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Effects of the Morphological Diversity of Leaf Surface and Phytochemicals Composition on Preference Behavior of Leafhopper and Planthoppers on some Solanaceous Crops

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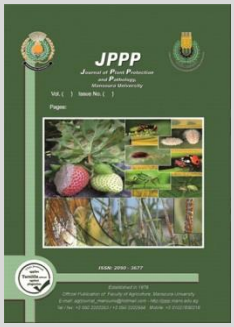

ABSTRACT

The present experiments were conducted to study the effect of different solanaceous host plants on the population density of the leafhoppers and planthoppers according to the morphological diversity of host surface and phytochemical composition on the preference behaviour of the insect pests. The leafhoppers, Empoasca decipiens and Empoasca decedens preferred eggplant as a host plant followed by tomato and pepper by using the three methods (leaf sample, yellow sticky traps, sweep net) during the two seasons. Meanwhile, Cicadulina chinai preferred tomato followed by eggplant and pepper by using the different methods. While, Balcutha hortensis preferred pepper followed by eggplant and tomato. On the other hand, the planthoppers, Sogatella futcifera preferred eggplant followed by pepper and tomato. Statistical analysis revealed that highly significant differences were recorded between the three host plants during the two seasons according to the average number of different leafhoppers and planthoppers by using the three sampling methods. The insect population varied among leaf surface morphological characters. The Scanning Electron Microscope pictures revealed that, the trichome type was non-glandular in eggplant and tomato, while in pepper was hairiness. Population density exhibited significantly of trichome length on eggplant, whereas had less significantly on tomato leaves with higher hair density. Peppers, with no trichome had the lowest population of insect. Depending on the analysis of phytochemical composition of plant leaves, a highly positive correlated leafhopper and plant hoppers with higher ratios was found for the total protein, total nitrogen, α-esterase, β- esterase and Glutathione S-transferase (GST).

***Keywords**:* leafhoppers, planthoppers, tomato, pepper, eggplant, morphological characters.

INTRODUCTION

In Egypt, the solanaceous crops (i.e. tomatoes, pepper and eggplants) are the most important vegetables for the consumption and for the export market. Piercing-sucking pests are attacking these crops and causing economic losses, either directly by sucking plant juice or indirectly as vector transmitting plant viral diseases.

Several species of leafhoppers (belong to family Cicadellidae) is common and serious pests, which they both phytophagus and vectors of diseases cause a damage in plant by feeding the plant stems and leaves and attacking different vegetable crops (Watkins & Lane, 2005).

Development of resistant varieties to the insect pests is an important strategy of integrated crop management (Gaikwad *et al.,* 1991). The recognition of physical and morphological characteristics of resistant varieties may lead to introduction of resistance character in favored genotypes. The resistant genotypes had more hairs than the susceptible ones (Uthamasamy, 1985). The plant defenses can be direct or indirect, the direct ones are those in which only the plant take place in antagonistic interactions include those plant structures (the tissue hardness, pubescent, glandular and non-glandular trichomes) that serve as protection the plant against arthropod (Howe and Jander, 2018). Also, those allele chemicals contained in plant tissues exhibiting antifeedant, toxic, or repellent effects arthropods that attack such as cyanogenic glycosides, digestive enzyme inhibitors, lectins, glucosinolates, and terpenoids, alkaloids (Smith, 2010).

Trichomes are specialized epidermal cells present on plant surface, trichomes may also complement the chemical defense of a plant by possessing glands which exude terpenes, phenolic, and alkaloids, etc. Insects are forced to overcome the challenges posed by various plant surfaces, either behaviorally or morphologically adaptations, to live and reproduced plants (Southwood, 1986).

leaf features may impact the preference and performance of herbivores (Gianoli and Hannunen, 2000) and consequently affect the herbivore aggregations (Peeters, 2002). On the other hand, they can provide shelter to hide behind and find more prey or provide a more efficient path to reach prey (Dicke and Sabelis, 1988).

The present work was carried out on the leafhoppers and plant hoppers infesting solanaceous crops (e.g. tomato, pepper and eggplant) cultivated in Gharbia Governorate, during 2017 and 2018 seasons. The study

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aimed to observe the morphological diversity of trichomes and phytochemicals in cultivated crops against leaf hopper insects. In addition to, Analyzing the chemical composition of host plant leaves and its effect on the population density of the leaf hoppers and planthoppers.

MATERIALS AND METHODS

Study location and layout of the experiment

The present experiments were carried out in Zefta, Gharbia governorate on the leafhoppers and planthoppers infesting tomato, pepper and eggplant cultivated in summer plantation during two successive seasons (2017 and 2018).

The studies crops varieties seed of tomato *Lycopersican esculentum* Mill. were 086 hyprid, pepper *Capcicum annum* L. var. Mohanad, and eggplant *Solanum melongena* L. var. Dai El-Kamar. The studied crop seeds were shown in nursery on the 4th week of March for the two seasons of 2017 and 2018.

An experimental area ca. 1200 m^2 was divided into 12 plots and each plot considered a replicate with an area of 100 m^2. Each replicate consisted of seven rows, each 1 m wide and 10 m long and transplanted in the first week of May for the two seasons (2017 and 2018). For each crop, four replicates were distributed in a randomized complete block design. Normal agricultural practices without any insecticides were done throughout the whole season.

Population density

The population densities of the leafhopper and planthopper insect pests were investigated by different collecting methods:

A- Leaf sample:

The samples of plant leaves were collected during the summer season of the studied crops (e.g. tomato, pepper and eggplant) 4th weeks old after transplantation. The leaves for each host plant were picked weekly at random from three levels of upper middle and lower parts of the plants. Samples of 25 leaves for each replicate (100 leaves for each crop) were picked in tightly closed paper bags with a piece of cotton saturated with either for anesthetizing the collected insects. The bags were transferred to the laboratory in the same day for inspection by a binocular microscope. The adult and immature stages on both leaf surfaces were counted and recorded.

B- Sweep net:

The sweep net was made from the muslin cloth (30cm in diameter and 60cm in deep). Two rapid strokes of across direction were performed over the plants every two steps, the sweep net was used after the 4th week of planting. Twenty five double strokes were performed in two diameters at a cross direction in each replicate (100 double strokes for each crop). The collected insects were transferred in plastic bags containing with a piece of cotton saturated with either for anesthetizing the collected insects were transferred to the laboratory for inspection according to Hegab *et al*. (1989).

C- Sticky traps:

The traps used in this study were constructed from yellow cardboard and coated by insect adhesive (stickers), were held by small wooden stick. The traps with 10 x 20 cm to captured the highest number of the insect, the method constructed by Afsha *et al.* (2015). The traps were released every week to attract adult insects. All the traps were constructed 20 cm above the surface of plant with 4 traps for each replicate (16 traps for each crop). The traps were transferred to the laboratory and the number of the insect caught was counted and recorded.

Identification of the collected insect species

The taxonomic identification of the insect was done in Piercing and Sucking Insect Research Department, Plant Protection Research Institute.

Chemical constituents of cultivated tomato, pepper and eggplant

To explain the relationship between certain chemical constituents of tomato, pepper and eggplant and the population density of the leafhoppers, chemical analysis of different host plants were carried out on physiologically Research Department, Plant Protection Research Institute.

Plant samples were taken at random from each replicate at the start of flowering and oven dried at 60 ^oC tell constant weight. The dried plants were finally grounded and digested with mixture of per chloric acid and nitric acid to determine the total protein, carbohydrate contents, pH value, phosphorous, calcium, potassium , nitrogen, total phenolic and flavonoids contents in each host plant according to Kang *et al.* (2012).

The supernatant was immediately frozen for future enzyme activity assays Ni *et al*., (2001). The total proteins were determined by the method of Jones *et al.* (1991). Total carbohydrates were estimated in acid extract of sample by the phenol-sulphuric acid reaction of Dubois *et al*., (1956).

Total carbohydrates were extracted and prepared for assay according to Crompton and Birt (1967). The total phenolic was performed and described by kâhkônen *et al.*, (1999). Alpha esterase (α-esterase) and beta esterase (β-esterase) were determined according to Van Asperen (I962). Glutathione S-transferase (GST) catalyzes the conjugation of reduced glutathione (GSH) with 1-chloro 2, 4-dinitrobenzene (CDNB) via the -SH group of glutathione. The conjugate, S-(2,4-dinitro-phenyl)-L-glutathione could be detected and described by the method of Habig *et al*., (I974).

Morphological diversity of trichomes in cultivated crops

For each test plant, 15 fully developed fresh leaves were collected randomly,were kept in polythene covered inside ice box and brought to the laboratory for further studies. A Cork borer (0.5 cm diameter) was used to punch a disc of leaf and three such leaf discs were taken randomly from each leaf for trichome studies. Discs of leaves of all the species of crops were subjected to SEM analysis to better understand the morphological structure of different types of trichomes (length, thickness, and density of trichomes) and stomata.

The Scanning Electron Microscope for samples. Using SEM Model Quanta 250 FEG (Field Emission Gun) attached with EDX Unit (Energy Dispersive X-ray Analyses), with accelerating voltage 30 K.V., magnification14x up to 1000000 and resolution for Gun.1n) in Central Laboratories Sector, the Egyptian Mineral Resources Authority, the Ministry of Petroleum. Trichome density was measured by using the software created by Bakr (2005).

Statistical analysis

The obtained data were analyzed using one-way ANOVA (CoState), and means were compared using Duncan's Multiple Range Test (Duncan, 1955).

RESULTS AND DISCUSSION

The results illustrated in Table (1) showed the average number of the leafhoppers and planthoppers on different host plants. These numbers were estimated by the leaf sample method during the two successive seasons (2017 and 2018) in Gharbia governorate. The leafhopper *Empoasca decipiens* (Paoli) came in the first category and recorded the highest average number on the different host plants during the two seasons and presented by 85.2, 49.2 and 19.3 individuals on eggplant, tomato and pepper during the first season 2017, respectively. During the second season 2018, it represented by 106.4, 58.6, and 13.5 individuals on the three host plants, respectively. The leafhopper, *Empoasca decedens* (Poali) ranked the second class and represented by 39.7, 26.8 and 12.9 individuals in the first season and 51.6, 24.3 and 6.8 individuals in the second season 2018 on the three host plants, respectively.

On the other hand, *Balclutha hortensis* (Lindb) came in the last category and represented by 11.3, 6.2 and 18.1 individuals in the first season 2017 and 12.6, 5.8 and 19.6 individuals during the second season of 2018 on the three host plants, respectively. It can be noticed that eggplant as a host plant attracted the highest percentage of the insect pests during the two seasons (48.8 and 53.9 %) followed by tomato (31.3 and 30.3 %) and pepper attracted the lowest percentage of occurrence (19.9 and 15.8 %) by using leaf sample method, respectively.

Table 1. The average number of leafhoppers and planthoppers on different host plants by leaf sample method during 2017 and 2018 seasons in Gharbia governorate.

Insect species	Season 2017			Season 2018		
	Eggplant	Tomato	Pepper	Eggplant	Tomato	Pepper
Empoasca decipiens	85.2 a	49.2 b	19.3 c	106.4 a	58.6 b	13.5 c
Empoasca decedens	39.7 a	26.8 b	12.9 c	51.6 a	24.3 b	6.8 c
Cicadulina chinai	15.1 b	25.5 a	7.7 c	17.6 b	28.2 a	8.8 c
Balclutha hortensis	11.3 b	6.2 c	18.1 a	12.6 b	5.8 c	19.6 a
Sogatella futcifera	29.2 a	7.9 c	15.8 b	37.2 a	9.8 c	17.7 b
Total	180.5	115.6	73.8	225.4	126.7	66.4
Occurrence %	48.8	31.3	19.9	53.9	30.3	15.8

Means followed by different letters in a raw for each season are significantly different at 5% probability level

The data arranged in Table (2) showed the average number of leafhoppers and planthoppers on the different solanaceous host plants. These numbers were estimated by the yellow sticky traps during the two seasons. Also, *E. decipiens* ranked the first category and recorded the highest average number and presented by 109.4, 82.3 and 34.0 individuals in the first season and 131.7, 87.9 and 37.9 individuals in the second season on eggplant, tomato and pepper, respectively. Moreover, *E. decipiens* came in the second class and presented 56.9, 33.1, and 21.3 individuals in the first season and 52.4, 37.2, and 20.7 individuals in the second season on the three host plant, respectively. It can be noticed that eggplant attracted the highest percentage of occurrence by using tallow sticky trap method during the two seasons (45.8 and 46.1 %) followed by tomato (32.1 and 32.4 %) and pepper (22.1 and 21.5 %), respectively.

Table 2. The average number of leafhoppers and planthoppers on different host plants by yellow sticky traps method during 2017 and 2018 seasons in Gharbia governorate.

Insect species	Season 2017			Season 2018		
	Eggplant	Tomato	Pepper	Eggplant	Tomato	Pepper
Empoasca decipiens	109.4 a	82.3 b	34.0 c	131.7 a	87.6 b	37.9 c
Empoasca decedens	56.9 a	33.1 b	21.3 c	52.4 a	37.2 b	20.7 c
Cicadulina chinai	21.3 b	39.2 a	11.3 c	20.9 b	40.8 a	13.1 c
Balclutha hortensis	24.6 b	15.8 c	32.0 a	27.2 b	16.7 c	33.9 a
Sogatella futcifera	49.7 a	13.4 c	27.4 b	52.1 a	17.5 c	26.7 b
Total	261.9	183.8	126.0	284.3	199.8	132.3
Occurrence %	45.8	32.1	22.1	46.1	32.4	21.5

Means followed by different letters in a raw for each season are significantly different at 5% probability level

As shown in Table (3) the same trend of the results were recorded by using sweep net method. Data revealed that *E. decipiens* showed the highest average number followed by *E. decedens* and *E. chinai*. On the other hand, *B. hortensis* recorded the lowest average number followed by the planthopper, *Sogatella futcifera* (Horv.) during the two seasons. Moreover, by using sweep net method also eggplant attracted the highest percentage of occurrence (42.3 and 44.9 %) followed by tomato (34.0 and 34.2 %) and pepper attracted the lowest percentage (23.7 and 20.9 %) during the two seasons, respectively.

Table 3. The average number of leafhoppers and planthoppers on different host plants by sweep net method during 2017 and 2018 seasons in Gharbia governorate.

Insect species	Season 2017			Season 2018		
	Eggplant	Tomato	Pepper	Eggplant	Tomato	Pepper
Empoasca decipiens	236.2 a	168.6 b	99.2 c	291.7 a	173.0 b	63.7 c
Empoasca decedens	166.4 a	91.3 b	51.6 c	162.5 a	99.1 b	49.3 c
Cicadulina chinai	87.0 b	173.1 a	37.9 c	92.4 b	185.6 a	41.6 c
Balclutha hortensis	39.2 b	37.3 b	93.7 a	45.1 b	38.4 b	97.8 c
Sogatella futcifera	113.7 a	46.3 c	77.3 b	124.1 a	49.5 c	81.2 c
Total	642.5	516.6	359.7	715.8	545.6	333.6
Occurrence %	42.3	34.0	23.7	44.9	34.2	20.9

Means followed by different letters in a raw for each season are significantly different at 5% probability level

Results presented in Table (4) revealed to the total average number of the leafhoppers and planthoppers and the occurrence percentage by different methods during the two seasons. Eggplant as a host plant attracted the highest numbers by using the three methods during the two seasons followed by tomato and pepper. Moreover, sweep net method collected the highest percentage of occurrence during the two seasons (61.8 and 60.6 %) followed by yellow sticky traps (23.2 and 23.5 %) and the leaf sample method collected the lowest percentage of occurrence (15.0 and 15.9 %).

Table 4. The total average number of leafhoppers and planthoppers as well as the occurrence percentage collected by the different methods during seasons 2017 and 2018 in Gharbia governorate.

Insect species	Season 2017			Season 2018		
	Leaf samples	Sticky traps	Sweep net	Leaf samples	Sticky traps	Sweep net
Egg plant	180.5	261.9	642.5	225.4	284.3	715.8
Tomato	115.6	183.8	516.6	126.7	199.8	545.6
Pepper	73.8	126.0	359.7	66.4	132.3	333.6
Total	369.9	571.7	1518.8	418.5	616.4	1595.0
Occurrence %	15.0	23.2	61.8	15.9	23.5	60.6

As a conclusion, data arranged in Tables (1-4) revealed that the leafhoppers, *E. decipiens* and *E. decedens* preferred eggplant as a host plant followed by tomato and pepper by using the three methods (leaf sample, yellow sticky traps, sweep net) during the two seasons. Meanwhile, *Cicadulina chinai* (Ghauri) preferred tomato followed by eggplant and pepper by using the different methods. While, *B. hortensis* preferred pepper followed by eggplant and tomato. On the other hand, the planthoppers, *S. futcifera* preferred eggplant followed by pepper and tomato. Statistical analysis revealed that highly significant differences were recorded between the three host plants during the two seasons according to the average number of different leafhoppers and planthoppers by using the three sampling methods. Depending on the percentage of insect pest occurrence, sweep net recorded the highest percentage followed by yellow sticky traps and the lowest percentage of occurrence was recorded by leaf sample method. Similar results were obtained by El-Gindy (2003), Hashem et al., (2009) and Nabil et al. (2015).

Effect of plant leaf surface morphology and phytochemicals analysis on population density of the insect pests

This study was conducted to investigate the relationship between plant leaf surface morphology and certain chemical constituents of tomato, pepper and eggplant with leafhoppers infestation.

Data in Table (5) and Fig. (1) showed that, variation in physical structure of leaf surfaces of eggplant had a trichome branched stellar ranging from 5-9, with pointed tip approximately 283.97µM in length and density was 9 in mm^2, while trichome thickness was 16.9 µM.

Whereas, tomato trichomes were individuals in close distance of each other with thickness 21.767 µM and 106 µM in length, where the density was 87.5 in mm^2. Regarding to the obtained results, the pepper leaf surface has no trichomes (hairiness). In contrast, there was a relationships between the physical structure of the plant host and the population densities of insect pests. Whereas, obtained results showed that, the studied insect pests were highly recorded in eggplant followed by tomato and was lowest in pepper. This results was similar to Naqvi *et al.* (2008), he stated that, jassid didn't preferred hairiness or even long hairs on the leaf surface indicating that there might be oviposition hindrances. The above mentioned results were declared by many scientists, Leite et *al*. (2001) found that, leaf hopper preferred the host plant according to its trichome density to find a suitable oviposition site so the absence of trichomes on pepper leaf surface made it less infected with insects than other plants. Also, higher tomato trichome density can preclude natural enemies from colonized this plant. On the other side, Clark and Messina (1998) and Tianr *et al.* (2012) showed that the density of trichome can affect the movement of parasitoids and small predators especially at first contact. It can be concluded that, Hair-like physical structures on plant surface (Plant's trichomes) may help plants to defend themselves against herbivores (Moles and Westoby, 2000; Kennedy, 2003) by impeding insect walking, feeding, and oviposition. Muhammad *et al*. (2016) concluded that, the jassid not preferring hairiness or even long hairs on the leaf surface indicating that there may be oviposition hindrances observed by the leafhopper. As similar type of results were observed by Naqvi *et al*. (2008). Whereas, Marta Álvarez (2015) showed that trichomes present in wild tomato species conferred resistance to many taxa that may constitute pests, although researches on tomato have been focused on Hemiptera.

Table 5. Variation in physical structure of leaf surfaces of different vegetable plant hosts

Plant Species	Trichome type	Trichome length µm	Trichome thickness µm	Stoma µm		Trichome density / mm^2
		Mean	Mean	Width	Length	Mean
Eggplant	Non- glandular	283.970	16.9	4.286	8.489	9
Tomato		106	21.767	2.304	19.69	87.5
Pepper	0	0	0	7.492	18.2625	0

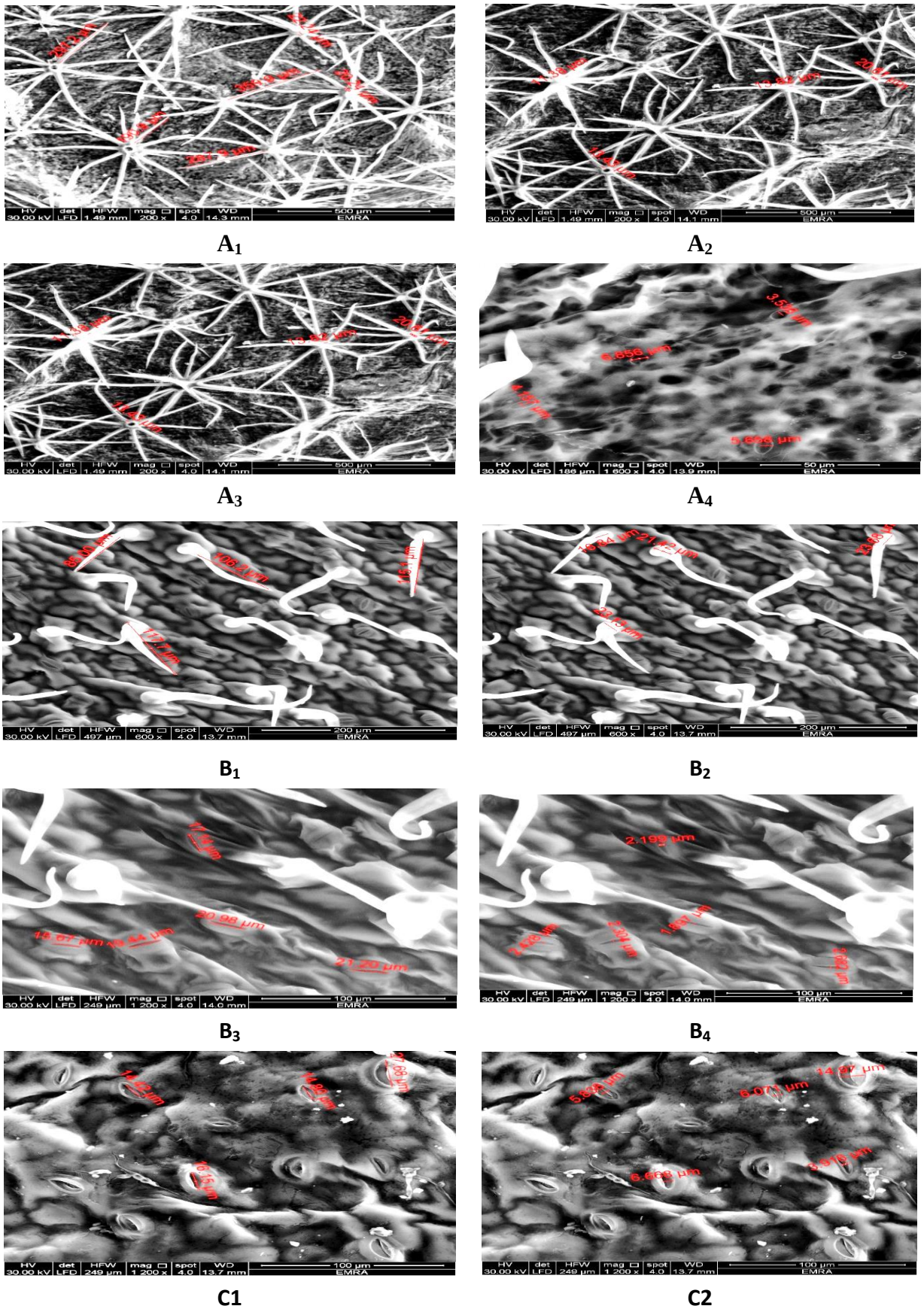

Figure 1.Plant leaf surface morphology: Eggplant (trichome length (A1), trichome thickness (A2), stoma length (A3), stoma width (A4)), Tomato (trichome length (B1), trichome thickness (B2), stoma length (B3), stoma width (B4)), and Pepper (stoma length (C1), stoma width (C2)).

The effect of the chemical components of the different host plants on population density of the studied insect pests was observed in the Table (6). There were a highly positive correlation of leafhopper occurrence with higher ratios of the total protein, total nitrogen, α-esterase, β- esterase and Glutathione S-transferase (GST). However, the leafhoppers and planthoppers were not related to the total carbohydrate. While, there was a negative relation between the insect infestation and the contents of phenols, potassium, phosphorus and the plant soap acidity (pH). The related results to the relation between total carbohydrate and insect infestation, it is concluded that, the high infestation of insect in eggplant decreased the amount of carbohydrate in the infested plant.

In the context of the obtained results, Bayoumy *et al.* (2017) indicated that, the numbers of some piercing-sucking insects were positively correlated with the higher ratios of P and K in eggplant leaves and lowest density of insects in sweet pepper, it was due to the highest K levels that can minimize the magnitude of cumulated amino acids. The similar results were obtained by Leite *et al.* (2001) revealed that, eggplant was the most suitable host for some piercing-sucking insects. According to Jansson and Ekbom (2002), there was positive relation between some piercing-sucking insect infestation in the higher ratios of total protein, total carbohydrates, Nitrogen, and in lower ratio of K and P the high level of K.

Saleh and El-Shareef (2010) revealed that, with increasing the phenol and pH value led to negative relation with insect infestation.

Table 6. Phytochemicals analysis (%) of the different host plants.

Chemical constituents	Host plants		
	Eggplant	**Tomato**	**Pepper**
Total carbohydrate	87.7 ± 2.80 b	115.7 ± 4.8 a	121.6 ± 8.3 a
Total protein	44.9 ± 0.90 a	36.4 ± 0.4 b	30.8 ± 0.4 c
Total phenolic	2.3 ± 0.10 b	2.1 ± 0.1 b	3.4 ± 0.1 a
α-esterase	202.3 ± 3.40 a	158.0 ± 4.0 b	137.3 ± 1.8 c
β- esterase	245.6 ± 11.5 a	201.3 ± 3.7 b	150.0 ± 3.5 c
GST	64.5 ± 1.30 a	55.3 ± 2.0 b	48.3 ± 0.9 c
Nitrogen (N)	7.1 ± 0.10 a	5.9 ± 0.1 b	5.2 ± 0.1 c
Potassium (K)	512.0 ± 5.70 c	671 ± 6.4 b	865 ± 30.1 a
Phosphorus (P)	2.4 ± 0.05 c	3.0 ± 0.03 a	2.7 ± 0.07 b
Calcium (Ca)	0.3 ± 0.02 c	1.5 ± 0.08 b	3.9 ± 0.21 a
pH	3.8	3.9	4.5

Means followed by different letters in a raw for each season are significantly different at 5% probability level

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تأثير الاختلاف المورفولوجي لسطح الورقة والمكونات الكيميائية علي سلوك تفضيل نطاطات الأوراق ونطاطات النبات لبعض محاصيل العائلة الباذنجانية

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أجريت التجارب الحالية لدراسة تأثير العوائل النباتية المختلفة من العائلة الباذنجانية علي كثافة التعداد لنطاطات الأوراق ونطاطات النباتات طبقا للاختلاف المورفولوجي لسطح الورقة والمكونات الكيميائية وذلك علي سلوك التفضيل الغذائي لهذه الافات الحشرية وذلك خلال موسمين متتاليين 2017، 2018 في محافظة الغربية. اظهرت النتائج ان نطاطات الاوراق *Empoasca decipiens* و *Empoasca decedens* تفضل نباتات الباذنجان كعوائل نباتية يليها الطماطم والفلفل وذلك باستعمال الثلاث طرق لجمع العينات وهي عينات الأوراق، المصائد اللاصقة الصفراء، وشبكة الجمع خلال موسمي الدراسة. بينما وجد نطاط الاوراق *Cicadulina chinai* يفضل نباتات الطماطم يليها الباذنجان ثم الفلفل باستخدام طرق تقدير التعداد المختلفة. وقد وجد ان *Balclutha hortensis* يفضل نباتات الفلفل يليها الباذنجان ثم الطماطم. من ناحية أخري وجد أن نطاط النباتات *Sogatella futcifera* يفضل نباتات الباذنجان يليها الفلفل ثم الطماطم. التحليل الاحصائي أشار إلي أن هناك اختلاف عالي المعنوية بين العوائل النباتية الثلاثة خلال موسمي الدراسة طبقا لمتوسط تعداد نطاطات الأوراق ونطاطات النباتات بواسطة الثلاث طرق لتقدير التعداد. أوضحت النتائج أن اعلي نسبة تواجد للآفات الحشرية سجلت باستخدام شبكة الجمع يليها المصائد اللاصقة الصفراء ثم عينات الأوراق حيث سجلت اقل نسبة. وجد ان تعداد الحشرات يختلف طبقا للصفات المورفولوجية لسطح الورقة، حيث أوضحت صور الميكرسكوب الاليكتروني وجود أنواع من الشعيرات غير الغدية في الباذنجان والطماطم بينما نباتات الفلفل لا تحتوي علي مثل هذه الشعيرات. وجد أن كثافة التعداد جذبت لطول الشعيرات في أوراق الباذنجان، بينما كان اقل معنوية بالنسبة لكثافة الشعيرات في أوراق الطماطم، أما أوراق الفلفل بدون شعيرات جذبت اقل تعداد من الحشرات. بالنسبة للتحليل الكيماوي لمكونات الأوراق، وجد أن هناك ارتباط عالي المعنوية بين نطاطات الأوراق ونطاطات النباتات مع النسبة العالية للبروتين الكلي والنتروجين الكلي وأنزيم ألفا استيريز وبيتا استريز و وانزيم الأكسدة "الجلوتاثيون أس-ترانسفيراز" . كما وجد أيضا أن كثافة التعداد تتأثر بنسبة الكربوهيدرات الكلية في أوراق الباذنجان بينما وجد ارتباط سالب بين تعداد الحشرات ومحتوي الأوراق من الفينولات والبوتاسيوم والفسفور ودرجة الحموضة، حيث كانت تعداد الحشرات عالي مع انخفاض هذه المكونات في أوراق الباذنجان يليها الطماطم ثم الفلفل. هذه الدراسة أوضحت أن تطور المقاومة في العائل النباتي ضد الآفات الحشرية تكون إستراتيجية مهمة في برامج المكافحة المتكاملة للآفات وان التعرف علي الصفات المورفولوجية والكيماوية ربما تؤدي إلي تطور صفة المقاومة في الأنماط الوراثية النباتية المقبولة.