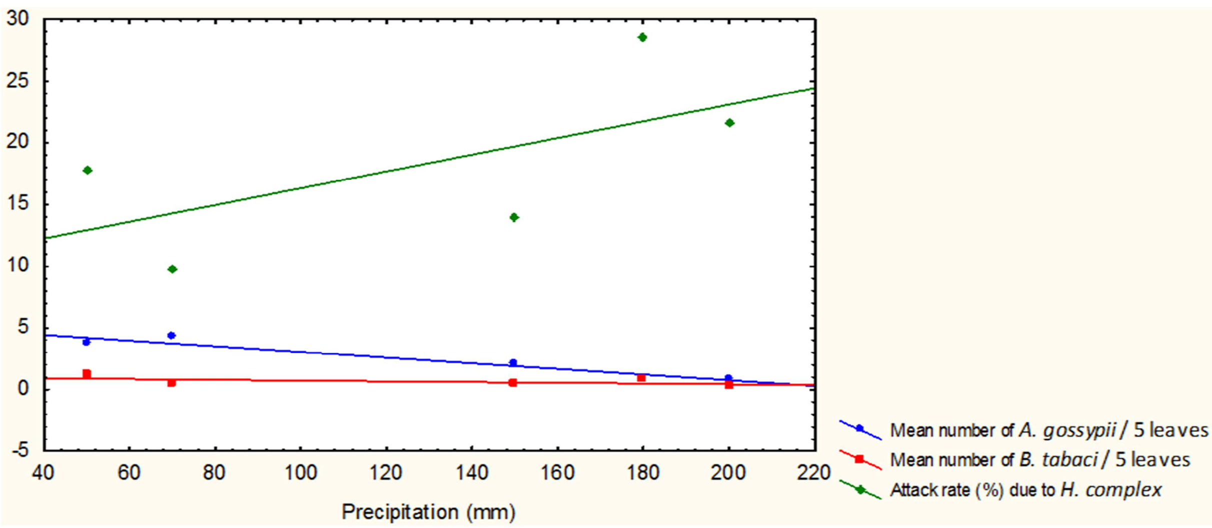
Pair of		Temperature (°C)	Relative Humidity (%)	MN of *A. gossypii* / 5 leaves	MN of *B. tabaci* / 5 leaves	MAR (%) due to *H. complex*
Rainfall (mm)	Valid N	5	5	5	5	5
	r-Value	0.86ns	-0.78ns	-0.80ns	-0.60ns	0.60ns
	T (N-2)	3.00	-2.17	-2.30	-1.29	1.29
	p-Level	0.058	0.117	0.104	0.284	0.285

Pair of		Temperature (°C)	Relative Humidity (%)	MN of *A. gossypii* / 5 leaves	MN of *B. tabaci* / 5 leaves	MAR (%) due to *H. complex*
Temperature (°C)	Valid N		5	5	5	5
	r-Value		-0.96**	-0.87ns	-0.29ns	0.86ns
	T (N-2)		-6.71	-3.00	-0.52	3.00
	p-Level		0.006	0.057	0.637	0.057
Relative Humidity (%)	Valid N			5	5	5
	r-Value			0.89*	0.11ns	-0.86*
	T (N-2)			3.46	0.19	-3.46
	p-Level			0.040	0.857	0.041
MN of *A. gossypii* / 5 leaves/plant	Valid N				5	5
	r-Value				0.00	-0.90*
	T (N-2)				0.00	-3.58
	p-Level				1.00	0.037
MN of *B. tabaci* / 5 leaves/plant	Valid N					5
	r-Value					0.20ns
	T (N-2)					0.35
	p-Level					0.747

Note: MN=Mean number, MAR=Mean attack rate, *=Significant at $p<0.05$ level, **=Significant at $p<0.01$ level, ns=non-significant at $p\geq0.05$. r=Correlation co-efficient, H. complex=hemipterans complex.

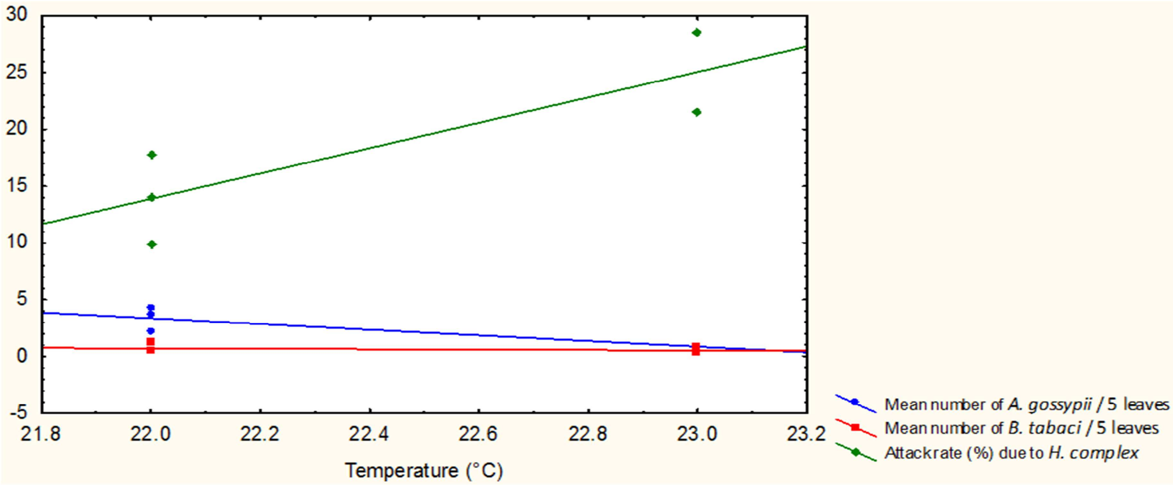
3.3.3. Multiple Regression Equation for A. gossypii and B. tabaci Populations and Attack Rate Due to H. complex and Abiotic Factors

The study showed a negative linear regression between precipitation (Y=-0.0229x + 5.3376, R^2=0.9302), temperature (Y=-2.4917x + 58.173, R^2=0.7421) and average number of individuals / 5 leaves of *A. gossypii* (Figures 9 and 10 respectively), and a positive linear regression between relative humidity (Y=0.6342x-51.5442; R^2=0.4807) and the average number of individuals / 5 leaves of *A. gossypii* (Figure 11). In addition, it shows a negative linear regression between the average number of individuals / 5 leaves of *B. tabaci* and precipitation (Y=-0.003x + 1.03, R^2=0.3144), temperature (Y=-0.1833x + 4.7467, R^2=0.0791) and relative humidity (Y=-0.0092x + 1.4192, R^2=0.002) (Figures 9, 10 and 11 respectively). The multiple regression analysis revealed that the weather parameters contributed for 93.02% and 31.44% (for total rainfall), 74.21% and 7.91% (for mean temperature) and 48.08% and 0.20% (for relative humidity) of the variation of population/5 leaves of *A. gossypii* and *B. tabaci* respectively during April to August 2018. This study also shows a positive linear regression between precipitation (Y=0.0678x + 9.5337, R^2=0.3968), temperature (Y=11.185x-232.19, R^2=0.7271) and attack rates due to the hemipterans complex (Figures 9 and 10 respectively); and a negative regression between relative humidity (Y=-3.675x + 330.72, R^2=0.7840) and the same attack rates. The multiple regression analysis indicated that the weather parameters contributed for 39.68% (for total rainfall), 72.71% (for mean temperature) and 78.40% (for relative humidity) of the variation of attack rate due to *H. complex*.



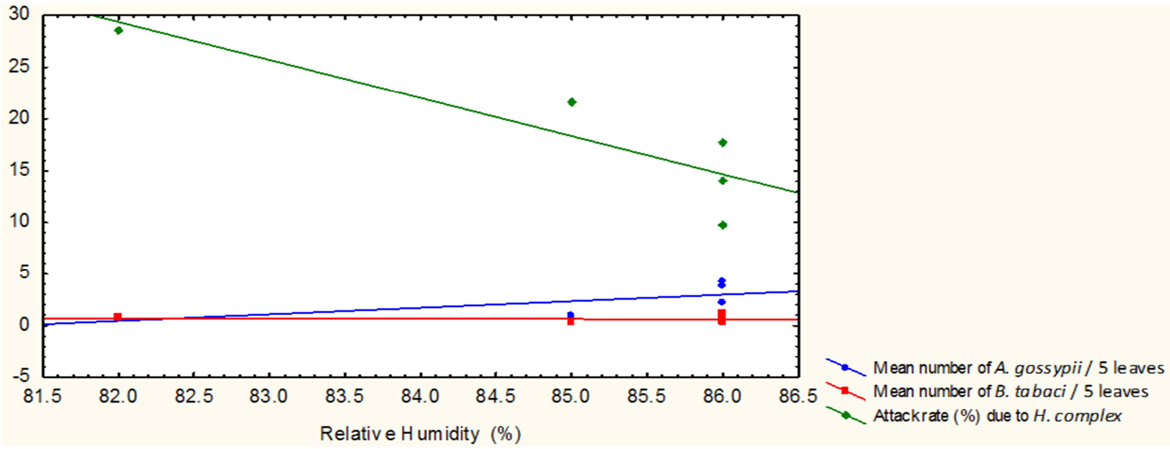
Note: H. complex=hemipterans complex (includes *A. gossypii* and *B. tabaci*).

Figure 9. *Multiple regression equation for A. gossypii and B. tabaci population and damage due to H. complex and precipitation (mm) during April to August 2018.*



Note: H. complex=hemipterans complex (includes *A. gossypii* and *B. tabaci*).

Figure 10. *Multiple regression equation for A. gossypii and B. tabaci population and damage due to H. complex and Temperature (°C) during April to August 2018.*



Note: H. complex=hemipterans complex (includes *A. gossypii* and *B. tabaci*).

Figure 11. *Multiple regression equation for A. gossypii and B. tabaci population and damage due to H. complex and Relative Humidity (%) during April to August 2018.*

Under field conditions, many factors can influence population density of whitefly and aphids in host plants such as weather, levels of nitrogen (N) and potassium (K), allelo-chemicals and natural enemies [38, 39, 37]. In this study, multiple regressions were negative between *A. gossypii* and *B. tabaci* populations and precipitation followed by mean temperature, but positive (for *A. gossypii*) and negative (for *B. tabaci*) between their populations and the average relative humidity. The linear multiple regressions were positive between damage due to the *A. gossypii* / *B. tabaci* complex and precipitations then temperature and rather negative between the same damages and the relative humidity. The results of [22] give negative regressions with the minimum temperature ($Y=-0.923x + 17.084$, $R^2=0.011$) and the relative humidity ($Y=-13.615x + 85.75$, $R^2=0.754$) on the populations of *A. gossypii* in India.

4. Conclusion

Pepper (*C. annuum*) was subject to seasonal variations of the populations of *A. gossypii* and *B. tabaci* (pests of the leaves of this plant) and damage done to the leaves by the same pests. The different data collected made it possible to understand that the highest population abundance of these two pests were recorded during the short dry season (period running from July to August 2018) and the highest average damage recorded in the short rainy season (period running from April to June 2018). The co-efficient of correlation (r) provided negative and non-significant values between the average number of individuals / 5 leaves / plant of *A. gossypii* and *B. tabaci* and the precipitation and then the temperature. In revenge, the study presented a positive and non-significant correlations between the damage due to the *A. gossypii* / *B. tabaci* complex with the same climatic factors. With regard to the different phenological stages, the study showed that the most abundant populations were noted at the fruiting stage for *A. gossypii* and at the flowering stage for *B. tabaci*; the pre-flowering stage providing the lowest abundances of populations of both pests. Highest damage due to the *A. gossypii* / *B. tabaci* complex was recorded during the pre-flowering phase. These different periods and development stages should constitute a database for farmers and thus allow the establishment of integrated management strategies against *A. gossypii* and *B. tabaci* on *C. annuum*. In the following, studies may be carried out on the biochemical properties of leaves of different varieties of *C. annuum* in order to evaluate the densities of the egg, nymph and adult populations of *A. gossypii* and *B. tabaci* and study the natural enemies associated with them.

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References

[1] Gayatri, K., Padhi, Labani, M., Arup, C. and Arunava, S. (2017). Population dynamics of whitefly (*Bemisia tabaci* Genn.) in chilli and screening of genotypes against chilli leaf curl virus. Journal of Entomology and Zoology Studies. 5 (5): 104-107.

[2] Djiéto-Lordon, C., Heumou, C. R., Elono Azang, P. S., Aléné, D. C., Ngueng, A. C. and Ngassam P. (2014). Assessment of pest insects of *Capsicum annuum* L. 1753 (Solanaceae) in a cultivation cycle in Yaoundé. International Journal of Biological and Chemical Science. 8 (2): 621-632.

[3] Elono Azang, P. S. (2008). Contribution à l'étude de l'Arthropodofaune de *Capsicum annuum* LINNEE (Solanaceae) à Yaoundé. Mémoire de DEA. Université de Yaoundé I., Cameroun. 73p.

[4] Reckhaus, P. (1997). Maladies et ravageurs des cultures maraîchères: à l'exemple de Madagascar. Weikeisheim. Margaf, Allemagne. 402p.

[5] MINAGRI. (1999). Annuaire des statistiques du secteur agricole. Ministère de l'Agriculture. Décembre 1999.

[6] James, B., Atcha-Ahowé, C., Godonou, I., Baimey, H., Goergen, G., Sikirou, R. and Toko, M. (2010). Gestion intégrée des nuisibles en production maraîchère: Guide pour les agents de vulgarisation en Afrique de l'Ouest. Institut International d'Agriculture Tropicale (IITA), Ibadan, Nigeria. 120 p.

[7] Sunitha, T. R. (2007). Insect pests of *Capsicum annuum* var. frutescens (L.) and their management. Master thesis University of Agriculture Sciences Dharwad, Dharwad p. 67.

[8] MINADER /DESA/. (2012). AGRI-STAT N° 17: Annuaire des statistiques du secteur Agricole Ministère de l'Agriculture et du Développement Rural. Campagne 2009-2010. MINAGRI, Cameroun, 123p.

[9] Grubben, G. J. H., El Tahir, I. M. (2004). *Capsicum annuum* L. in Grubben G. J. H., Denton O. A. (eds) Ressources végétales de l'Afrique tropicale 2. Légumes. Fondation PROTA, Wagengen, 737 p.

[10] Waterhouse, D. F. (1998). Biological Control of Insect Pests: Southeast Asian Prospects. ACIAR Consultant in Plant Protection. 548p.

[11] FAO. (2003). Eggplant Integreted Pests Management (An Ecological guide). 175p.

[12] Bachmann, A. C., Nault, B. A. and Fleischer, S. J. (2014). Alate aphid (Hemiptera: Aphididae) species composition and richness in northeastern USA snap beans and an update to historical lists. Fla Entomology. 97, 979-994.

[13] Francisco, S. F., Wesley, A. C. G., Francisco, S. R., Adriano, G. G., Bárbara, D. B. S and José, B. M. (2018). Population dynamics of *Aphis gossypii* Glover and *Aphis craccivora* Koch (Hemiptera: Heteroptera: Aphididae) in sole and intercropping systems of cotton and cowpea. Annals of the Brazilian Academy of Sciences. 90 (1): 311-323.

[14] Kadam, D. B., Kadam, D. R. and Lekurwale, R. S. (2014). Seasonal incidence of sucking pests of *Bt* cotton in different intercropping systems and their natural enemies. Journal Plant Pest Science 1: 29-34.

[15] Nava-Camberos, U., Riley, G. D. and Harris, K. M. (2001). Temperature and Host Plant Effects on Development, Survival, and Fecundity of *Bemisia argentifolii* (Homoptera: Aleyrodidae). Entomological Society of America. 30 (01): 0055-0063.

[16] Fereres, A., Avilla, C., Collar, J. L, Duque, M. and Fernández-Quintanilla, C. (1996). Impact of Various Yield-Reducing Agents on Open-Field Sweet Peppers. Environmental Entomology. 25: 983-986.

[17] Ramalho, F. S., Fernandes, F. S., Nascimento, A. R. B., Nascimento, Júnior J. L, Malaquias, J. B. and Silva, C. A. D. (2012). Feeding damage from cotton phids, *Aphis gossypii* Glover (Hemiptera: Heteroptera: Aphididae), in cotton with colored fiber intercropped with fennel. Ann. Entomol. Soc. Am. 105: 20-27.

[18] Singh, J., Sohi, A. S., Mann, H. S. and Kapur, S. P. (1994). Studies on whitefly *Bemisia tabaci* (Genn.) transmitted Cotton Leaf Curl Disease in Punjab. Journal of Insect Science. 7: 194-198.

[19] Vikas, J. and Dhaliwal, G. S. (2009). Elucidating resistance in cotton genotypes to whitefly, *Bemisia tabaci*, by population build up studies. Phytoparasitica. 137-145.

[20] Mansour, S. A. A., Mohamad, R. M. N., Khalid, A. S., Ismail, A. and Idris, A. G. (2013). Population abundance of whitefly, *Bemisia tabaci* (Genn.), on chilli and other vegetable crops under glasshouse conditions. Journal of Tropical Agriculture and Food Science. 41 (1): 149-157.

[21] Elbert, A., Nauen, R. (2000). Resistance of *Bemisia tabaci* (Homoptera: Aleyrodidae) to insecticides in Southern Spain with special reference to neonicotinoids. Pest Management Science. 56: 60-64.

[22] Sunil, K. R. G. (2017). Seasonal incidence of aphid (*Aphis gossypii* Glov.) infesting tomato (*Lycopersicon esculentum* L.) and their management by using botanical pesticides. International Journal of Advances in Science Engineering and Technology. 5 (1): 14-17.

[23] Ryckewaert, P., Fabre, F., (2001). Lutte intégrée contre les ravageurs des cultures maraîchères à la Réunion. Pp. 99 – 103. In AMAS (eds.) Foods and Agricultural Research Council, Mauricius.

[24] Sequeira, R., Dixon, A. F. G. (1997). Population dynamics of tree-dwelling aphids: the importance of seasonality and time scale. Ecology. 78: 2603-2610.

[25] Suchel, F. G. (1988). Les régions climatiques du Cameroun. Les climats du Cameroun. Thèse de Doctorat d'Etat. Université de St Etienne, France. 188p.

[26] Kekeunou, S. (2007). Influence de différents types de végétation de jachères sur les populations de *Zonocerus variegatus* (Orthoptera: Pyrgomorphidae) dans la zone de forêt humide du Sud Cameroun. Thèse de Doctorat ph/D. Université de Yaoundé I. 184pp.

[27] Vicat, J. P., Bilong, P. (1998). Introduction, Environnements et Paléo environnements. In Géosciences au Cameroun. Presses Universitaires de Yaoundé: 3-40.

[28] Abessolo, M. (2000). Pédologie et problème de fertilité des sols tropicaux. In «Utilisation des biofertilisants microbiens pour une agriculture biologique». Unité de Microbiologie Appliquée et Biofertilisants (UMAB). Rapport du 1er atelier de formation à Yaoundé. p. 52.

[29] Ngobo-Nkongo, M. P. (2002). Ecology and socio-economic importance of Southern Cameroun. Thesis. University of Wales. 202p.

[30] Grubben, G. J. H., Denton, O. A. (2004). Ressources végétales de l'Afrique tropicales 2. Légumes. Ed. Fondation PROTA/CTA. Pays-Bas. 737 pp.

[31] Schippers, R. R. (2004). Légumes africaines indigènes. Margraf Publishers. CTA/Wageningen, Pays-Bas. 482p.

[32] Heumou, C. R., Djiéto-Lordon, C., Aléné, D. C. and Elono Azang, P. S. (2015). Diversity and agronomic status of tomato and pepper fruit pests in two agro-ecological zones of Southern Cameroon: Western Highland and Southern Plateau of Cameroon. African Journal of Agricultural Research. 10 (11): 1224-1232.

[33] Elono Azang, P. S., Heumou, C. R., Aléné, D. C., Ngassam, P. and Djiéto-Lordon, C. (2016). Diversity, abundance and incidence of fruit pest insects on three *Solanum* varieties (Solanaceae) in two agroecological zones of Southern Cameroon. African Journal of Agricultural Research. 11 (39): 3788-3798.

[34] Djiéto-Lordon, C., Aléné, D. C. (2002). Inventaire des insectes ravageurs et auxiliaires des cultures maraîchères dans la région de Yaoundé. Rapport -CIRAD. Yaoundé 35p.

[35] Djiéto-Lordon, C., Aléné, D. C. (2006). Inventaire diagnostique des insectes de quelques cultures dans les exploitations maraîchères périurbaines dans la région de Yaoundé – Cameroun. In «Pôle de compétence en Partenariat (PCP) Grand Sud Cameroun. Actes atelier de présentation des résultats de recherche participative». IRAD. Yaoundé, Cameroun pp. 7-17.

[36] Elono Azang, P. S. (2017). Arthropodofaune associée à quelques Solanaceae maraîchères dans la région forestière du Sud-Cameroun: écologie et impact agronomique des principaux carpophages. Thèse de Doctorat/Ph. D. Université de Yaoundé I., Cameroun. 202p.

[37] Germano, L. D. L., Marcelo, P., Raul, N. C. G. and Carvalho, C. E. (2006). Factors affecting the attack rate of *Bemisia tabaci* on cucumber. Pesq. Agropec. Bras. 41 (8): 1241-1245.

[38] Dent, D. R. (1995). Integrated pest management. London: Chapman and Hall. 356p.

[39] Leite, G. L. D. (2000). Fatores que influenciam a intensidade de ataque de mosca-branca em tomateiro. Dissertação (Doutorado) - Universidade Federal de Viçosa, Viçosa. 46p.