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Biochemical and Morphological Characteristics of Leaves and their Relation with Infestation of Selective Piercing-Sucking Pests on Cucumber (*Cucumis sativus*), Okra (*Abelmoschus esculentus*) and Eggplant (*Solanum melongena*)

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Abstract

The present study was undertaken on cucumber (*Cucumis sativus* L.), okra (*Abelmoschus esculentus* L.) and eggplant (*Solanum melongena* L.) to investigate the effect of some leaf chemical and morphological characteristics on the infestation of spider mite (*Tetranychus urticae* Koch), aphid (*Aphis* spp.), whitefly (*Bemisia tabaci* Gen.) and thrips (*Thrips tabaci* L.). The appropriate chemical analysis methods have been used to estimate the leaf chemical constituents. The morphological traits of the leaf surface were determined using a Scanning Electron Microscopy. Our data indicated that the aphid population negatively related with presence of high phenolic compounds in eggplant. Positive correlation was found between population of *T. urticae*, *B. tabaci* and *T. tabaci*, and between lowest ratios of each of phenols, P and K. Furthermore, the lowest numbers of *T. urticae* and *T. tabaci* were recorded on okra plant with the highest value of chlorophyll. The lowest content of proteins negatively correlated with the pests population on cucumber plant. The results showed that the highest ratios of trichome density, trichome length and stomatal density were recorded in cucumber, which harbored the higher densities of all tested pests. We concluded that the cucumber exhibited high susceptibility for infestation of these pests. Okra was highly resistant against infestation of spider mite and thrips. Eggplant showed high resistance against infestation of aphids and thrips compared to the cucumber. Our study suggested that leaf chemical and morphological characteristics can affect the susceptibility or tolerance of the plant against pest infestation. © 2024 Friends Science Publishers

Keywords: Phytochemical constituents; Leaf surface traits; Plant defense; Sucking pests; Infestation density

Introduction

Cucumber (*Cucumis sativus* L.) is a widespread vegetable crop worldwide (Wehner and Guner 2004). It is grown in Egypt as a summer crop in the open field during March to September (Alkharpotly *et al*. 2019). Cucumber is a major vegetable crop with important economic and biological value (Che and Zhang 2019). Eggplant (*Solanum melongena* L.) is a warm-weather crop and one of the most prevalent vegetable crops worldwide, especially in Africa, subtropical regions, Southeast Asia and the Middle East (FAO 2017; Chapman 2019). Eggplant fruit is a rich source of numerous nutrients, carbohydrates, dietary fiber, protein, vitamins, essential minerals and some bioactive compounds (Oladosu *et al*. 2021; Mahamad *et al*. 2022). Okra *Abelmoschus esculentus* L. (Moench.) is one of the most common and popular summer vegetable crops in Egypt due to its delicious taste and high nutritional value (Abdel-Fattah *et al*. 2020). Okra is cultivated in tropical, subtropical, and warm temperate climates in different countries (Durazzo *et al*. 2018; Islam 2019). Okra fruit has a high moisture content, rich in nutrients, and is important source of vitamins, minerals, proteins, carbohydrates, and lipids (Al-Shawi *et al*. 2020; Dantas *et al*. 2021). The total cultivated area in Egypt reached 24184, 63233 and 9408 hectares (ha) in 2022 producing 593901, 1972593 and 118055 tons with an average of 24.56, 31.18 and 12.55 tons/ha for cucumber, eggplant and okra respectively, (Anonymous 2023).

Sucking insect pests are most notorious group of pests for agricultural crops. Unlike most chewing insect pests, sucking insect pests cause more severe damage to the crops (Yadav and Rathee 2020). Sucking insect pests such as aphids, whitefly and thrips are common sucking pests of vegetables. Extensive feeding by these pests not only results

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in plant damage and yield reduction, but it also predisposes plants to various pathogens that increase the severity of damage and crop losses (Khan *et al*. 2020; Rani *et al*. 2020).

The spider mite, *Tetranychus urticae* Koch is considered in particular one of the most dangerous pests in different regions of the world (Grbić *et al*. 2011; Abad *et al*. 2019) and affects a very wide range of plants. It is particularly predominant in intensive agricultural systems and affects crops by its direct feeding (Gorman *et al*. 2001). The intensive feeding of mites combined with a rapid increase in population size has a negative effect on the physiology of the whole plant, as well as the yield and quality (Archer and Bynum 1993; Suekane *et al*. 2012). The increase in *T. urticae* population and its feeding cause leaf malformation and a web formation occurs on the plant apex (Jakubowska *et al*. 2022). It causes significant losses in the yield of many important economic crops (Salman 2007). Sucking pests are causing serious damage to agricultural and horticultural crops by reducing their quantity and quality (Ward *et al*. 2002; Hassan 2009; Rani *et al*. 2020).

Plants differ in their degree of susceptibility to infestation and level of damage, and this is due to many various factors, including the morphological and chemical characteristics of the plant. Plant direct defense against insect herbivores is involved both physical and chemical barriers which hinder insect herbivore's development and reproduction (Tibebu 2018). Plants have a variety of defense mechanisms to defend themselves from pest attack, and these include structural and chemical defenses (Pedras and Yaya 2015; Lev-Yadun 2016). Plants also use several morphological and biochemical defenses to withstand insect herbivores (War *et al*. 2020). Besides, these characteristics are also crucial for crop yield and quality, which are fundamental criteria in selecting resistant varieties (Amin *et al*. 2016).

The crops have intrinsic chemical defenses to protect themselves from pests. Improving the capabilities of these defensive factors could have the potential to help improve agricultural pest management (Yactayo-Chang *et al*. 2020).

Plant morphological traits such as trichomes, spines and cell wall are the first defense line against piercing-sucking insect pests and have a substantial role in plant resistance to phytophages (Hanley *et al.* 2007; He *et al*. 2011; War *et al*. 2012). Trichomes play a principal role in plant defense against many plant pests, and that include both toxic and deterrent effects (Chamarthi *et al.* 2010).

Leaf characteristics may affect the preference and activity of herbivores (Gianoli and Hannunen 2000) and then impact the herbivore assemblages (Peeters 2002). Because there are many types of hairs on different plant species, their defensive roles differ against plant-feeding pests (Steinite and Ievinsh 2003).

Plant biochemical defense mechanisms against herbivores are a wide range, highly dynamic, and affect directly and indirectly (War *et al*. 2012). Defense mechanism and nutritional factor of plant often influence the host choice and potential behavior of herbivores (Bernays and Chapman 1994).

Therefore, the main purpose of this work was to investigate the impact of chemical content and the morphological characteristics of the leaves against infestation of two spotted spider mite, aphids, whitefly and thrips on cucumber, eggplant and okra plants. The population dynamic of these pests was also monitored.

Materials and Methods

The field studies

The field experiment was carried out at Ibshway, Fayoum Governorate, Egypt during summer 2021. Three different vegetable crops: *C. sativus* L. (Cucurbitaceae), *A. esculentus* L. (Malvaceae) and *S. melongena* L. (Solanaceae) were chosen for this study.

Plant cultivation: The growing season extended from February to June 2021. All cultivars were sown on the same date with the same surrounding environmental conditions. The three crops were cultivated in late February in an area around 0.20 ha divided into three plots of about 700 m^2/crop, and each plot divided into three equal replicates using Randomized Complete Block Design. Normal agricultural practices were followed with no pesticides applied in the entire experimental area throughout the study period.

Population of sucking pests: The occurrence of the phytophagous mite (*T. urticae* Koch (Tetranychidae), aphids (Aphididae), whitefly {*Bemisia tabaci* Genn. (Aleyrodidae)} and thrips {*Thrips tabaci* L. (Thripidae)} were investigated under open field conditions.

The investigation started after three weeks from planting date (February 24, 2021). Randomly 25 leaves per replicate were taken weekly from the different plant portions representing all cultivated area for each crop. The picked leaves were held in separate sample bag which were properly labeled and individually examined in the laboratory under a binocular. The number of spider mite was counted in 2.5cm^2 area on the leaf lower surface according to Kumar *et al*. (2015), while the number of aphids, whitefly and thrips was counted in the whole leaf surface as described by Poe (1980).

Laboratory studies

Chemical analysis of plant leaves to determine certain biochemical constituents: Non-infested leaf samples of cucumber, okra and eggplant were taken and transferred to the Research Park, Faculty of Agriculture, Cairo University for chemical analysis. Some chemical components of leaves were determined as follows: Total carbohydrates were extracted and estimated according to (Kostas *et al*. 2016). Total protein was calorically examined by ninhydrin reagent as described by (Lee and Takabashi 1966). Total phenols were assessed by Folin-Ciocateu method as modulated by

(Singleton and Rossi 1965). Total chlorophyll in leaf extracts was determined colorimetrically as defined by Holden (1965).

Macro-elements NPK analysis: Plant macronutrients NPK were estimated in the analysis laboratory of the Soil, Water and Environment Research Institute (SWERI), Agricultural Research Center (ARC), Giza, Egypt.

Total nitrogen was determined using Micro-Kjeldahl method according to (A.O.A.C. 1970). Vanadomolybdate yellow method spectrophotometrically was used to estimate Phosphorus content in plant sample as stated by (Jackson 1973). A flame photometer was used to measure potassium (K) content in plant leaf sample as applied by (Jackson 1973).

Scanning Electron Microscopy (SEM) of plant leaf surface: Leaf samples of cucumber, okra and eggplant plants were collected and scanned using a Scanning Electron Microscopy (SEM) (Joel JSM. 5200LA) at the Applied Center for Entomonematodes (ACE), Faculty of Agriculture, Cairo University, Egypt. SEM technique was used as described in previous studies (Karnowsky 1965; Fischer *et al.* 2012). Trichome and stomata measurements were determined with the AnalySIS®3.2 software program for image analysis (Olympus-Hamburg, Germany) and their frequency (n/mm^2).

Statistical analysis

InfoStat software package was used to detect significant differences. Mean values of all studied variables were separated by Duncan's multiple range test (Duncan 1955) ($P \leq 0.05$). The significance was determined using Pearson's correlation coefficient at $P = 0.05$.

Results

Population dynamics of the main sucking pests

The data indicated the population dynamics of certain sucking pests (spider mite, aphid, whitefly and thrips) on three vegetable crops (cucumber, okra and eggplant) during 2021 season (Table 1).

Population of *T. urticae*: The population of *T. urticae* was observed on cucumber throughout the growing season. The population gradually increased in high numbers to reach the peak at the end of the season (June 9) with 852.0 individuals and 3325.7 eggs. The total number reached 1771.3 individuals and 10770.0 eggs.

In contrast to infestation in cucumber, *T. urticae* was recorded in eggplant and okra plants with low numbers. The total number reached 116.0 individuals and 458.7 eggs in eggplant, and less numbers were observed on okra leaves in a few samples throughout the season and the total number recorded was 31.3 individuals and 78.3 eggs (Table 1).

Population of aphids: The population of aphids was observed in cucumber at the beginning of the season on the 17th of March 34.7 individuals and reached the peak 136.3 individuals at the end of March and then the population declined to reach 5.3 individuals in mid of April. Thereafter the population increased to record 115.0 individuals at the end of April and then gradually reduced to 9.0 individuals at the end of the season. The total number recorded was 676.0 individuals/season.

In okra, aphids observed at the end of March with 5.7 individuals and progressively increased to reach the peak 177.7 individuals on the 5th of May, then greatly decreased to record 2.0 individuals in the 3rd week of May. After that significantly increased to 104.3 individuals at the end of the season. The total number reached 624.7 individuals/season. In contrast, only few numbers of aphids were recorded in eggplant throughout the season with total number of 35.0 individuals/season (Table 1).

Population of whitefly: The infestation of *B. tabaci* was observed throughout the season in the three crops. High numbers of *B. tabaci* were recorded in cucumber throughout the season, the highest number was registered in the 2nd week of May 909.0 nymphs. The total number reached 5216.7 nymph/season. In contrary to the population of whitefly in cucumber, low total numbers were recorded 552.0 and 458.3 nymphs/season in eggplant and okra, respectively (Table 1).

Population of thrips: *T. tabaci* was recorded with high numbers in cucumber at the beginning of the season and recorded highest number 309.0 individuals on the 24th of March, then population gradually decreased to record 26.0 individuals in mid April. Thereafter the population increased with fluctuating numbers to reach 278.0 individuals at the end of the season. The total number of *T. tabaci* recorded was 1707.0 individuals/season. Contrarily, few total numbers were recorded in eggplant and okra (44.0 and 11.0 individuals/season, respectively) (Table 1).

The relation between population of the certain piercing-sucking pests and some leaf chemical characteristics

The data in Table 2 reveal the relationship between the pest population density and the plant type. Table 3 shows the relationship among the biochemical constituents (total chlorophyll mg/kg, total protein%, total carbohydrates g/100 g, total phenols g/100 g, N%, P% and K%) and plant type. These results are described as follows:

The mean number of *T. urticae* (mobile stages & eggs) on cucumber 1771.33 and 10770.00 was significantly higher than those recorded in eggplant and okra 116.00 & 458.67 and 31.33 & 78.33, respectively (Table 2). Highly negative correlation (r = -0.60 and -0.95) was found between *T. urticae* (mobile stages and eggs) and the highest value of total chlorophyll 46.72 mg/kg in okra, while positive relation (0.75 and 0.58) was found in cucumber (Table 4). Non-significant positive correlation (0.01 and 0.23) was found between *T. urticae* and the ratio of total carbohydrates in cucumber, whilst this correlation was negative (-0.63 and

Table 1: Mean number and population fluctuation of certain sucking pests on cucumber, okra and eggplant plants during Summer season, 2021

Crop	Pest		Sampling date													Total	Average
			17/03/2021	24/03/2021	31/03/2021	07/04/2021	14/04/2021	21/04/2021	28/04/2021	05/05/2021	12/05/2021	19/05/2021	26/05/2021	02/06/2021	09/06/2021		
			No. of pest/25 leaves														
Cucumber	*T. urticae*	M. stages	8.3	5.0	36.0	25.0	7.3	17.0	61.7	30.0	84.7	105.0	124.0	415.3	852.0	1771.33	136.26
		Eggs	25.7	32.3	112.0	171.7	47.3	136.7	290.3	222.0	847.7	1173.7	1958.0	2427.0	3325.7	10770.00	828.46
	Aphid sp.		34.7	5.3	136.3	34.0	5.3	33.7	115.0	112.7	45.7	66.3	53.0	25.0	9.0	676.00	52.00
	B. tabaci		39.0	158.0	115.3	123.7	144.0	107.0	279.0	333.3	909.0	632.7	783.3	894.0	698.3	5216.67	401.28
	T. tabaci		146.0	309.0	149.7	106.7	26.0	27.3	76.3	63.0	168.3	70.3	162.7	123.7	278.0	1707.00	131.31
Okra	*T. urticae*	M. stages	1.7	1.0	6.3	6.0	0.7	1.7	1.0	4.7	0.0	1.3	0.7	3.3	3.0	31.33	2.41
		Eggs	2.3	5.7	16.7	11.7	0.0	0.7	4.7	26.0	0.0	3.7	1.0	5.0	1.0	78.33	6.03
	Aphid sp.		0.7	0.0	5.7	3.0	14.0	24.0	139.0	177.7	6.0	2.0	85.3	63.0	104.3	624.67	48.05
	B. tabaci		25.7	23.0	32.0	43.3	12.0	11.0	45.3	63.0	36.7	51.7	48.0	35.3	31.3	458.33	35.26
	T. tabaci		0.3	2.7	0.7	0.7	0.3	2.0	0.0	1.0	1.0	0.7	0.7	0.0	1.0	11.00	0.85
Eggplant	*T. urticae*	M. stages	2.0	12.0	10.3	4.7	14.0	9.0	8.7	1.0	5.7	4.3	5.3	9.3	29.7	116.00	8.92
		Eggs	7.3	20.3	42.0	10.7	62.7	57.0	17.7	0.7	20.3	23.0	19.0	35.0	143.0	458.67	35.28
	Aphid sp.		0.3	7.3	1.7	0.7	0.3	5.3	1.0	5.3	7.7	4.0	0.0	0.0	1.3	35.00	2.69
	B. tabaci		23.0	67.3	60.0	76.0	67.3	47.7	23.7	24.0	55.3	35.3	25.3	34.0	13.0	552.00	42.46
	T. tabaci		2.0	3.7	11.7	1.7	3.7	2.7	3.0	1.3	2.7	3.3	2.3	4.7	1.3	44.00	3.38

Table 2: Mean ± SD of certain sucking pests in cucumber, okra and eggplant plants during 2021 season

Plant sample	Pest species				
	T. urticae		Aphid spp	*B. tabaci*	*T. tabaci*
	Individuals	Eggs			
Cucumber	1771.33a ± 197.64	10770.0a ± 812.62	676.00a ± 90.70	5216.67a ± 355.17	1707.00a ± 218.17
Okra	31.33b ± 6.66	78.33b ±10.50	624.67b ± 57.57	458.33b ± 75.66	11.00b ± 5.57
Eggplant	116.00b ± 27.62	458.67b ± 66.88	35.00b ± 7.00	552.00b ± 77.70	44.00b ± 13.45
ANOVA 5%	**	**	**	**	**

Means with the same letter not significant ($P \leq 0.05$) using Duncan Multiple Range Test
(**) highly significant

Table 3: Mean ± SD of some leaf chemical characteristics in cucumber, okra and eggplant plants during 2021 season

Plant sample	Leaf chemical characteristics						
	Total chlorophyll mg/Kg	Total protein%	Total carbohydrates g/100 g	Total phenols g/100 g	N%	P%	K%
Cucumber	32.26b ± 0.44	11.11c ± 0.11	3.79c ± 0.14	0.04b ± 0.005	2.12a ± 0.04	0.34a ± 0.04	1.09a ± 0.03
Okra	46.72a ± 0.42	17.33b ± 0.12	4.82b ± 0.17	0.03c ± 0.004	3.23b ± 0.08	0.23b ± 0.04	0.83c ± 0.05
Eggplant	31.54b ± 0.46	19.24a ± 0.16	8.10a ± 0.11	0.06a ± 0.003	3.79c ± 0.19	0.27ab ± 0.02	1.62b ± 0.05
ANOVA 5%	**	**	**	**	**	ns	**

Means with the different letters are significant ($P \leq 0.05$) using Duncan Multiple Range Test
(**) highly significant, (ns) no significant

-0.37) in eggplant. Otherwise, highly negative relation (-0.85 and -0.72) and (-98 and -99) was recorded with P 0.34, 0.27 & 0.23% in cucumber and eggplant, respectively, however this correlation was positive (0.16 and 0.99) in okra. Furthermore, the population of *T. urticae* (moving stages) was negatively correlated (-0.80 and -0.50) with the ratios of K and N 0.83 and 3.23% in okra respectively, but this correlation was positive (0.30 and 0.65) with eggs of *T. urticae*.

The lowest mean number of aphids recorded with eggplant 35.0 that positively correlated (0.10) with the lowest value of total chlorophyll 31.54 mg/Kg. Highly significant negative correlation (-0.95 and -1.00) was found between the population of aphids and the ratios of total protein 11.11 and 19.24% in cucumber and eggplant respectively, while the population was positively correlated (0.25) with the total protein 17.33% in okra. For the correlation between the aphid population and total carbohydrates 4.82, 8.10 and 3.79 g/100 g was negative (-0.51 and -0.11) in okra and eggplant, however was positive (0.65) in cucumber, respectively (Tables 3 and 4). Highly significant positive correlation (0.94 and 0.70) was reported between the aphid population and the total phenols 0.03 and 0.04 g/100 g in okra and cucumber, respectively. Correspondingly, a highly significant negative correlation (-0.97) was investigated with the highest value of total phenols 0.06 g/100 g in eggplant. On the other hand, strong negative correlation was found between the aphid population and the ratios of N, P and K (-0.84, -0.31 and -1.00) and (-1.00, -0.93 and -0.65) in cucumber and eggplant, respectively. On contrast, positive correlation with N, P and K (0.89, 0.39 and 1.00) was registered in okra,

Table 4: The correlation between the pest population and leaf chemical and morphological characteristics in cucumber, okra and eggplant plants

Plant	Cucumber					Okra					Eggplant				
Pest	*T. urticae*		Aphid sp.	*B. tabaci*	*T. tabaci*	*T. urticae*		Aphid sp.	*B. tabaci*	*T. tabaci*	*T. urticae*		Aphid sp.	*B. tabaci*	*T. tabaci*
Leaf characteristic	Mobile stages	Eggs				Mobile stages	Eggs				Mobile stages	Eggs			
Total carbohydrates	+ 0.01	+0.23	+0.65	+0.36	+0.82	−0.02	−0.95	−0.51	−0.67	+0.60	−0.63	−0.37	−0.11	+0.13	−0.50
Total phenols	+0.07	+0.29	+0.70	+0.42	+0.85	−0.61	+0.55	+0.94	+1.00	−0.97	−0.67	−0.86	−0.97	−1.00	−0.78
Total chlorophyll	+0.75	+0.58	+0.14	+0.47	−0.10	−0.60	−0.95	+0.09	−0.24	+0.02	+0.62	+0.35	+0.10	−0.15	+0.48
Total protein	−0.52	−0.70	−0.95	−0.79	−1.00	+0.30	+1.00	+0.25	+0.56	−0.36	−0.80	−0.94	−1.00	−0.99	−0.89
N	−0.29	−0.49	−0.84	−0.60	−0.95	−0.50	+0.65	+0.89	+0.99	−0.93	−0.79	−0.94	−1.00	−0.99	−0.88
P	−0.85	−0.72	−0.31	−0.62	−0.07	+0.16	+0.99	+0.39	+0.67	−0.49	−0.98	−0.99	−0.93	−0.81	−1.00
K	−0.73	−0.86	−1.00	−0.92	−0.98	−0.80	+0.30	+1.00	+0.97	−1.00	−0.96	−0.83	−0.65	−0.45	−0.90
Trichome density	+0.92	+0.98	+0.96	+1.00	+0.86	−0.98	−0.52	+0.71	+0.44	−0.63	+1.00	+0.92	+0.79	+0.62	+0.97
Trichome length	−0.37	−0.15	+0.32	−0.02	+0.54	−0.97	−0.09	+0.95	+0.80	−0.91	+0.57	+0.30	+0.04	−0.21	+0.43
Trichome thickness	+0.08	−0.14	−0.58	−0.27	−0.76	−0.31	+0.80	+0.77	+0.93	−0.83	−0.77	−0.93	−0.99	−0.99	−0.86
Stomatal density	−0.12	+0.11	+0.56	+0.24	+0.74	+0.22	−0.85	−0.70	−0.90	+0.78	+0.73	+0.49	+0.25	+0.01	+0.61
Stomatal aperture area	−0.77	−0.89	−1.00	−0.95	−0.97	+0.36	+1.00	+0.19	+0.50	−0.30	−0.06	+0.25	+0.49	+0.69	+0.11
Stomatal dimension length	+0.97	+0.89	+0.58	+0.82	+0.37	−0.74	−0.88	+0.27	−0.06	−0.16	+0.11	−0.20	−0.44	−0.65	−0.05
Stomatal dimension width	−0.10	−0.32	−0.72	−0.44	−0.87	+0.22	−0.85	−0.70	−0.90	+0.78	−0.94	−1.00	−0.98	−0.89	−0.98

Correlation coefficient: (+) positive correlation; (-) negative correlation

respectively (Table 4).

The *B. tabaci* infestation was observably higher in cucumber with mean number 5216.67 than in eggplant and okra 552.00 & 458.33, respectively (Table 1). A positive relationship (0.36 & 0.13) was found between *B. tabaci* and the value of total carbohydrates in cucumber and eggplant respectively, while this relation was negative (-0.76) in okra (Table 4).

Negative relation (-0.24 & -0.15) was found between *B. tabaci* and the total chlorophyll in okra and eggplant, respectively, however this relation was positive (0.47) in cucumber. Similarly, considerable negative relationship was observed with N, P and K (-0.60, -0.62 & -0.92) and (-0.99, -0.81 & -0.45) in cucumber and eggplant, respectively. On contrary, this relation was highly positive with N, P and K (0.99, 0.67 & 0.97) in okra, respectively (Table 4).

The correlation between *T. tabaci* population and the values of each of total protein, carbohydrates, phenols, N, P and K was negative (-0.89, -0.50, -0.78, -0.88, -1.00, and -0.90), while was positive (0.48) with total chlorophyll in eggplant, respectively. Also in cucumber, negative relationship was found with protein, N, P, K and chlorophyll (-1.00, -0.95, -0.07, -0.98 and -0.10), but was positive with carbohydrates and phenols (0.82 and 0.85), respectively. Likewise, negative relation was obtained in okra with the ratios of protein, phenols, N, P and K (-0.36, -0.97, -0.93, -0.49 and -1.00), whilst was positive with carbohydrates and chlorophyll (0.60 and 0.02), respectively (Table 4).

The relation between population of the certain piercing-sucking pests and some leaf morphological characters

The relation between the population of piercing-sucking pests and certain leaf morphological traits (trichomes and stomata) is elucidated in Tables (1 and 4). The morphology of leaf hairs is photographed using SEM as illustrated in (Fig. 1, 2 and 3).

Trichome density 7.20, 4.89 and 4.49 no/mm^2, trichome length 470.06, 461.96 and 370.18 µm, and stomatal density 569.80, 321.68 and 239.39 no./mm^2 in cucumber higher than in eggplant and okra, respectively. Hence, *T. urticae, B. tabaci* and *Thrips tabaci* infestation in cucumber was significantly higher than in eggplant and okra (Table 5).

Moreover, high significant positive relationship was found between *T. urticae* (mobile stages and eggs) and each of the trichome density (0.92 and 0.98) and stomatal length (0.97 and 0.89), while negative relation was recorded with trichome length (-0.37 and -0.15) and stomatal dimension width (-0.10 and -0.32) in cucumber, respectively. On contrast, negative correlation was observed with trichome density (-0.98 and -0.52) and stomatal length (-0.74 and -0.88) in okra, respectively. In eggplant, the population of *T. urticae* positively correlated with trichome density (1.00 and 0.92) and trichome length (0.57 and 0.30), while was negatively correlated with stomatal dimension width (-0.94 and -1.00), respectively (Table 4).

For aphids on cucumber, highly positive correlation was found with trichome density, stomatal density and stomatal dimension length (0.96, 0.56 and 0.58), while was highly negative with trichome thickness, stomatal aperture area and stomatal dimension width (-0.58, -1.00 and -0.72), respectively. In okra, this correlation was positive with trichome density, stomatal dimension length, trichome thickness and stomatal aperture area (0.71, 0.27, 0.77 and 0.19), but was negative with stomatal density and stomatal dimension width (-0.70 and -0.70), respectively. In eggplant, the population of aphids positively correlated with trichome density, stomatal density and stomatal aperture area (0.49, 0.25 and 0.49), whilst was negatively correlated with stomatal dimension length, trichome thickness and stomatal dimension width (-0.44, -0.99 and -0.98), respectively (Table 4).

For *B. tabaci*, also in cucumber positive relation was recorded with trichome density, stomatal density and stomatal dimension length (1.00, 0.24 and 0.82), and was

Table 5: Mean ± SD of some leaf morphological characteristics in cucumber, okra and eggplant plants during 2021 season

Plant sample	Leaf morphological characteristics (± SD)						
	Trichome density (no/mm^2)	Trichome length (μm)	Trichome thickness (μm)	Stomatal density (no./mm^2)	Stomatal aperture area	Stomatal dimensions (length; μm)	Stomatal dimensions (width; μm)
Cucumber	7.20a ± 0.83	470.06a ± 32.51	75.44b ± 0.60	569.80a ± 71.23	19.76a ± 5.77	12.87b ± 0.34	10.26c ± 1.27
Okra	4.49b ± 0.56	370.18b ± 34.49	93.91ab ± 10.67	239.39b ± 41.46	28.17a ± 9.32	15.20b ± 0.81	11.36b ± 0.53
Eggplant	4.89b ± 0.68	461.96a±23.83	100.34a ± 7.76	321.68b ± 44.82	13.01a ± 1.33	27.34a ± 3.44	16.11a ± 0.52
ANOVA 5%	*	*	ns	**	ns	**	**

Means with the different letters are significant ($P \leq 0.05$) using Duncan Multiple Range Test
(**) highly significant, (*) significant, (ns) no significant

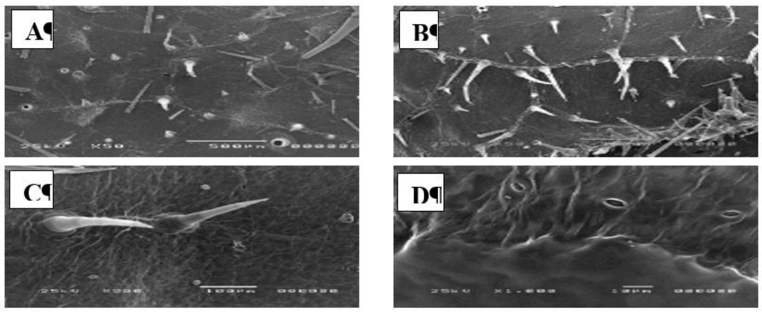

Fig. 1: Scanning electron micrographs on the abaxial leaf epidermis (lower surface) of cucumber (*Cucumis sativus* L.). (**A**, **B**) simple hairs (straight trichomes), (**C**) simple hairs (appressed trichomes), (**D**) stomata

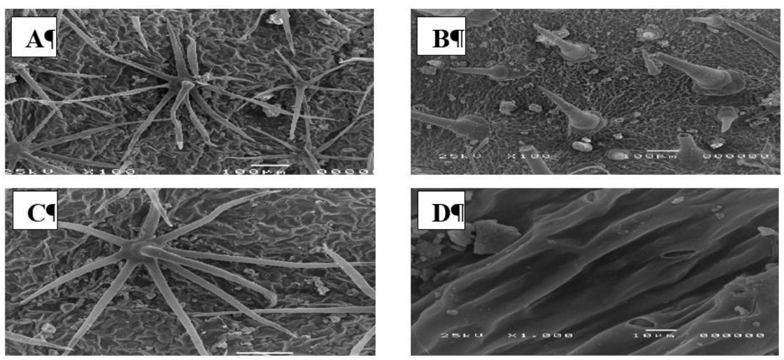

Fig. 2: Scanning electron micrographs on the abaxial leaf epidermis (lower surface) of okra (*Abelmoschus esculentus* L.). (**A**) simple hairs (trichomes with pedestal), (**B**) appressed stellate trichomes, (**C**) sessile trichomes, (**D**) stomata

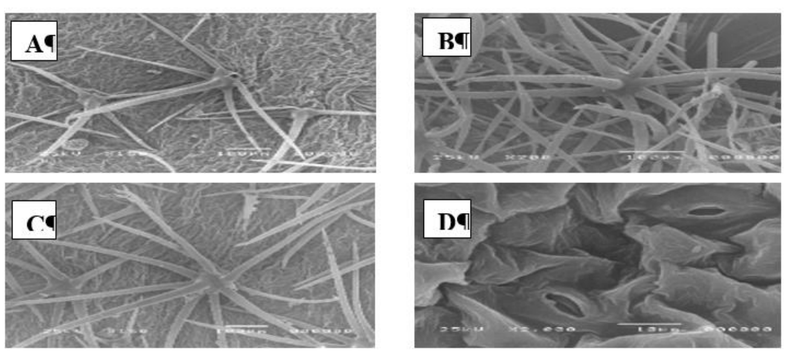

Fig. 3: Scanning electron micrographs on the abaxial leaf epidermis (lower surface) of eggplant (*Solanum melongena* L.). (**A**, **B**, **C**) appressed stellate trichomes, (**D**) stomata

negative with trichome thickness, stomatal aperture area and stomatal dimension width (-0.27, -0.95 and -0.44), respectively. The relation differed in okra whereas was positive with trichome density, trichome thickness and stomatal aperture area (0.44, 0.93 and 0.50), nevertheless was negative with stomatal density, stomatal dimension length and stomatal dimension width (-0.90, -0.06 and -0.90), respectively. Similarly, different correlations were observed in eggplant whereas the population was positively correlated with trichome density, stomatal density and stomatal aperture area (0.62, 0.01 and 0.69), yet was negatively correlated with stomatal dimension length, trichome thickness and stomatal dimension width (-0.65, -0.99 and -0.89), respectively (Table 4).

For *T. tabaci* on cucumber, comparable as formerly mentioned with aphids and *B. tabaci*, the correlation was positive with trichome density, stomatal density and stomatal dimension length (0.86, 0.74 and 0.37), however was negative with trichome thickness, stomatal aperture area and stomatal dimension width (-0.76, -0.97 and -0.87), respectively. Otherwise in okra, the population was positively correlated with stomatal density and stomatal dimension width (0.78 and 0.78), but was negatively correlated with trichome density, stomatal dimension length, trichome thickness and stomatal aperture area (-0.63, -0.16, -0.83 and -0.30), respectively. Furthermore, in eggplant the relationship was positive with trichome density, stomatal density, trichome length and stomatal aperture area (0.97, 0.61, 0.43 and 0.11), yet was negatively correlated with stomatal dimension length, trichome thickness and stomatal dimension width (-0.05, -0.86 and -0.98), respectively (Table 4).

In general, highly significant positive correlation was obtained between the population of aphids, whitefly and thrips with trichome density in cucumber, while this correlation was highly significant negative with stomatal aperture area. Also in eggplant, there was a significant positive correlation between these insect pests and trichome density; however, this correlation was significantly negative with trichome thickness and stomatal dimension width. As for okra, these pests differed in their correlation with each of the morphological features (Table 4).

Discussion

Cucumber, okra and eggplant significantly varied in their infestation with the different sucking pests. The highest numbers of two spotted spider mite *T. urticae* was obtained in cucumber plants during June and its increase was associated with an increase in temperature. Mustafa and Al Mallah (2021) mentioned that heat and humidity are suitable for growth and reproduction of mites.

In this study, the highest numbers of aphids were recorded in cucumber and it coincides with the findings of Bayoumy *et al*. (2017), who indicated that squash plants harbored higher numbers of *Aphis* spp.

The population of *Thrips tabaci* was greatly higher in cucumber than in eggplant and okra, and the highest number was recorded during March. Comparable result was obtained in previous studies in which, by who reported that *T. tabaci* population on onion plants was peaked in February, March and April (Hendawy *et al*. 2011; El-Fakharany *et al*. 2012).

It is well known that high levels of K can reduce the volume of accumulated amino acids, that can decrease sucking pest infestation (Jansson and Ekbom 2002; Leite *et al*. 2011). Thus, we found a negative relationship between the number of aphids and the highest ratio of K. However, this is in contrast with the findings of Bayoumy *et al*. (2017) who found a positive correlation between the population of *Aphis* spp and the higher values of total proteins, carbohydrates and N in squash plants.

Our results revealed that the spider mite *T. urticae* infested cucumber plants greatly more than okra 1771.3 and 31.3 individuals that may be due to phenolic content 0.04 and 0.03 g/100 g in cucumber and okra, respectively. This may be due to the higher ratios of carbohydrates, protein, nitrogen and phenols, despite the negative correlation between mites and these components, in eggplant leaves. Similarly, Helmi and Rashwan (2015) demonstrated a negative relationship between the infestation of sucking insects and phenol content in some solanaceous cultivars. Further, Kielkiewicz and Vrie (1990) mentioned that phenolic compounds have been pointed out as an important factor mediating plant resistance to spider mites.

Population density of *T. tabaci* was significantly higher in cucumber plants, that were positively related with total phenols and carbohydrates, while it was negatively related with total protein and nitrogen. Similar findings were reported by El-Fakharany and Knany (2018) who pointed out positive correlation between population density of *T. tabaci* and each of chlorophyll content, total phenols and P. However, this correlation was negative with total protein, N and K. These results are supported by the findings of Wahyuni *et al*. (2021) who indicated that some chemical compounds gave a significant negative correlation with feeding damage by thrips in Gladiolus varieties.

Okra leaves contained a higher ratio of chlorophyll than cucumber and eggplant, that may due to vegetation type, growth nature and plant composition. El-Fakharany and Knany (2018) suggested that the high chlorophyll content in lettuce may cause the nature shading of lettuce leaf growth compared to the other crops which have low chlorophyll content.

Moreover, in regard to the chlorophyll content in okra and eggplant, the population of aphids and *T. tabaci* was positively correlated with total chlorophyll, while a negative correlation was found with *B. tabaci*. This finding is confirmatory with Elanchezhyan *et al*. (2008) who reported that the total chlorophyll was positively correlated with plant injury caused by aphids. Total protein in cucumber and eggplant showed negative correlation with aphid and *B. tabaci* population, while this correlation was positive in okra. This result is contradictory to Hegab *et al*. (2014) who mentioned that the *B. tabaci* population was positively correlated with proteins in eggplant varieties.

Furthermore, the mite infestation in okra and eggplant was positively correlated with all chemical characteristics measured, except only total chlorophyll in eggplant, and protein and P in okra. Ali *et al.* (2015) revealed that the correlation between the mite infestation and total carbohydrates was positive; however, it was negative with total carotenes in five tomato hybrids. Kamel *et al*. (2019) reported that the mite population was positively related with total carbohydrates and nitrogen, but the relation was negative with total phenols in pea leaves, while Abdallah *et al*. (2018) indicated a significant positive correlation between *T. urticae* infestation and total phenol, while a significant negative correlation was recorded with total protein, chlorophyll and carbohydrates in three squash cultivars. Comparable results were obtained in previous studies in which the correlation between sucking pests infestation and biochemical leaf components was positive or negative in different crops (Khan *et al*. 2015; Kharbangar *et al*. 2015; Shah *et al*. 2016).

Plant morphological factors often affect the mechanisms of pest locomotion, feeding, digestion and oviposition (Kumar 1984). Our findings clearly showed that leaf morphological traits significantly affected the population density of considered pests. For example, from the results obtained, these pests had a positive relation with trichome density and stomatal density, while had a negative relation with trichome thickness and stomatal dimension width in cucumber and eggplant. For okra, trichome (density, length and thickness) positively affected the population of aphids and *B. tabaci*, however it negatively affected the population of *T. tabaci* and *T. urticae*. Stomatal density and stomatal dimension width negatively affected the population of aphids and *B. tabaci*, while it positively affected the population of *T. tabaci* and *T. urticae*. These results corroborate the findings of El-Samahy and Saad (2010) who stated the high significant positive correlation between leaf trichome density and population of *T. urticae* and *B. tabaci*, while negative correlation was recorded with *A. gosssypii* in three soybean varieties. Similarly, Abdallah *et al*. (2018) noted a positive correlation between mite population and leaf trichome density in three squash cultivars.

Identically results were obtained by Hasanuzzaman *et al*. (2016) who stated that the number of whitefly was positively correlated with leaf trichome density and length in different varieties of eggplant. Similarly, Harish *et al*. (2023) indicated that the leaf trichome density and trichome length showed a significant positive correlation with the whitefly population on soybean genotypes. Consequently, leaves having lower trichome density considered more resistance against *B. tabaci* infestation (Ayyasamy and Baskaran 2005). In addition, whitefly population was positively correlated with trichome length in eggplant (Singh *et al*. 2002; Hasanuzzaman *et al*. 2016), and beans (Oriani *et al*. 2005).

Conclusion

Although cucumber leaves contained the lowest ratios of proteins, carbohydrates and nitrogen, were highly infested with all the investigated pests. This may be due to some leaf morphological traits such as trichome density, trichome length and stomatal density. It can be concluded that neither the chemical components nor the morphological characteristics alone can always be the main reason for the susceptibility or resistance of plants against pests, but this can be attributed to more than one of these factors. On the basis of these results, it is possible to increase plant resistance against pests by improving the morphological and chemical characteristics of plants using advanced agricultural technology and by developing resistant plant varieties.

Author Contributions

HSA planned the experiments, HSA and MAR interpreted the results and made the write up, HSA and IAA statistically analyzed the data and made illustrations.

Conflicts of Interest

All authors declare no conflicts of interest.

Data Availability

Data presented in this study will be available on a fair request to the corresponding author.

Ethics Approval

Not applicable in this paper

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