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Leafhopper and Leafminer Incidence in Faba Bean as Related to Plant Chemical Components Based on Bi-Plot Analysis

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Abstract: Field studies were carried out at the experimental farm of Sakha Agricultural Research Station, Kafr El-Sheikh Governorate during 2019/2020 and 2020/2021 to survey insect pests and arthropod predators on five faba bean varieties. Sixteen insect species belonging to eight families and three orders were recorded. In addition to eight insect predators as well as one unidentified spider were detected. Each of leafhoppers, *Empoasca* spp and leafminer, *Liriomyza trifolii* had two peaks of abundance, mainly during March and April. The highest infested variety with leafhoppers was Nubaria 1, followed by Misr 3, while the lowest infested one was Giza 40. In respect to the leafminer, the highest infestation was found in Giza 843, while Nubaria 1 recorded low infestation. *Empoasca* spp infestation correlated negatively with each of total faba bean carbohydrates, crude protein, silica, acidity and chlorophyll contents, but it positively correlated with total phenols. *Liriomyza trifolii* had nonsignificant correlations with total carbohydrates, silica, acidity and crude protein. The principal components analysis (PCA)-loading plot graph; shows the direction of association among *Empoasca* spp, *L. trifolii* insect infestations and chemical composition revealed that the one and two principal components accounted for 92.94% (PCA1= 74.16 % + PCA2 =18.78 %) of the total variability. PCA-Biplot analysis graph viewed that the five faba been varieties were classified based on their response to effect of *Empoasca* spp and *L. trifolii* infestation into four clusters. Sakha 4 was the most resistant variety to both insect species followed by Misr 3, Giza 40, while Giza 843 was the most susceptible variety.

Key words: Faba bean · Insect pests · Abundance · *Empoasca* spp. · *Liriomyza trifolii* · Chemical composition · Varietal susceptibility

INTRODUCTION

Faba bean (*Vicia faba* L.) is one of the most important legume food crops in Egypt, as it is a main source of protein for human and domestic animals [1].

This crop is attacked with many insect pests such as broad bean leafminers, *Liriomyza congesta* (Becker); and *Liriomyza trifolii* (Burgers), cowpea aphid, *Aphis craccivora* Kock; leafhoppers, *Empoasca* spp. and green stink bug, *Nezara viridula* L. These damaging insect pests are widespread in many geographical regions and affect negatively on the quality and quantity of the crop El-Samahy [2], Akca *et al*. [3], Abdel Khalek *et al*. [4], Metwally *et al*. [5], Abou-Attia *et al*. [6], Bassiony *et al.* [7], Abou-Elkassem [8], Allam [9] and Sharabash [10] found that faba bean varieties differ in their sensitivity to the abovementioned insects due to differences in morphological traits and chemical components. Gamieh and El-Basuony [11] attributed the relative susceptibility of soybean cultivars to infestation by some piercing-sucking pests to leaf morphological characters and the nutrient components in leaf and stem tissues, as well. Because of climate change, it has been necessary to update the information regarding the initial insect pest infestations and to follow up the fluctuations in the insect populations.

The present study therefore aimed to monitor the population fluctuations of leafhopper, *Empoasca* spp. and leafminer, *L. trifolii* on faba bean cultivars. In addition, the correlations between chemical, biochemical and chlorophyll contents of faba bean and insect pest infestations were calculated.

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MATERIALS AND METHODS

The current investigation was conducted at the experimental farm of Sakha Agricultural Research Station, Legume Research Department, during 2019/2020 and 2020/2021 seasons.

Land Preparation: The experimental area (about one feddan) was ploughed twice and received calcium super phosphate (P_2O_5) at the rate of 150 kg/fed, just before the third plough. Then, the land was dry levelled and divided into 20 plots, 200 m2 each. The 20 plots were allocated to sowing of five faba bean cultivars, each in four replicates, distributed in a randomized complete block design.

Faba Bean Sowing: The faba bean cultivars were sown on the first of November in 2019/2020 and 2020/2021 seasons. The plots were irrigated directly after sowing and the seedlings of faba bean received nitrogen fertilizer (15kg/fed) as ammonium sulphate and potassium sulphate at the rate of faba bean sowing just before the first irrigation.

Faba Bean Genotypes: Five faba bean genotypes; Sakha-4, Giza-843, Giza-40, Misr-3 and Nubaria-1 were obtained from Legume Research Department, Sakha Agriculture Research Station. The seeds were sown as two seeds per hill.

Survey of Arthropod Insect Pests and Predators: Insect pests and arthropod predators were visually recorded on from faba bean plots beginning from December 5th up to April 9th, during 2019/2020 and 2020/2021 faba seasons.

Sampling Technique: Weekly samples were taken beginning from 5th of December up to 9th of April, from the considered faba bean genotypes.

***Empoasca* spp.:** Every week, numbers of leafhopper, *Empoasca* spp. were counted on 30 faba bean leaflets/ plot, using a lens. Both nymphs and adults of the leafhoppers were considered.

***Liriomyza trifolii*:** Every week, 30 leaflets were picked up from each plot and put into paper bags and transferred to the laboratory. Number of the leaf miners, *Liriomyza trifolii* larvae, confined in the mines of leaflets, was counted using the binocular microscope.

Analysis of Plant Components: Three months after sowing, leaflet samples of faba bean varieties were picked and kept in paper bags. The leaflet specimens were sent to laboratory belonging to Soil, Water and Environment Research Institute, Agricultural Research Center Mansoura. Total carbohydrates, crude protein, total lipids, silica, total phenols and organic acids were assessed according to Hedge and Hofreiter [12], Jones *et al.* [13], A.O.A.C. [14], APHA [15] and Malick and M.B.Singh [16] respectively. Chlorophyll content was determined using chlorophyll meter (Model No. SPAD-502, made by Minolta co.).

Statistical Analysis: Data were subjected to ANOVA and variable means were compared using Duncan [17] at 5% level and simple correlation. The principal component analysis was conducted among traits for classifying the first two principal components that were graphically plotted against each other, using loading and bi-plot graph according to Yan and Rajcan [18]. Statistical analysis was performed using Minitab 18.1 statistical software (Minitab Inc., Coventry, UK). Correlation coefficient values, among chemical components of leaflets and faba bean genotypes insect infestations were calculated and their significances were indicated.

RESULTS

Survey: Insect pests and arthropod predators collected from faba bean fields at Sakha Agricultural Research Station during 2019/2020 and 2020/2021 seasons are listed in Table (1).

Insect Pests: Sixteen insect pest species were surveyed, as belonging to eight families and three orders; Hemiptera, Lepidoptera and Diptera, each had eight, seven and one species, respectively. Aphids constituted all surveyed hemipterous insect pests. The most occurring insect pests were *Aphis craccivora* Koch. (39.32 and 37.52 %), *Empoasca* spp (24.45 and 25.30 %) and *Liriomyza trifollii* (Burges) (18.84 and 21.09 %) in the first and second seasons, respectively. *Acyrthosiphon pisum*, *Myzus persicae* Sulzer. And *Aphis gossypii* Glover. Occurred at the rates of 7.74 & 7.91, 5.24 & 4.49 and 3.17 & 2.18% in the first and second seasons, respectively. However, the 10 remaining insect pests were found in very low numbers, ranging between 0.02 and 0.32% out of total surveyed insect pest's species.

Table 1: Insect pests and arthropod predators surveyed from faba bean fields at Sakha Agricultural Research Station, during 2019/2020 and 2020/2021seasons

				Season			
				2019/2020		2020/2021	
Order	Family	Scientific name	Stage	No	Occurrence%	No	Occurrence%
			Insect pests				
Hemiptera	Aphididae	*Aphis gossypii* (Glover).	N, A	170	3.17	102	2.18
		Aphis craccivora (Kock).		2108	39.32	1756	37.52
		Myzus persicae (Sulzer).		281	5.24	210	4.49
		Acyrthosiphon pisum (Harris).		415	7.74	370	7.91
		Brevicoryne brassicae (L)		9	0.17	11	0.24
	Cicadellidae	*Empoasca* spp	N, A	1311	24.45	1206	25.3
	Pentatomidae	*Nezara viridula* (L)	N, A	17	0.32	13	0.28
	Aleyrodidae	*Bemisia tabaci* (Genn).	N, A	11	0.21	8	0.17
Diptera	Agromyzidae	*Liriomyza trifolii* (Burges)	L, P	1010	18.84	987	21.09
Lepidoptera	Noctuidae	*Spodoptera littoralis* Boisd.	L	4	0.07	2	0.04
		Spodoptera exigua (Hubner)	L	1	0.02	0	0
	Geometridae	*Scopula donovani* (Distant, 1892)	L	5	0.09	7	0.15
		Autographa gamma (L, 1758)		7	0.13	6	0.13
		Chrysodeixis chalites (Esper, 1789)		2	0.04	1	0.02
	Pieridae	*Pieris rapae* (L)	A	3	0.06	2	0.04
		Pieris brassicae (L.)	A	7	0.13	5	0.11
Total				5361		4680	
			Arthropod Predators				
Coleoptera	Coccinellidae	*Coccinella undecimpunctata* L	L, A	89	33.33	71	32.42
		Cydonia vicina nilotica (Muisan)	L, A	11	4.12	16	7.31
		Cydonia vicina isis	L, A	7	2.62	3	1.37
		Scymnus interruptus	A, N	11	4.12	9	4.15
	Staphylinidae	*Paederus alferii* (Koch)	A	16	5.99	9	4.15
Diptera	Syrphidae	*Mitsyrphus corollae*	L, A	7	2.62	3	1.37
Neuroptera	Chrysopidae	*Chrysoperla carnea*	E, L, A	113	42.32	92	42.01
Hemiptera	Anthocoridae	*Orius* spp (F.)	A, N	11	4.12	9	4.15
Araneae	Araneidae	Unidentifiied	A	2	0.75	7	3.20
Total				267		219	

N: nymph, L: larvae, P: pupa, A: adult

Arthropod Predators: Eight arthropod predator species were surveyed, as well as one unidentified (Araneidae: Araneae) species (Table 1). The collected arthropod predators were categorized as six families and five orders. Taking the numbers of each species in the account, the most abundant predators were *Chrysoperla carnea* and *Coccinella undecimpunctata* with percentages of 42.32& 42.01 and 33.33& 32.42 in the 2019/2020 and 2020/2021seasons, respectively. Two predatory species; *Paederus alfierii* (Koch) and *Orius* spp. were less abundant, with values of 5.99 & 4.15 and 4.12 & 4.15%, for the first and second seasons, respectively. The remaining predators were found with very low values of abundance, particularly the araneid species.

Seasonal Abundances: The seasonal abundance of two major insect pests attacking faba bean plantations were monitored for the two seasons of investigation (Tables 2-5).

Leafhoppers, *Empoasca* spp.: *Empoasca* spp. were observed to infest faba bean plantations from early December up to 9th of April in both seasons of study (Table 2-3).

In the first season, 2019/2020 (Table 2), the leafhoppers were found, over the five faba bean varieties. They started in relatively low average numbers during December (3.45-13.90 nymphs and adults / 30 leaflets), the theirs. Population increased gradually during January to exhibit the first peak of occurrence (21.85 nymphs and adults) on February 6th. The second peak (23.20 nymphs and adults) was detected on March 5th and afterwards the insect densities steadily declined to reach the minimum (0.45 nymphs and adults) on April 9th.

In the second season, 2020/2021, the obtained results (Table 3) were similar to those of the first one. Leafhoppers, *Empoasca* spp. population densities were obviously low during December, late March and early April. However, the densities, regardless of faba bean

Table 2: Seasonal abundance of *Empoasca* spp. nymphs and adults infesting faba bean varieties at Sakha Agricultural Research Station, 2019/ 2020 seasons

	Mean No./ 30 leaflets					
Sampling date	Giza 843	Giza 40	Sakha 4	Misr 3	Nubaria 1	Average over varieties
Dec 5, 2019	0.75	0.0	4.25	4.50	7.75	3.45
12	2.75	0.50	9.50	8.75	14.5	7.20
19	4.50	7.00	5.75	10.50	13.25	8.20
26	17.25	13.75	13.75	10.75	14.00	13.90
Jan 2, 2020	25.5	15.75	16.00	14.00	15.5	17.35
9	19.00	12.50	19.00	16.75	18.00	17.05
16	18.00	10.75	14.50	21.25	22.00	17.30
23	17.00	11.50	14.50	28.00	23.75	18.95
30	19.00	14.25	19.25	21.75	23.5	19.55
Feb 6, 2020	27.00	18.75	22.25	19.25	22	21.85
13	23.00	14.25	14.75	19.75	22.75	18.90
20	23.25	11.00	11.25	21.5	24.00	18.20
27	22.00	11.00	11.25	25.75	30.25	20.05
Mar 5, 2020	21.00	10.5	18.25	30.25	36.00	23.20
12	19.25	9.00	6.75	18	18.75	14.35
19	11.00	6.25	4.75	9.00	11.5	8.50
26	5.75	5.25	3.75	5.75	7.00	5.50
April 2, 2020	1.25	3.00	7.00	3.00	4.75	3.80
9	0.50	0.50	0.25	0.50	0.50	0.45
Mean ± SE	14.88±0.49b	9.24±0.20d	10.89±0.27c	15.21±0.20b	17.26±0.24a	

In the same column, means followed by the same letter are not significantly different at 5% level according to Duncan's multiple range test

Table 3: Seasonal abundance of *Empoasca* spp. nymphs and adults infesting faba bean varieties at Sakha Agricultural Research Station, 2020/ 2021 seasons

	Mean No./ 30 leaflets					
Sampling dates	Giza 843	Giza 40	Sakha 4	Misr 3	Nubaria 1	Average Over varieties
Dec 5, 2020	2.50	7.25	10.00	4.25	6.75	6.15
12	2.75	12.75	16.75	5.25	8.75	9.25
19	4.50	5.75	5.75	11.75	15.25	8.60
26	7.25	16.75	15.00	13.75	18.25	14.20
Jan 2, 2021	13.25	24.00	21.00	19.75	24.25	20.45
9	23.75	22.25	19.00	17.00	20.5	20.50
16	31.75	17.75	16.00	16.25	21	20.55
23	40.00	19.00	16.25	17.75	22.5	23.10
30	26.00	14.25	12.00	19.5	26	19.55
Feb 6, 2021	21.00	12.75	12.50	22.25	26.25	18.95
13	21.25	14.00	12.75	23.00	28.5	19.90
20	23.25	14.5	13.75	31.25	31.5	22.85
27	24.25	22.00	17.00	36.00	38.25	27.50
Mar 5, 2021	30.25	18.25	18.25	22.5	21.5	22.15
12	21.75	10.75	9.50	19.00	19.75	16.15
19	13.25	8.00	7.50	15.25	18.5	12.50
26	5.75	6.25	5.75	14.25	13.75	9.15
April 2, 2021	2.00	7.00	7.00	7.25	7.75	6.20
9	0.50	2.25	0.25	1.00	1.00	1.00
Mean ±SE	16.38±0.19a	13.49±0.37b	12.42±0.22b	16.68±0.41a	11.46±0.28c	

In the same column, means followed by the same letter are not significantly different at 5% level according to Duncan's multiple range test

varieties, were higher during January and February. Likewise the first season, the leafhopper population densities recorded two peaks of occurrence; 23.10 nymphs and adults / 30 faba bean leaflets on January 23rd and 27.50 individuals on February 27th.

***Liriomyza trifolii*:** Larvae of *L. trifolii* were counted inside the faba bean mines during 2019/2020 and 2020/2021 seasons (Tables 4 and 5).

In the first season (Table 4), numbers of larvae per 30 faba bean leaflets were very low during December and

Table 4: Seasonal abundance of *Liriomyza trifolii* and susceptibility of faba bean varieties to insect infestation, Sakha Agriculture Research Station, 2019/ 2020 seasons

	Mean No./ 30 leaflets					
Sampling date	Giza 843	Giza 40	Sakha 4	Misr 3	Nubaria 1	Average Over varieties
Dec 5, 2019	1.00	0.25	1.25	1.25	0.50	0.85
12	2.75	1.00	2.75	2.00	1.75	2.05
19	4.50	2.25	5.75	5.75	4.50	4.55
26	5.75	4.00	7.25	4.25	5.00	5.25
Jan 2, 2020	7.00	4.25	8.00	6.25	5.50	6.20
9	11.75	5.75	11.5	9.50	9.25	9.75
16	16.75	8.50	12.75	9.75	10.25	11.60
23	15.00	14.5	13.25	12.5	12.75	19.60
30	16.00	14.25	14.00	16.00	13.75	14.80
Feb 6, 2020	16.00	18.75	11.25	15.75	15.75	15.10
13	17.75	17.00	10.75	13.00	13.5	14.40
20	18.25	13.75	14.00	18.00	12.25	15.25
27	21.75	12.00	19.00	24.75	11.00	17.70
Mar 5, 2020	17.75	15.00	18.25	18.25	12.75	16.40
12	11.75	11.25	11.25	13.00	10.00	11.45
19	9.50	11.00	10.00	9.00	9.00	9.70
26	7.50	7.00	8.75	7.25	7.00	7.50
April 2, 2020	3.75	4.75	7.00	7.00	4.75	5.45
9	0.50	0.50	0.50	0.50	0.50	0.50
Mean ±SE	10.79±0.23a	8.72± 0.15c	9.75±0.23b	10.20±0.12ab	8.41±0.20c	

In the same column, means followed by the same letter are not significantly different at 5% level according to Duncan's multiple range test

Table 5: Seasonal abundance of *Liriomyza trifolii* and susceptibility of faba bean varieties to insect infestation, Sakha Agricultural Research Station, 2020/ 2021 seasons

	Mean No./ 30 leaflets					
Sampling dates	Giza 843	Giza 40	Sakha 4	Misr 3	Nubaria 1	Average over varieties
Dec 5, 2020	1	0.75	2.25	0.75	2	1.35
12	4	2.5	4.25	2	3.75	3.30
19	6.5	5.25	5.75	5.75	5.75	5.80
26	9.5	4.5	8.25	5.25	5.25	6.55
Jan 2, 2021	13.25	6	10.5	6.25	6.25	6.55
9	14.75	11.25	18.25	8.25	11.25	12.75
16	20.25	12.25	15.25	10.25	11.75	13.95
23	19.25	14.5	15.75	7	14.75	14.24
30	19.25	16.5	17.5	11.25	16	16.10
Feb 6, 2021	19	21	17	20.75	18.75	19.30
13	24.5	18.5	12.75	26.75	16.5	19.80
20	26.5	16.75	19.5	21.25	14.75	19.75
27	28	21	24.5	16.75	14.25	20.90
Mar 5, 2021	22.25	24.5	18.25	12.25	18.25	19.10
12	18.5	20.75	28	12.5	16	19.15
19	19.5	15.25	26.75	20.5	12.25	18.85
26	26.5	17.5	17	14.25	17	18.45
April 2, 2021	16	7.75	11	7	11	10.55
9	2.75	4	1	0.25	2.25	2.15
Mean ±SE	16.38± 0.19a	12.66± 0.28c	14.39± 0.25b	11± 0.23c	11.46± 0.28c	

In the same column, means followed by the same letter are not significantly different at 5% level according to Duncan's multiple range test

March, moderate in January and high during late January, throughout February and early March. However, two larval peaks were recorded; the first on February 6th (15.10 larvae/30 faba bean leaflets) and the second one on February 27th (17.70 larvae).

In the second season (Table 5), the results were similar to those of the first season. The density of *L. trifolii* larvae was obviously high during February and early March, with only one peak (20.90 larvae/30 faba bean leaflets).

Susceptibility of Faba Bean Varieties to Insect Infestations:

***Empoasca* spp.:** In 2019/2020 season (Tables 2), the five evaluated faba bean varieties significantly varied in their susceptibility to the leafhoppers, *Empoasca* spp. The highest infested variety was Nubaria-1 (17.26 nymphs and adults / 30 leaflets), followed by Misr 3 (15.21 nymphs and adults / 30 leaflets) and Giza 483 (14.88 nymphs and adults / 30 leaflets). However, the two latter varieties had no significant differences in leafhoppers infestation. The lowest infested variety was Giza 40 (9.24 nymphs and adults / 30 leaflets).

In the second season (Table 3), the two varieties, Misr 3 and Giza 843 had the highest leafhopper infestation; 16.68 and 16.38 nymphs and adults/30 faba bean leaflets, respectively without a significant difference. The least infested varieties were Sakha 4 and Giza 40 with 12.42 and 13.49 nymphs and adults respectively, but without a significant difference.

It could be reported, from the results of both seasons, that Misr 3 and Giza 843 exhibited higher infestations than did Sakha 4 and Giza 40 in both seasons.

***Liriomyza trifolii*:** The infestation by faba bean leafminer was not the same in both seasons (Table 4 and 5). In general, the infestation was highest on Giza 843 in both seasons, (10.79 and 16.38 larvae/30 faba bean leaflets in the first and second seasons, respectively). Nubaria-1 had low faba bean leafminer infestations in 2019/ 2020 (8.41 larvae) and in 2020/2021 (11.46 larvae) seasons.

Leaflet Chemical Compositions of Five Faba Bean Varieties and Their Relation with Insect Infestation: Data presented in Table (6) show the chemical analysis of faba bean varieties. The highest variety in carbohydrates content was Sakha 4 (51.21%), while the lowest one was Giza 843 (43.4%). The highest variety in protein was Giza 843 (20.13%), while Misr 3 contained the lowest protein (17.62%). Concerning lipid content, the highest content was recorded in Giza 843 (2.72 %) while the lowest content was in Sakha 4 (0.85%). The highest variety in silica content was Giza 40 (2.34 %), whereas the lowest one was Giza 843 variety (1.73 %). With regard to phenol content, the highest content was recorded in Giza 843 variety (0.56%) and the lowest content was recorded in Giza 40 (0.47%). The highest variety in chlorophyll content was in Sakha 4 (53.53%), whereas the lowest content was in Nubaria1 (36.67 %). Data revealed that the highest variety in proteins, lipids and phenol content was Giza 843 variety, whereas it has the lowest value in silica. This may promote it to have the highest average of *L. trifolii* larvae during both seasons. Whereas Nubaria1 and Misr3 had the highest average of *Empoasca* spp during two seasons respectively.

Infestation by *Empoasca* spp. negatively correlated with each of total carbohydrates, crude protein, silica, acidity and chlorophyll content.

In respect to *Liriomyza trifolii*, population non-significant correlated with total carbohydrates, silica and acidity in both seasons.

Principal Component Analysis (PCA): Data presented in Table (6) show the concentrations of chemical components in the fresh tissues of the five considered faba bean plants. The loadings plot graph of PCA, presented in the horizontal axis, indicated the direction of association among *Empoasca* spp, *Liriomyza trifolii* and chemical composition (Figure1 A and B). Results presented in Fig (1A) illustrated the first and two principal components accounted for 81.6 % (PCA1= 64.3 % + PCA2 =17.3 %) of the total variability on *Empoasca* spp. So, it is noted that chlorophyll, acidity, total carbohydrates and silica located in quarter in the right side positive of the horizontal axis according to their negative correlations with *Empoasca* spp as determined in Table (7).

About the PCA-loading plot graph for *L. trifolii*, results in Fig (1B) showed that the horizontal axis which shows the direction of association between *L. trifolii* and chemical composition, as the first and two principal components accounted for 85.5 % (PCA1= 62.4 % + PCA2 =23.1 %) of the total variability on *L. trifolii*. Chlorophyll, acidity, total carbohydrates and silica were located in right positive side of the horizontal axis according to their positive correlations with *L. trifolii* as determined in Table (7) during 2019/2020 and 2020/2021seasons, respectively.

Table 6: Leaflet of chemical composition of faba bean varieties

Variety	Total carbohydrate %	Crude protein %	Total lipid %	Silica %	Total phenol %	Acidity %	Chlorophyll ppm
Sakha 4	51.21± 0.95a	18.26 ± 0.15a	0.85 ± 0.08c	2.25 ± 0.13a	0.49±0.02ab	0.92±0.03a	53.53±7.04a
Giza 843	42.52 ± 0.26c	20.13 ± 0.22a	2.72 ± 0.18a	1.73 ± 0.12a	0.56±0.01a	0.72± 0.06a	43.4 ± 5.73a
Giza 40	47.17 ± 0.26b	18.32 ± 0.83a	2.14 ± 0.11b	2.34 ± 0.17a	0.47±0.01b	0.93± 0.04a	43.47±4.36a
Misr 3	49.92 ± 0.23a	17.62 ± 0.48a	1.69 ± 0.06b	2.27 ± 0.07a	0.49±0.01ab	0.75± 0.06a	40.6 ± 1.76a
Nubaria1	46.52 ± 0.28b	20.01 ± 0.18a	1.92 ± 0.06b	2.30 ± 0.18a	0.51±0.01ab	0.80± 0.10a	36.67±1.52a

In the same column, means followed by the same letter are not significantly different at 5% level according to Duncan's multiple range test

Table 7: Simple correlation coefficient values between faba bean insect pests and some chemical components plant

Insect pest	Season	Total carbohydrates %	Crude protein %	Total lipids %	Silica %	Total phenol %	Acidity %	Chlorophyll %
Empoasca spp.	2019/2020	-0.334	-0.334	0.285	-0.266	0.569	-0.827	-0.686
	2020/2021	-0.270	-0.270	0.450	-0.559	0.372	-0.651	-0.111
Liriomyza trifolii	2019/2020	-0.183	-0.047	0.165	-0.748	0.575	-0.566	0.313
	2020/2021	-0.496	0.432	0.272	-0.820	0.656	-0.080	0.540

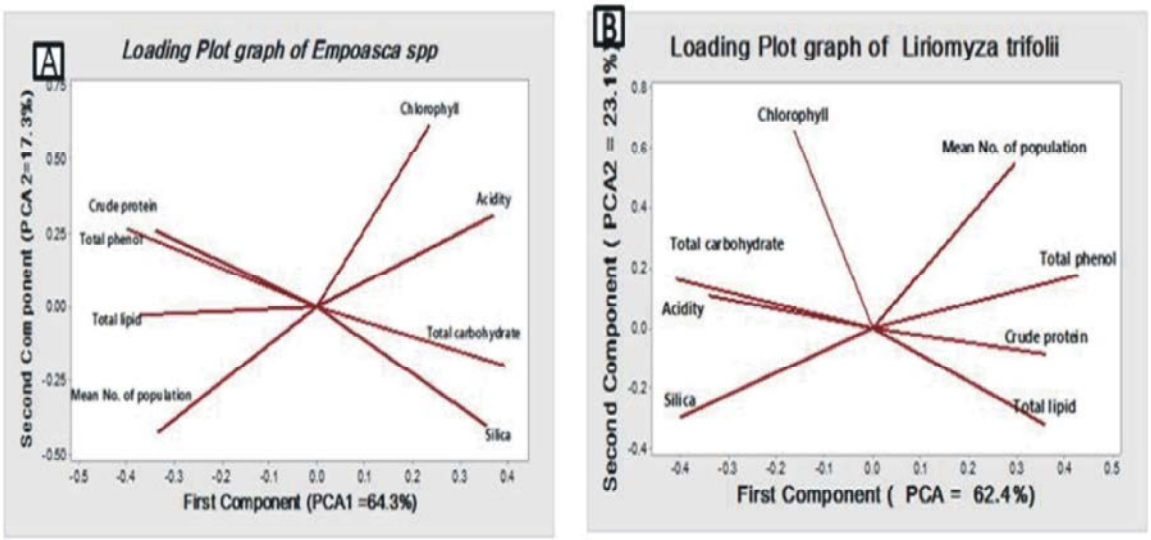

Fig. 1 (A and B): Loading plot graph, showing the first two principal components (PCA) of the correlation matrix among *Empoasca* spp., *Liriomyza trifolii* and chemical composition of faba bean leaflets

PCA-Biplot analysis was used to classify the varieties based on principal component analysis and the average of all the phenotypic characters and their response to *Empoasca* spp and *L. trifolii* as shown in (Fig. 2 A&B). PCA-Biplot analysis classified the five faba been varieties into four classes according to their response to *Empoasca* spp infestation. Results showed that Sakha4 and Giza 40 varieties were the most resistant to *Empoasca* spp. which are located in the right side, Misr 3 variety was susceptible to *Empoasca* spp shown in (Fig. 2 A). For the PCA-Biplot analysis graph, the five faba been varieties were classified based on their response to *L. trifolii* infestation and they're of chemical composition into four cluster. Sakha 4 was the most resistant to *L. trifolii* infestation followed by Giza 40, while Giza 843 was variety the most susceptible to *Empoasca* spp infestation as shown in (Fig. 2 B).

To examine the interaction effects of the two *Empoasca* spp and *L. trifolii*, infestation together on the five faba been varieties and their content of the chemical composition the PCA- loading plot and PCA- Biplot were done to understand the interaction effect of the two insects at the same time across the two growing seasons Fig. (3 A and B).

PCA-loading plot graph presented in the horizontal axis shown the direction of association among *Empoasca* spp, *L. trifolii* insect infestation and chemical composition (Figure 3, A). The first and two principal components accounted for 92.94% (PCA1= 74.16 % + PCA2 =18.78 %) of the total variability were total lipids, total phenols and crude protein in the same quarter in the right positive side of the horizontal axis referring to their positive association among *Empoasca* spp, *L. trifolii* and chemical composition of the five faba bean.

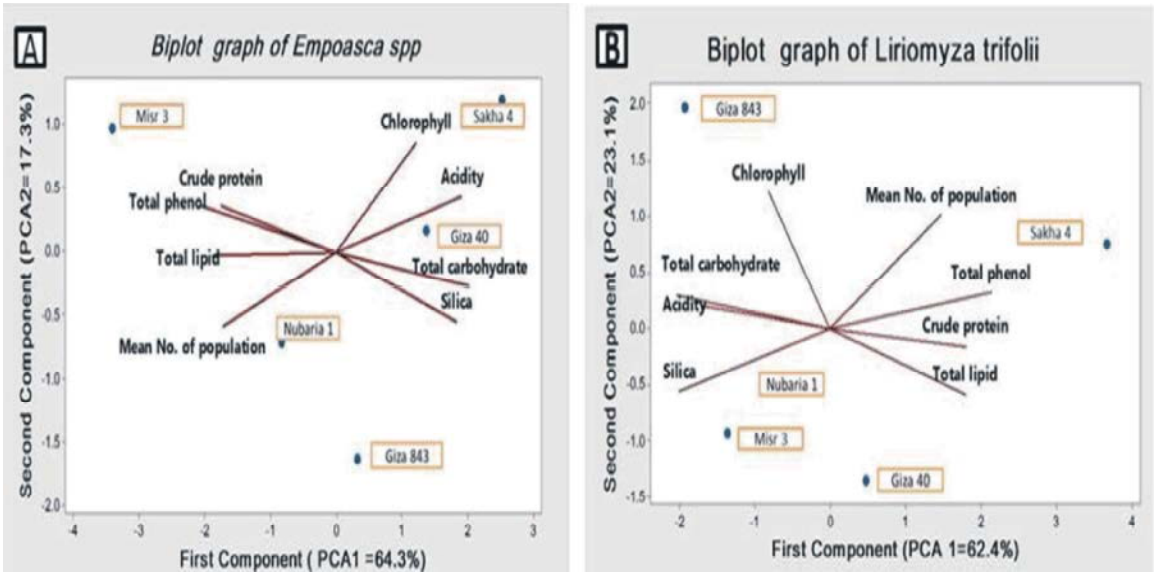

Fig. 2 (A and B): Bi- plot graph, showing the first two principal components (PCA) of the correlation matrix among *Empoasca* spp, *Liriomyza trifolii* and chemical composition on five faba bean varieties

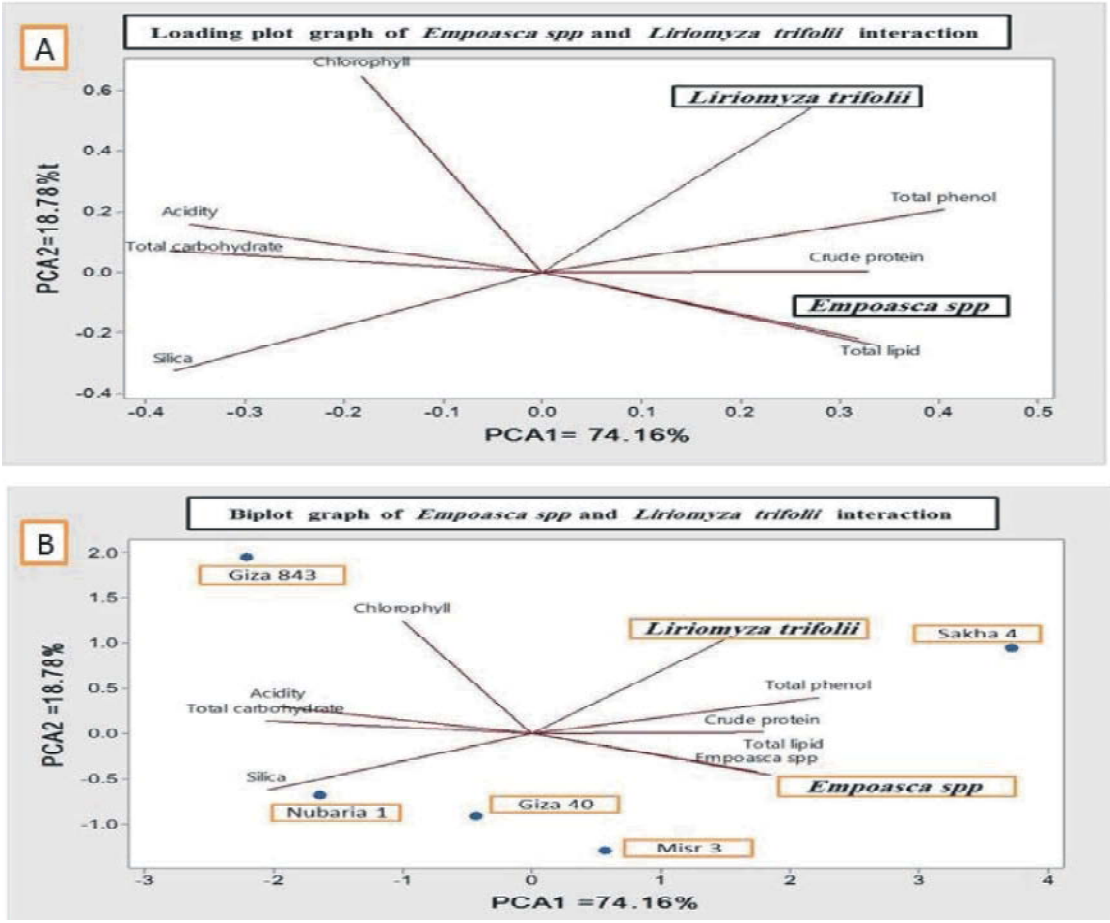

Fig. 3 (A and B): Loading and Bi- plot graph, showing the first two principal components (PCA) of the correlation matrix among *Empoasca spp, Liriomyza trifolii* and chemical composition on five faba bean varieties

Based on the PCA-Biplot analysis graph Sakha 4 was the most resistant to both *Empoasca* spp and *Liriomyza trifolii* insect infestation followed by Misr 3, Giza 40 and Nubaria 1, while Giza 843 variety was the most susceptible to both *Empoasca* spp and *Liriomyza trifolii* (Fig 3 B).

DISCUSSION

In the current study, 16 insect species belonging to eight families and three orders were recorded. The current study revealed that aphid species are one of the major threats to faba bean. At Kafr El-Sheikh region, Sherif *et al*. [19] recorded 22 insect and mite species, categorized in 15 families and eight orders. Also, Ibrahim [20] recorded 16 insect species, belonging to 11families, attacking faba bean plants, most observed insects were *Aphis craccivora* and *Liriomyza congesta*. At Sharkia, Awadalla *et al*. [21] detected four aphid species, *A. craccivora*, *A. gossypii, A. pisum* and *Myzus persicae* attacking faba bean plants.

On the other hand, *Liriomyza trifolii* and *Empoasca* spp were surveyed in the current study. Several species of jassid were recorded by Helal *et al*. [22], El-Mashaly [23], Hatem [24], Abou-Elkassem [8], Allam [9] and El-Dessouki [25]. In this investigation, leafhoppers, *Emposca* spp. were found in relatively high population densities in February and early March during 2019/2020 and 2020/2021 faba bean season, with two peaks of this insect occurrence in each season. Each of Helal *et al.* [22], El-Gindy [26], Khattab *et al.* [27] and El-Sarand *et al.* [28]. Recorded two peaks for the leafhoppers, despite different locations. Other authors Ibrahim [29], El-Mashaly [23], Hatem[24] and Abou-El Kassem [8] recorded three or four peaks during faba bean season.

In addition, one of the targets of this study was monitoring the abundance of *L. trifolii*. Two peaks of insect abundance were recorded in each season of study on faba bean plantation. The first peak occupied the period from late January to early February, while the second one occurred from late February up to early March. Numbers of recorded peaks varied in the investigation of previous authors, may be due to variation in weather factors, to different cultivated faba bean varieties, or to the leaf miner species itself. *L. congesta* exhibited 2-3 peaks El-Mashaly [23], *L. trifolii* peaked three times Hatem [24]. Both Abou-El Kassem [8] and El-Sarand *et al.* [27] detected 3-4 of two peaks, respectively.

Giza 843 had moderate to high infestation by *Empoasca* spp in the current study, which is similar to the result obtained by Awadalla *et al*. [30]. As for Susceptibility of faba bean varieties to infestation by *Empoasca* spp, Abou-El Kassem [8] revealed that statistical analysis revealed significant differences among the 6 tested varieties to infestation with *Empoasca* spp. in the first season while the different were not significant during two seasons (2014/2015-2015/2016). Susceptibility of faba bean varieties to infestation with *L. trifoli* larvae, Our results are similar to those obtained by, Sherif *et al*. [19] indicated that Giza 461 and Giza 3 proved to be the most susceptible varieties to infestation with *L .trifolii* with number of larvae ranging between 79.22 and 155.91 per 100 faba bean leaflets Khattab *et al*. [31] and El-Mashaly [23] showed that the highest average number of *L .congesta* larvae was recorded on Giza 3 variety with an average of 157.6 ±3.4 larvae / 100 leaflets followed by Sakha 3 variety while the lowest average number of leaf miner was recorded on Sakha 2 variety with an average of 91.6±2.3 larvae /100 leaflets. The same trend was recorded in the second season. Bastawisy *et al*. [32] Found that Giza 3 was highly susceptible to leaf miner in both seasons, while lines 1.8415/797/92 and L848/1428/92 were least susceptible. Hashem *et al*. [33] and Allam [9].

PCA-Biplot analysis graph showed, in the current study, that Sakha-4 was the most resistant to both *Empoasca* spp and *L. trifolii*, followed by Misr-3, while Giza-843 was the most susceptible. The results are in the same trend of Metsalu *et al*. [34] and Mariey *et al*. [35] and Mariey *et al*. [36] who referred to the importance of understanding the relationships among phenotypic traits using the simple correlation coefficient, the principal component analysis (PCA) analysis and cluster analysis in classifying plant genotypes as well as interaction between behavioral genetics environmental stress (GXE).

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