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Diversity of Piercing-Sucking Pests Infesting Some Plants of Solanaceae and Cucurbitaceae Families

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ABSTRACT

Insects and plants have been living and relationship together for more million years. Cucurbitaceae and Solanaceae families were esteemed as important vegetable production in Egypt and were infested by numerous piercing-sucking pests. Recently, climatic changes led to changes in the distribution of these pests. Therefore, the diversity of *Bemisia tabaci*, *Aphis gossypii* & *Myzus persicae*, *Empoasca decipiens* and *Tetranychus urticae* on Solanaceae and Cucurbitaceae crops was studied during two summer seasons of 2022 and 2023 years. The obtained results show a susceptible and low resistance of whitefly and spider mite infestations, while, susceptible, moderate and low resistance were recorded with aphid and leafhopper infestations of tested hosts. Data emphasized that *B. tabaci* and *T. urticae* were the more dominant species infesting all plants. The tested piercing-sucking pests were recorded 1-3 peaks, concentrating through April-May during the two tested seasons. Data showed that the increasing of *B. tabaci* and *T. urticae* populations led to a decrease in GA3, IAA and KIN contents, and an increase in ABA contents, contrariwise, the reverse direction was found with aphids and *E. decipiens* populations. Moreover, a negative relationship was recorded between phenoloxidase and all tested pests except whitefly was detected a positive effect. A positive relation was reported between phytochemical components and these pests except spider mite was negative. Finally, these results offer useful and appealingly data to point out herein that the infestation rate of piercing-sucking insects must refer to the resistance degree of each cultivar to help in putting the IPM management strategy in the control programs of these pests.

INTRODUCTION

Insects and plants have been living and relationship together for more million years (War *et al*., 2012). Cucurbitaceae and Solanaceae were esteemed important crops of vegetable production, which are widely cultivated in large-scale areas in both old lands and newly reclaimed lands in Egypt (Mohamed, 2012, Fawzi and Habeeb, 2016). The cultivated area of the Cucurbitaceae, Solanaceae plantations was 595071 ha, and 18.5 million tons in Egypt (FAO, 2023). Cucurbitaceae comprises up to about 130 genera containing more than 800 plant species (Kocyan *et al*., 2007), additionally, Solanaceae family comprises about 1500 plant species, distributed in both tropical and temperate regions in the world (Jennifer and James, 1997). Many phytophagous pests including cotton whitefly, *Bemisia tabaci*, aphids, *Aphis gossypii* & *Myzus persicae*, leafhopper, *Empoasca decipiens* and two-spotted spider mites, *Tetranychus urticae* were infested Solanaceae and Cucurbitaceae crops (Abd El-Wahab *et al*., 2012 and Al-Habshy *et al*., 2013). A large scale of these sucking pests attack numerous Cucurbitaceae and Solanaceae species such as watermelon (Abou El-Saad, 2015) cucumber (Ibrahim, 2017), ash-gourd (Khan *et al*., 1999), squash (Abdallah *et al*., 2012), cantaloupe (Younes *et al*., 2010) snake-cucumber (Mondal *et al*., 2020) pepper (Havanoor and Rafee, 2018) and eggplant (Helmi and Rashwan, 2015). In addition to the direct infestation of piercing-sucking insects, which causes the transmission of viral disease to these plant families, as well as the secretion of honeydew, which leads to the growth of black mold, also, causing photosynthesis stop (Ghosh *et al*., 2019 and Kazak *et al*., 2015).

Whiteflies are polyphagous insects; they can be developed and colonized on a wide range of flower and vegetable crops in greenhouses and opening fields (Gonsebatt *et al*., 2012). Also, it can be found on weeds and spontaneous plants, which act as alternate hosts by offering food and shelter (Bezerra *et al*., 2004) and acting as a reservoir for plant viruses spread by whiteflies (Rodríguez-Pardina *et al*., 2006). Moreover, aphid damage is most apparent on a range of crops, including vegetables, ornamental and grains (Singh and Ghosh, 2002 and Singh *et al*., 2003). In addition to causing harm to plants by sucking the sap from leaves and stems, aphids can also spread plant viral infections (Chaudhary *et al*., 2009). It deposited honeydew on leaf surfaces that promoted the establishment of black mold, which caused the plants' ability to make photosynthesis abnormal (Raychaudhuri, 1980). Additionally, by directly feeding the plant sap or by indirectly serving as vectors for plant infections, leafhoppers of the order Hemiptera, namely leafhopper, *E. decipiens*, cause significant harm to vegetable crops, including potatoes, cucumbers, pumpkins, and chillies (Rehman *et al*., 2019 and Nielson, 1968). The two-spotted spider mite *Tetranychus urticae* Koch (Acari: Tetranychidae) is a common phytophagous pest that severely damages a wide range of crop plants including vegetables, fruits and ornamentals (Migeon & Dorkeld, 2007). It fed on lower leaves like a piercing-sucking pest and injected phytotoxic chemicals that caused the leaf to become necrotic and destroy the chloroplasts (Attia *et al*., 2013).

However, feeding on various host plants can have a significant impact on phytophagous pest susceptibility (Abro, 2013). Furthermore, the susceptibility of different host plants is especially important in the case of a harmful poly-phytophagous mite (*Tetranychus urticae*) with 1100 host plant species (almost 150 plant families) as reported by Grbić *et al*. (2011), *Bemisia tabaci* (Berlinger, 1986) aphids (Foster *et al*., 2012), leafhopper *Empoasca decipiens* (Homoptera: Cicadellidae) (Darwish, 2020). The initial line of defense against herbivores is provided by plant structures, which also contribute significantly to the host plant's insect resistance (Hanley *et al*., 2007). Insect feeding disruption is one of the key components of host plant resistance to insects. Enzymes such as phenoloxidases impair the nutrient uptake by insects by forming electrophiles. Host plant resistance results from the induction of antioxidant enzymes in plants (Dunse *et al*., 2010). The comprehension of plant immunity to herbivores requires an understanding of the critical role played by phyto-hormones such as gibberellins, cytokinins, salicylic acid, abscisic acid and brassinosteroids (Erb *et al*., 2012). Moreover, in order to plant defense against phytophagous herbivores like piercing-sucking pests, plants have evolved a variety of secondary metabolites including alkaloids, phenolics, flavonoids, amines, terpenes, cyanogenic, glucosinolates, glucosides, quinones and polyacetylenes (Divekar *et al*., 2022 and Elshafie *et al*., 2023).

Recently, the climatic changes affecting the Egyptian environment led to changes in the environmental distribution of these pests on vegetable crops. Therefore, the current study herein focused on studying the variability of population fluctuation, dominance and susceptibility of *Bemisia tabaci*, Aphids, *Aphis gossypii* & *Myzus persicae*, *Tetranychus urticae* and *Empoasca decipiens* on two Solanaceae crops i.e. sweet pepper and black eggplant, and Cucurbitaceae crops i.e. squash, cantaloupe, cucumber and snake-cucumber during two summer seasons of 2022 and 2023 years, then it was studied the relation between pest infestations and the levels of phyto-enzyme (phenoloxidase), phyto-hormones (gibberellic acid, indole-3-acetic acid, kinetin & abscisic acid) and phytochemical components (flavonoids & alkaloids) that may help to put and implement a novel decision support system against these pests.

MATERIALS AND METHODS

Field experiments were conducted throughout two successive summer seasons in 2022 and 2023 at a private farm in Berket El-Saba, Menoufia, Egypt, to study the diversity of piercing-sucking pest infestations such as cotton whitefly, *B. tabaci*, aphids, *A. gossypii* & *M. persicae*, two spotted spider mite, *T. urticae* and leafhopper, *E. decipiens* on two Solanaceae plants i.e. sweet pepper, *Capsicum annuum* L (Yaqot hybrid) and black eggplant *Solanum melongena* L. (Anan hybrid) and four Cucurbitaceae plants i.e. squash, *Cucurbita pepo* L. (Yara f1 hybrid), cantaloupe *Cucumis melo* (Yathrib 22 hybrid), cucumber *Cucumis sativus* L. (Prince hybrid) and snake-cucumber *Cucumis melo* L. subsp. *melo Var*. *flexuosus* (L.) (Maka hybrid). All field experiment areas received the recommended agricultural practices for each crop without any pesticide use. The area of 2100 m^2 was divided into 6 plots. The seedlings of all investigated cultivars were cultivated on 1^{st} March with the randomized complete block design for all crops with three replicates. Random samples of 10 leaves from each replicate were weekly collected through a period from 2^{nd} April to 18^{th} June during 2022 and 2023 seasons. The mean numbers of *B. tabaci* nymphs /leaf, Aphids *A. gossypii* & *M. persicae* individuals /leaf, *T. urticae* mobile stages /leaf and *E. decipiens* individuals /leaf were weekly recorded by direct inspection and under stereomicroscope. Abundance percentages of these investigated pests on all host plants were determined by Facylate (1971) formula:

Dominance percentage (D %) = (t/T) × 100

Where: **D** = Dominance. **t** = Total no. of each pest species through the inspection period.
T =Total no. of all tested species collected through the inspection period.

The susceptibility of each host plant to all tested piercing-sucking pests was dependently categorized on the mean number of the pest ($\bar{X}$) and the standard deviation (SD) according to Chiang and Talekar (1980), in which, a high susceptible (HS) was represented by the host plant that was harbored the infestation of this pest more than $\bar{X}$ +2 SD, a susceptible (S) was be situated between $\bar{X}$ and $\bar{X}$ +2 SD, a low resistance (LR) was located between $\bar{X}$ and $\bar{X}$ - SD, a moderate resistance (MR) was represented between $\bar{X}$ - SD and $\bar{X}$ -2 SD and high resistance (HR) was be situated less than $\bar{X}$ -2 SD.

The relation between the infestation rate of each tested pest and the contained of four endogenous plant growth hormones i.e. gibberellic acid (GA3), indole-3-acetic acid (IAA), kinetin (KIN) and abscisic acid (ABA), phyto-chemical components, flavonoids and alkaloids, and phyto-enzyme, phenoloxidase content at the fruiting stage during the examined summer seasons of 2022 and 2023 were studied. The leaf content of the tested endogenous phyto-hormones was extracted and determined according to Shindy and Smith (1975). Moreover, the leaf content of phenoloxidase, alkaloids and flavonoids was extracted and detected according to Fehrman and Dimond (1967), Dalli and Al-Hakim (1987) and Hang *et al*. (2004) at the Faculty of Agriculture, Menoufia Univ., respectively. The presented results were statistically analyzed by SAS program (SAS, 2003) including F-test and ANOVA analyses. The least significant differences (LSD) were estimated to compare the obtained results at 0.05 probability.

RESULTS AND DISCUSSION

1-Susceptibility of Some Vegetable Crops to Certain Piercing-Sucking Pests:

The obtained results in Table (1), show that there were no significant differences in *B. tabaci* infestations to eggplant and pepper plants along 12 periods of inspections throughout 2022 and 2023 seasons, where there was low resistance (LR) of the susceptibility degree to whitefly, with mean numbers ranged from 1.43-2.79. However, the tested Cucurbitaceae cultivars were susceptible (S) to *B. tabaci* infestations along the two seasons except the squash cultivar which was LR to whitefly infestation. The statistical analysis showed a significant difference between Cucurbitaceae cultivars with overall means of 2.06, 7.50, 8.33 and 16.49 nymphs/leaf on squash, cucumber, cantaloupe and snake-cucumber, respectively (Table 1). Regarding the aphids, *Aphis gossypii* & *Myzus persicae* calculated data according to Chiang and Talekar (1980) equation in Table (1), which recorded that the susceptibility to aphid species was low resistance (LR) with eggplant, but it was moderately resistant with pepper without significant differences, where the infestation of *A. gossypii* & *M. persicae* was not exceeded than 1.7 individuals/ leaf. While, as for Cucurbitaceae cultivars, the susceptibility degree was susceptible (S) with squash and cucumber cultivars, and low resistance (LR) with cantaloupe and snake-cucumber cultivars. The highest mean numbers were 2.82 and 3.48 individuals/ leaf during 2022 and 2023 with an overall mean of 3.15 individuals/ leaf on cucumber cultivar (Table 1**)**. Regards to two-spotted spider mite, *T. urticae* infestation (Table 1) it was susceptible (S) for eggplant (14.84, 15.5 and 15.17 during 2022, 2023 and altogether seasons, respectively), as well as for cantaloupe (14.14, 14.8 and 14.47 during 2022, 2023 and altogether seasons, respectively), while it was low resistance (LR) with other tested crops to *T. urticae* infestations during both tested two seasons without significant difference (LSD 5%= 6.59, 6.57 and 6.58 during 2022, 2023 and altogether seasons, respectively). Moreover, data presented in Table (1) indicated that the eggplant cultivar was susceptible to leafhopper *E. decipiens* infestations, while, the pepper cultivar had low resistance during the two investigated seasons. While cucumber and cantaloupe cultivars were susceptible, however, squash has moderate resistance, but snake-cucumber is exposed to low resistance for leafhopper infestations during the two tested seasons.

Generally, according to the determination of the susceptibility degrees, the obtained results showed that two susceptibility degrees were recorded for all tested cultivars during the two investigated seasons together to whitefly and two-spotted spider mite infestations. These groups are susceptible (S) and low resistance (LR) for Solanaceae and Cucurbitaceae cultivars. While, three susceptibility degrees were reported for all tested cultivars during two seasons, 2022 and 2023 to aphids and leafhopper infestations. These groups are susceptible (S), moderately resistant (MR) and low resistance (LR) for Solanaceae and Cucurbitaceae cultivars (Table 1). These results are in agreement with those findings by Abd El-Samea *et al.* (2019) who classified the susceptibility of cucumber cultivars to *B. tabaci* infestation as susceptible, moderately resistant and low resistant depending on mean numbers of *B. tabaci*. On cantaloupe cultivars, comparable findings were stated by Metwally *et al.* (2013) recording significantly in its susceptibility to *B. tabaci*. Similarly, El-Saiedy *et al.* (2011) found that the watermelon, Aswan cultivar had a high susceptible depending on *T. urticae* moving stages/leaf, followed by Daytona cultivar which was moderately infestation and Molokai and Giza-1 cultivars had a low infestation. On pepper, Ismail and Heikal (2023) reported that susceptibility to *T. urticae* infestation varied under greenhouse conditions. Walia *et al*. (2012) and Raeyat *et al*. (2021) found that seven eggplant varieties had diverse resistance and susceptibility to *T. urticae* and *M. persicae*. Also, a diverse infestation of melon aphids which feed on about 220 crop plants belong to 46 families including up to 30 Solanaceae crops e.g. eggplant, okra, pepper, tomato and 19 Cucurbitaceae crops e.g. muskmelon, watermelon, squash, cucumber, pumpkin) (Roy and Behura, 1983 and York, 1992). Concerning the sap-sucking insects like *Empoasca decipiens*, *E. decedens*, *Aphis gossypii*, *Mysus persicae*, *Bemisia tabaci*, Helmi and Rashwan (2015) reported that the susceptibility of six cultivars belonging to Solanaceous species: pepper, eggplant and potato was significantly different among plant species/cultivars and population density of these insects. Consequently, these categories of susceptibility degrees were important to point out herein that the infestation rate of piercing-sucking insects must refer to the resistance degree of each cultivar to plan the IPM management strategy in the control programs of these piercing-sucking pests.

Table 1: Susceptibility degrees of six vegetable plants to certain piercing-sucking pests during, 2022 and 2023 seasons.

Seasons	Host plants	Cotton whitefly, *B. tabaci* nymphs/leaf	Susc. D.	Aphids, *A. gossypii* & *M. persicae* individuals /leaf	Susc. D.	Two-spotted spider mite, *T. urticae* stage /leaf	Susc. D.	Leafhopper, *E. decipiens* individuals /leaf	Susc. D.
Season 2022	Eggplant	2.13c	LR	1.05 c	LR	14.84 a	S	0.8 abc	S
	Pepper	1.43 c	LR	0.62 c	MR	4.9 b	LR	0.56 bc	LR
	Squash	1.73 c	LR	2.63 ab	S	6.09 b	LR	0.47 c	MR
	Cucumber	7.17 b	S	2.82 a	S	3.97 b	LR	0.87 ab	S
	Cantaloupe	8.00 b	S	1.43 bc	LR	14.14 a	S	1.02 a	S
	Snake-cucumber	16.16 a	S	1.27 c	LR	3.56 b	LR	0.66 abc	LR
F value		12.37		3.37		4.79		2.14	
LSD at 5%		4.52		1.35		6.59		0.39	
Season 2023	Eggplant	2.79c	LR	1.7c	LR	15.5a	S	1.46ab	S
	Pepper	2.08c	LR	1.28c	MR	5.56b	LR	1.22b	LR
	Squash	2.39c	LR	3.28ab	S	6.75b	LR	1.13b	MR
	Cucumber	7.83b	S	3.48a	S	4.63b	LR	1.52ab	S
	Cantaloupe	8.66b	S	2.08bc	LR	14.8a	S	1.68a	S
	Snake-cucumber	16.82a	S	1.92bc	LR	4.22b	LR	1.32ab	LR
F value		12.50		3.28		4.81		2.01	
LSD at 5%		4.498		1.37		6.57		0.40	
The overall mean of two seasons	Eggplant	2.46c	LR	1.37c	LR	15.17a	S	1.13abc	S
	Pepper	1.75c	LR	0.95c	MR	5.23b	LR	0.89bc	LR
	Squash	2.06c	LR	2.95ab	S	6.42b	LR	0.80c	MR
	Cucumber	7.50b	S	3.15a	S	4.30b	LR	1.20ab	S
	Cantaloupe	8.33b	S	1.76bc	LR	14.47a	S	1.35a	S
	Snake-cucumber	16.49a	S	1.59c	LR	3.89b	LR	0.99abc	LR
F value		12.44		3.34		4.80		2.19	
LSD at 5%		4.51		1.35		6.58		0.38	

S =susceptible is between $\bar{X}$ and $\bar{X}$ +2SD **LR** =low resistant is between $\bar{X}$ and $\bar{X}$ -1SD **MR** =moderately resistant is between $\bar{X}$ -1SD and $\bar{X}$-2SD **Susc. D.**= susceptibility degree, which means that each column followed by the same letter is not significantly different

2-Dominance Percentage of Certain Piercing-Sucking Pests on Some Vegetable Crops:

Data illustrated in Figure (1), show the dominant % of cotton whitefly, *B. tabaci*, Aphids, *A. gossypii* & *M. persicae*, two-spotted spider mites, *T. urticae* and leafhopper, *E.*

decipiens on eggplant, pepper, squash, cucumber, cantaloupe and snake-cucumber cultivars along 2022 and 2023seasons, according to the equation of Facylate (1971). On Solanaceae plants, *T. urticae* was more abundant than other piercing-sucking insects by 75.3 and 59.3 % with mean numbers of 15.2 and 5.2 mobile stages/ leaf on eggplant and pepper plants throughout the two seasons, 2022 and 2023, respectively. Low abundance was recorded with *B. tabaci* as 12.2 and 19.9 % on eggplant and pepper with mean numbers of 2.5 and 1.8 mobile stages/ leaf, respectively. However, a scarce abundance percentage was observed for *E. decipiens* and aphids on two Solanaceae plants during the two investigated seasons 2022 and 2023, with no significant difference between them (LSD value equal 0.619, Figure 1). In view of Cucurbitaceae crops, the same trend was noticed on squash and cantaloupe plants, where the highest dominance percent was found for *T. urticae* (52.5 and 55.8% by 6.4 and 14.5 mobile stages/ leaf, respectively), followed by aphids and *B. tabaci* (16.8 and 24.1% on squash & 32.2 and 6.8% on cantaloupe plants, respectively) throughout 2022 and 2023seasons. On the contrary, *B. tabaci* has recorded the highest dominance percent (71.8 and 46.5 % on snake-cucumber and cucumber plants during two tested seasons, respectively, figure 1), followed by *T. urticae* (16.9 and 26.6% on snake-cucumber and cucumber plants, respectively). The lowest abundance was detected for leafhopper, *E. decipiens* on all tested host plants. The illustrated results in Figure (1) show a significant difference in all host plants between the dominance percent of four tested piercing-sucking pests. Generally, results offer useful and appealingly data about mainly piercing-sucking insects on the tested cultivars, this research emphasized that cotton whitefly, *B. tabaci* and two-spotted spider mite, *T. urticae* were more dominant species infesting Solanaceae and Cucurbitaceae crops during 2022 and 2023 seasons. These results are in harmony with those of Malka *et al*. (2021) who found that *B. tabaci* was a dominant species infesting Cucurbitaceae, Solanaceae, Malvaceae and Euphorbiaceae such as eggplant, tomato, squash, cucumber, okra, cotton and cassava crops. Also, Kaakeh *et al*., 2007, Abd El-Samea *et al*. (2019) stated that *B. tabaci* is a serious and dominant pest on cucumber cultivars, and on tomato, eggplant and melon. Accordingly, these two pests are considered dominant piercing-sucking pests on Solanaceae and Cucurbitaceae crops in Egypt. Phytophagous mites include spider mites and more than 69 species of Tetranychidae, it was reported that *T. urticae* acts as mainly pest infesting major host plants, okra, brinjal, beans, cucurbits, cotton and marigold crops Singh *et al*., 2020.

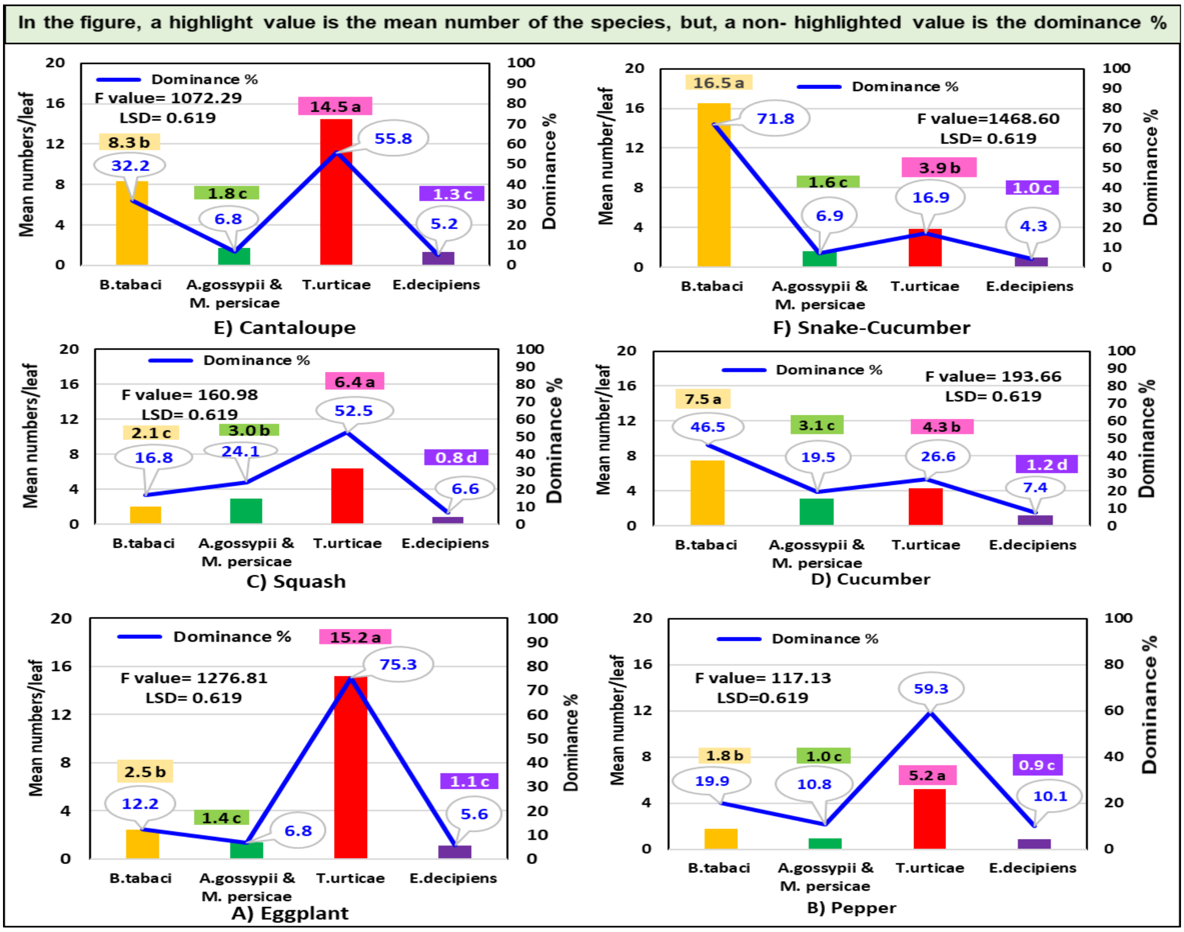


Fig. 1: The dominance of some piercing-sucking pests on different vegetable plants during seasons, 2022 and 2023**.**

3-Population Fluctuation of Certain Piercing-Sucking Pests on Some Vegetable Plants:

Data illustrated in Figures 2-5, show the population fluctuation of certain piercing-sucking pests such as cotton whitefly, *B. tabaci* nymphs /leaf, Aphids *A. gossypii* & *M. persicae* individuals /leaf, two-spotted spider mite, *T. urticae* mobile stage /leaf and leafhopper, *E. decipiens* individuals /leaf on some vegetable crops: eggplant, pepper, squash, cucumber, cantaloupe and snake-cucumber throughout the two examined summer seasons of2022 and 2023 years. The infestation of *B. tabaci* began to appear on April, 2nd in all tested cultivars. The population was concentrated through May on all cultivars, however, through April 2022 and 2023 on squash and snake-cucumber. It demonstrated three peaks on eggplant, squash and snake-cucumber cultivar, while, two peaks were observed on pepper and cucumber, but only one peak was found on cantaloupe cultivar (Fig. 2). The obtained results showed that *B. tabaci* infestations could be classified into two parts: the high infestation was represented on cantaloupe, cucumber, and snake-cucumber cultivars, and the low infestation was found on the other three tested cultivars during both tested seasons. Regarding the peaks of *T. urticae* in Figure (3), only high infestation was represented by the cantaloupe cultivar (up to 93.4 & 93.9 mobile stages/ leaf during 2022 & 2023, respectively), followed by a moderate infestation represented by Solanaceae cultivars, up to 26.9 & 27.6 mobile stages/ leaf on pepper and 38.3 & 39.7 mobile stages/ leaf on eggplant during seasons 2022 and 2023, respectively. In contrast, a low infestation of *T. urticae* appeared on cucumber and squash cultivars, in which, it wasn’t reached to 18 mobile stages/ leaf during two investigated seasons.

Regarding Figure (4), a high infestation of *A. gossypii* & *M. persicae* individuals/leaves was represented on squash and cucumber plants. The infestation of aphids began to appear at the beginning of the two tested seasons on squash, on the other hand, the highest density appeared on cucumber cultivars before the end of the season. The other four tested cultivars harbored a low infestation of aphids, where, the population wasn't exceeded than 5.6 individuals/ leaf on all examined host plants during 2022 and 2023 (Fig. 4).

Data illustrated in Figure (5), demonstrated a very slight infestation of leafhopper, *E. decipiens* individuals /leaf on all tested cultivars, where it was less than 4 individuals /leaf throughout the two examined seasons 2022 and 2023. Two peaks of *E. decipiens* were detected on all tested host plants during both two investigated seasons.

Generally, the infestation of all tested pests was recorded in 1-3 peaks, concentrating through a period of April - May along the two seasons. The population density of all tested pests was slightly higher in the second season than the first one on all tested cultivars. The population density of *B. tabaci* and *T. urticae* was higher than other tested piercing-sucking pests during the two tested seasons.

The obtained results were similar to the line of findings conducted by El-Saad and Aiman (2010) who reported that the high peaks with both two-spotted spider mite and leafhopper were observed through May, but in March with aphid and whitefly on Solanaceous crops. On summer plantations of cucumber and cantaloupe, the highest peaks of *B. tabaci* were observed after the second week of May (Ahmed, 1994 and Kamel *et al.*, 2000). However, Ismail and Heikal (2023) found that the highest density of *B. tabaci, T. urticae* and *M. persicae* during the summer plantations was recorded at the first peak in July, and they suggested that specific environmental conditions in the summer season may be more suitable and favorable for the development of these piercing-sucking pests. Moreover, on cucurbitaceous crops, a high infestation of *B. tabaci* was noticed by Hegab *et al*. (1989) during summer (July-October), and relatively low during spring (March-June)., Shalaby *et al*. (2013) reported a high infestation of whitefly occurring through September-March and was low through April to August. Also, high whitefly peaks occurred during September and October on cucurbits crops (Lanjar *et al*., 2012). Our findings were nearly comparable to those obtained by Al-Habshy *et al*. (2019) who reported that leafhopper and aphid peaks occurred in 3^{rd} week of February on barley plants. Also on pepper, the highest peak of aphid species was 165.67 individuals /plant in mid-March (Ibrahim, 2017). In the present study, the infestation of all tested pests was recorded with 1-3 peaks as in the direction of the findings by El-Hadary and Ahmed (2021) who detected four peaks with *A. gossypii*, two peaks with *B. tabaci* and three peaks with *Empoasca* spp. on the cotton plant. Accordingly, early summer plantations harbored higher occurrences of piercing-sucking pests than other seasons. So, the progressive increase in cucurbits and solanaceous pest infestations in these months suggests that we need initial control of these insect pests in the seedling stage before they reach their highest peak. In this study, the proper seasonal densities of the piercing-sucking pest complex of solanaceous and cucurbits at summer cultivations were conducted, and it is important to understand pest complexes and potential control strategies.

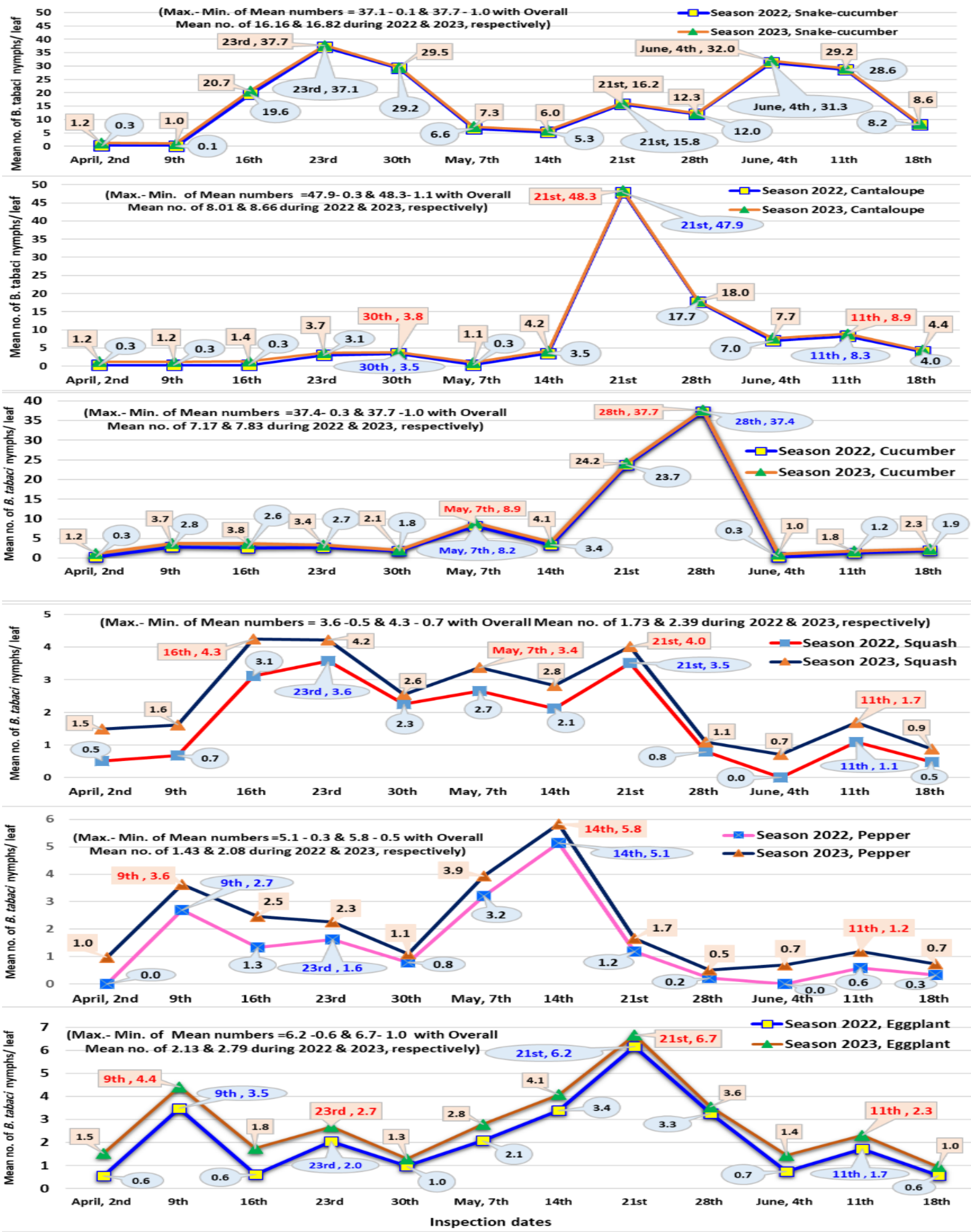


Fig. 2: Population fluctuation of *B. tabaci* nymphs/ leaf on some vegetable crops during the two summer seasons of 2022 and 2023.

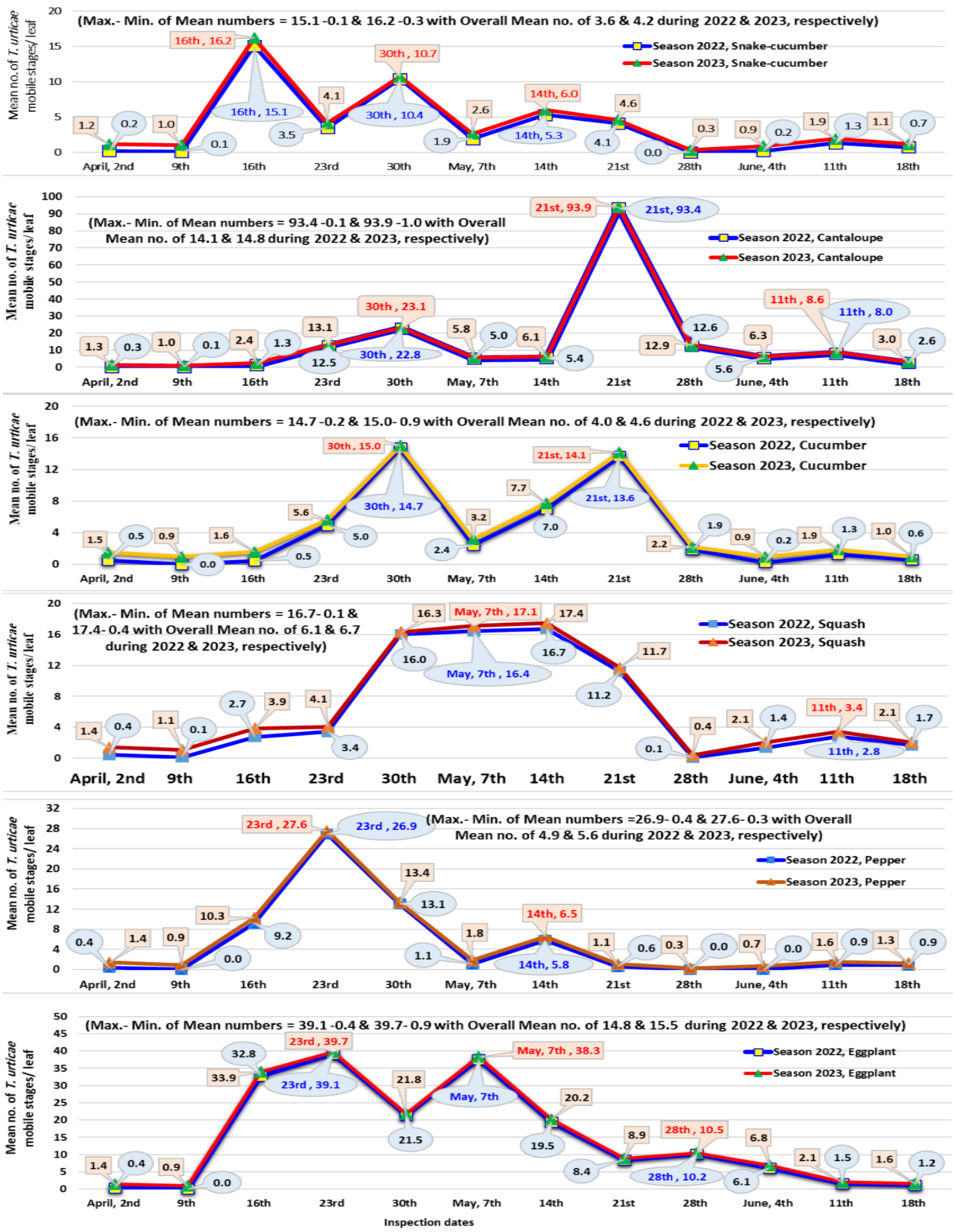


Fig. 3: Population fluctuation of *T. urticae* mobile stages/ leaf on some vegetable crops during the two summer seasons of 2022 and 2023.

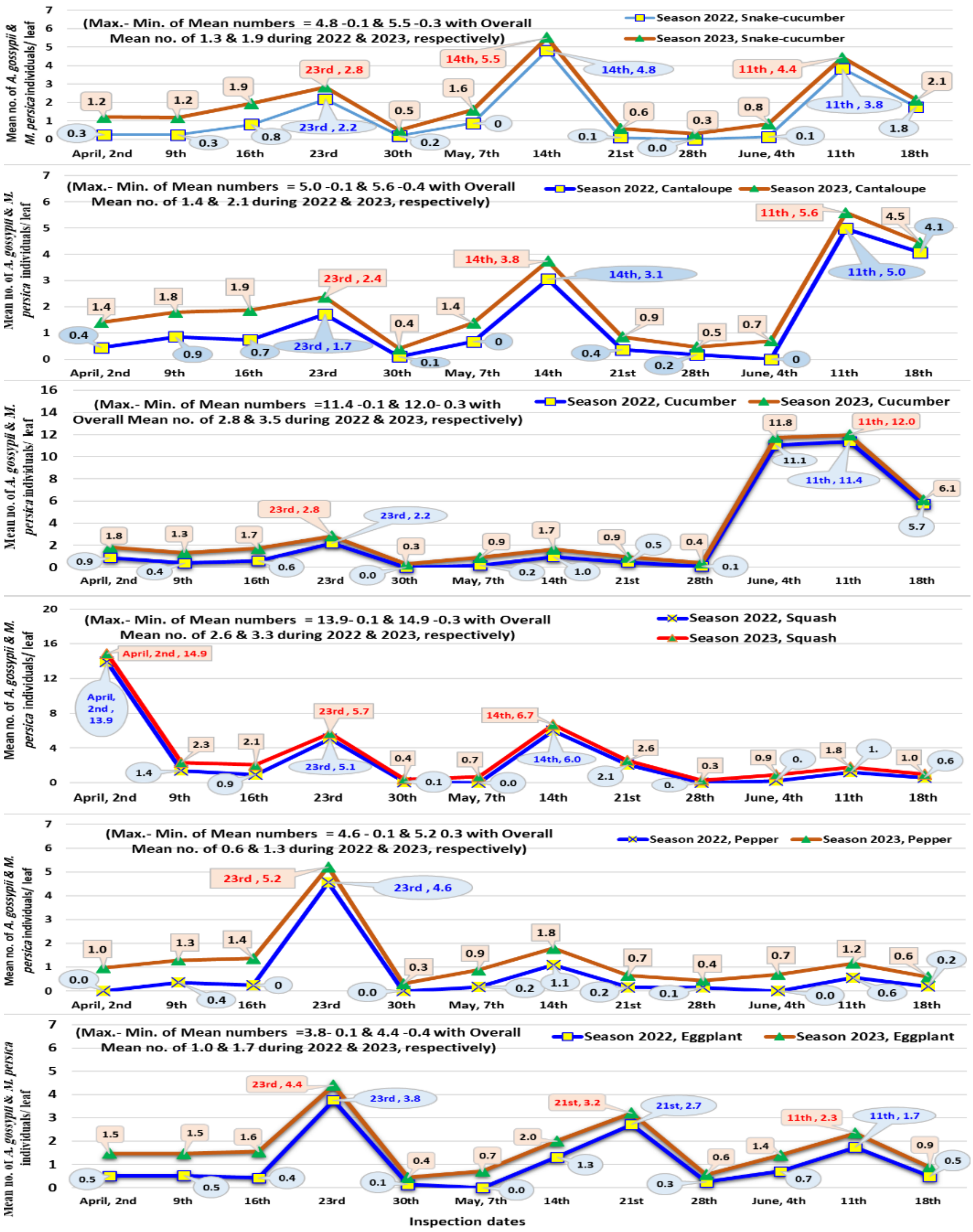


Fig. 4: Population fluctuation of *A. gossypii* & *M. persicae* individuals/ leaf on some vegetable crops during the two summer seasons of 2022 and 2023.

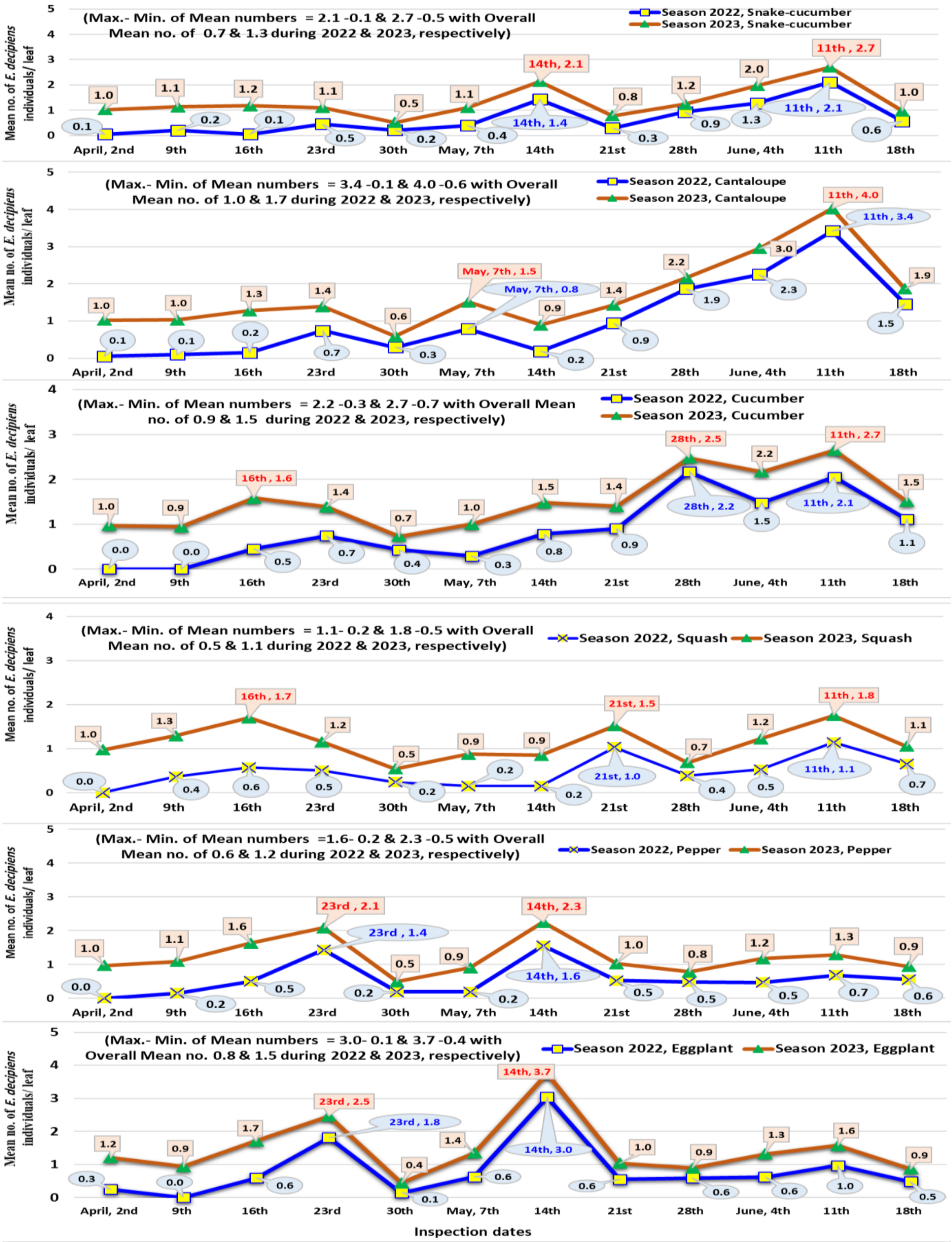


Fig. 5: Population fluctuation of *E. decipiens* individuals/ leaf on some vegetable crops during the two summer seasons of 2022 and 2023.

4-Relationship Between Some Biochemical Properties in Host Plants and Infestations with Some Piercing-Sucking Pests:

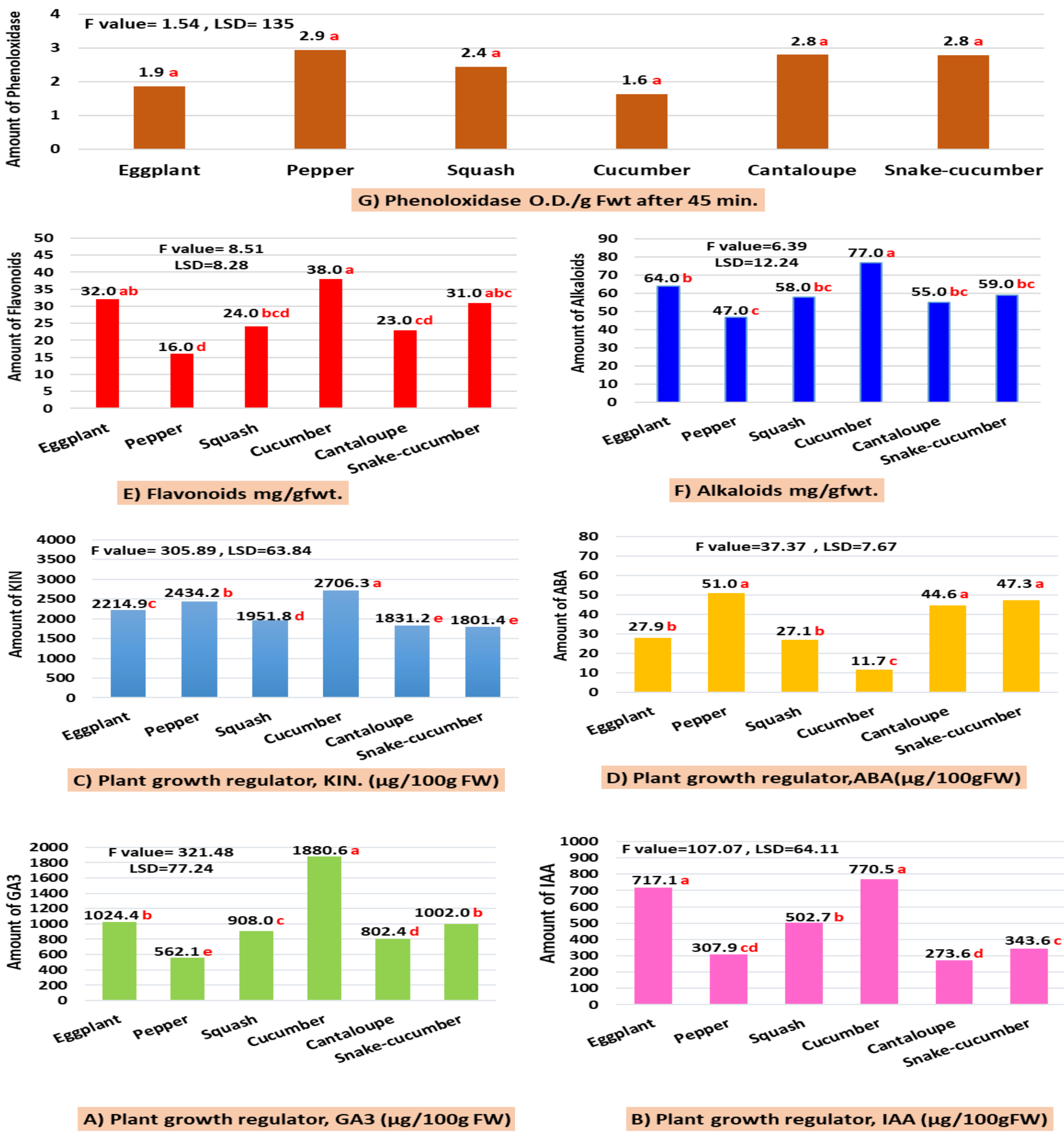
The obtained data illustrated in Figure (6), revealed significant differences between the tested vegetable host plants in their contents of four plant growth hormones: gibberellic acid (GA_3), indole-3-acetic acid (IAA), kinetin (KIN) and abscisic acid (ABA) and phyto-chemical components, flavonoids and alkaloids, while there were no significant differences among tested plants in their contents of phyto-enzyme, and phenoloxidase at the fruiting stage during the examined summer seasons of 2022 and 2023. The lightest level of GA_3 and IAA was represented in pepper and cantaloupe cultivars, while, the highest level was obtained with cucumber cultivars throughout the seasons of 2022 and 2023. The kinetin and ABA contents ranged from 1801.4 to 27006.3 and 11.7 to 51.0 µg/100g fw, respectively. The lowest value of flavonoid and Alkaloid contents were obtained with pepper, squash and cantaloupe cultivars, but the highest level was found with cucumber cultivar, followed by eggplant cultivar. Statistically, no significant differences were found in phyto-enzyme, phenoloxidase contents, and were extended from 1.6- 2.9 O.D./g fwt after 45 min**.** (Figure 6).

In view of the obtained data (Table 2), it is clear that no significant differences were recorded between the amount of plant growth hormones, IAA and KIN and *B. tabaci* infestation rate of all tested host plants, moreover negative relationship was noticed whereby the increasing of *B. tabaci* infestations the amount of these plant hormones were decreased. While, a positive relationship with other plant growth hormones, GA_3 and ABA, plant enzyme, phenoloxidase and phytochemical components, flavonoids and alkaloids with whitefly, in which, the correlation coefficients (r-value) were extended from 0.183-0.398 (Table 2) that means by the increasing of *B. tabaci* infestations the amount of these components were increased.

As for aphids, *A. gossypii* & *M. persicae*, a significant negative effect was stated with abscisic acid and phenoloxidase with r values -0.799 and -0.546, respectively. Contrariwise, a significant positive effect with GA_3, IAA and alkaloids, but it is not significant with kinetin and flavonoids (r-values ranged from 0.206 to 0.713. Regarding *T. urticae* infestations, a slightly negative relation but non-significant with the tested components where it did not exceed -0.289 except with each of IAA (r=0.051) and ABA (r=0.038) recording a very slight positive effect). As for results in Table 2 simple correlation analysis confirmed that the population of leafhopper, *E. decipiens* individuals/ leaf on all tested host plants significantly affected the GA3, IAA, kinetin, flavonoids and alkaloids contents, but, it did not significant effect in leaves, where it was ranged from 0.040-0.389. On the other hand, the correlation between *E. decipiens* population and ABA and phenoloxidase was with r values -0.162 and -0.278, respectively (Table 2).

Finally, increasing of *B. tabaci* and *T. urticae* populations led to a decrease in GA3, IAA and KIN contents, and increased ABA contents, contrariwise, the increase of, aphids and *E. decipiens* populations increased GA_3, IAA and KIN contents, but decreased ABA contents. Moreover, a negative relationship was detected between phenoloxidase contents and all tested pests except *B. tabaci* recorded a positive effect. On the other direction, a positive relation was reported between phyto-chemical components, flavonoids and alkaloids and all pests except *T. urticae* which had a negative effect.

The obtained results are similar to those of Sereme *et al*., 2016 and Hassan *et al*., 2017, who found that in relation to piercing-sucking pest infestations, the host plants had various phytochemical defensive for example, phenolic compounds, antioxidants like peroxidase, and phenoloxidase, glutathione-s-transferase (). Moreover, high phenoloxidase activity was strongly associated with aphids (Soffan *et al*. 2014 and Sharma and Ortiz, 2002). In addition, Mitchell *et al*., 2016 and Silva *et al*., 2021 reported that *B. tabaci* and *T. urticae* populations in tomatoes were positively related to fatty acid derivatives, indole, phenyl propanoids as methyl salicylate, and the host plant resistance could be reduced the piercing-sucking pest infestations by antixenosis and antibiosis (). Contradictorily, Chapman, 1995 reported that aphid mouthparts lack contact chemoreceptors, which accounts for their unique reaction to non-volatile plant allelochemicals. Recently, phytochemical of primary and secondary metabolites as flavonoids (Stec *et al*., 2021), alkaloids (Tiku, 2021), phyto-hormones including cytokinins, abscisic acid, jasmonic acid and salicylic acid (Bari and Jones, 2009 and Wasternack, 2007) and phyto-enzymes, peroxidase and phenoloxidase enzymes (Hassan *et al*., 2017 and Amin *et al*., 2021) affect the piercing-sucking pest behavior, later on, the aphids behavior changed depending on the flavonoid treated caused a decrease in the intensity of plant sap ingestion. Our research findings provide plant breeders and protection services on how to best focus their efforts to safeguard Cucurbitaceae and Solanaceae plants from piercing-sucking pests in a sustainable and eco-friendly management.



GA_3= Gibberellic acid IAA= Indole-3-acetic acid KIN= Kinetin is a cytokinin-like ABA= Abscisic acid

Fig. 6: Some biochemical properties in vegetable host plants at the fruiting stage during the examined summer seasons of 2022 and 2023.

Table 2: Correlation between some biochemical properties in host plants and piercing-sucking pest infestations.

Factors		Plant growth regulator				Phyto-Enzyme	Phyto-Chemical components	
		GA_3 (µg/100g FW	IAA (µg/100g FW)	KIN (µg/100g FW)	ABA (µg/100g FW)	Phenoloxidase (O.D./g Fwt after 45 min.)	Flavonoids (mg/gfwt.)	Alkaloids (mg/gfwt.)
Cotton whitefly, *B. tabaci*	r	0.229	-0.275	-0.410	0.243	0.211	0.398	0.183
	P	0.66	0.60	0.42	0.64	0.69	0.43	0.73
Aphids, *Aphis gossypii & Myzus persicae*	r	0.713	0.518	0.206	-0.799	-0.546	0.506	0.682
	P	0.01	0.03	0.69	0.05	0.03	0.31	0.02
Two-spotted spider mite, *T. urticae*	r	-0.263	0.051	-0.289	0.038	-0.105	-0.061	-0.089
	P	0.61	0.92	0.58	0.94	0.84	0.91	0.87
Leafhopper, *E. decipiens*	r	0.356	0.140	0.040	-0.162	-0.278	0.387	0.389
	P	0.49	0.79	0.94	0.76	0.59	0.45	0.45

GA_3= Gibberellic acid IAA= Indole-3-acetic acid KIN= Kinetin a cytokinin-like ABA= Abscisic acid r = Correlation coefficient P = Probability

Conclusion.

This study confirmed that the high infestation peaks of whiteflies occurred throughout April-May during both seasons. Fluctuations in the populations of piercing-sucking pests were affected by plant secondary metabolism as phytochemicals, phyto-enzymes, and phyto-hormones. The degree of susceptibility refers to the degree of resistance of each cultivar against insect infestation, which will aid the setting up of the selected piercing-sucking management programs.

Declarations:

Ethical Approval: Ethical Approval is not applicable.

Conflict of interest: The authors declare no conflict of interest.

Contributions: I hereby verify that all authors mentioned on the title page have made substantial contributions to the conception and design of the study, have thoroughly reviewed the manuscript, confirm the accuracy and authenticity of the data and its interpretation, and consent to its submission.

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Availability of Data and Materials: All datasets analysed and described during the present study are available from the corresponding author upon reasonable request.

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