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Impact of Some Foliar Applications on The Yield and its Components of Some Pea Cultivars and their Tolerance to Infestation by Main Insect Pests

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ABSTRACT

The present work was carried out during the 2021/2022 and 2022/2023 seasons at The Experimental Farm of Shandweel Agricultural Research Station, Sohag Governorate, Egypt to evaluate the effects of foliar spray applications with abscisic acid, salicylic acid and chitosan on some vegetative and yield characteristics of four pea cultivars and their susceptibility to infestations by each of aphid, thrips, and leafminer. Data revealed that the foliar spray application enhanced all vegetative and yield characteristics, however, the infestations with the three studied insect pests decreased significantly compared to the control. It is clear that the differences between the four pea cultivars and between the four foliar spray applications were significant in both seasons of the study, also, the interaction between them was significant in both seasons. In almost, salicylic acid was the best foliar spray application in regard to pea production and insect pest control. On the other hand, pea cultivars varied in their response to the foliar spray application with the previous materials and they need more studies.

Keywords: *Pisumsativum*, Salicylic, Abscisic and Chitosan.

1. Introduction

Pea (*Pisum sativum* L.) is one of the most important vegetable crops belonging to the family Leguminoceae grown during winter plantation in Egypt for exportation and local consumption as fresh, frozen or dehydrated. Pea is considered a good source in human food nutrition, it contain a good amount of protein, carbohydrates, fats, minerals and vitamins (Marwa *et al.*, 2020). Increasing the pea yield in the unit area and enhancing its quality could be achieved by using the exogenous application of some antioxidants, i.e., abscisic acid (ABA), salicylic acid (SA) and chitosan (CHI) (Hayat *et al.*, 2010; Latif, 2014; Malerba and Cerana 2016 and Abdelmageed *et al*., 2020). Infestation of pea plants by aphid (*Aphis craccivora* (Koch.), thrips (*Thrips tabaci* Lindeman) and leafminer (*Liriomyza trifolii* Burg.) can cause notable yield loss (Shaalan and El-Ghanam, 2016 and Shalaby *et al.*, 2021). In addition to the positive effects of ABA, SA and CHI on yield, the previous compounds can improve plant resistance against insect infestation (El-Khawas, 2012; Mony *et al.*, 2017; Hammam *et al.*, 2019 and Ragab *et al.*, 2021). Increasing the production of pea green pods yield and decreasing insect infestation are considered the main aims, therefore, the present study was conducted to evaluate the effects of foliar spray applications with ABA, SA, and CHI on the growth and green yield as well as the susceptibility of some pea cultivars to infestations by aphid, thrips, and leafminers under Sohag Governorate conditions.

2. Materials and Methods

The experiment was carried out during the two growing seasons of 2021/2022 and 2022/2023 at The Experimental Farm of Shandweel Agricultural Research Station, Sohag Governorate, Egypt. The experiment included 16 combinations between four pea cultivars, *i.e.,* Balmoral, Sweet 2, Progress 9 and On Ward along with four antioxidants as foliar application treatments consisted of ABA (20 ppm), SA (200 ppm) and CHI (200 ppm) in addition to the control treatment (water only). The fore mention combinations were arranged in a split plot in a complete randomized block design with three replicates.

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The main plots and the subplots were used for the pea cultivars and the foliar applications, respectively. Each experimental unit was 10.5 m^2 (5 ridges at 0.6 m apart and 3.5 m in length). Sowing was done on 22nd November in both seasons. Normal agricultural practices were adopted and no insecticidal treatments were used during the whole of two seasons. Experimental plots were sprayed with the three antioxidants after 30 and 45 days of sowing date using a hydraulic sprayer (control plots applied only with water).

2.1. Recorded data

2.1.1. Horticultural traits:

For the flowering date, the time from the planting date until 50% of the plants had the first open flower in the plot was recorded. At the end of each season, samples consisted of 10 plants were randomly taken from each plot to determine stem length (cm, at ripeness), number of branches/plant (after harvesting), pod length (cm, at fresh harvesting time), number of seeds per pod, shellout percentage (by dividing the weight of seeds per pods by the weight of the whole pods as average of randomly sampled pods multiplied by 100), number of pods per plant (at harvesting), green100 seeds weight (g, after fresh seed harvesting), fresh pod yield/plant (g, after fresh harvesting) and fresh yield/feddan (ton, total fresh pod yield per feddan).

2.1.2. Insect data:

The experimental plots were left for natural insect infestation. The inspection period started after 15 days from the planting date (6th December) and continued at weekly interval till crop harvest (14th March) for the three studied insect pests. The number of adults and immature stages of thrips was recorded on 10 leaves which were randomly chosen per each plot in the early morning in the field. After that, samples of 10 leaves were randomly collected from three levels, i.e., lower, middle and upper of pea plants, then transferred in polyethylene bags to the laboratory to determine the numbers of aphid and mines due to leafminers.

3. Statistical analysis:

The mean of horticultural and insect data was subjected to statistical analysis following the analysis of variance technique according to Gomez and Gomez (1984) and means were compared using new L.S.D at 5%.

3. Results and Discussion

Two seasons applied experiments were conducted without any insecticides to study and evaluate the probability of some anti-oxidants [abscisic acid (ABA), salicylic acid (SA) and chitosan (CHI)] and their role in mitigating the adverse effect of insects on pea plants in Upper Egypt region. It seems very likely that, in the current work, the effect of insect stress on the pea crop is restricted to exposure to the effect of insects without any protection. Therefore, the control plants of the sub-plot treatment), which do not receive any recommended pesticides (with distilled water foliar spray) was not protected against insects and their adverse effects. Thus, the results of the corresponding sub-plot control treatments are considered insect stress data.

3.1. Cultivar effects:

Sweet 2 was the earliest cultivar (57 and 56.93 days) and the highest of seeds numerous per pod while Progress 9 recorded the latest cultivar (62.75 and 61.25 days) and exhibited the highest values all other studied traits except shellout percentage and no. of pods/plant in which Balmoral and On Ward were the highest values, with no significant differences between them for both traits in both seasons (Table 1). However, the heaviest weight of green 100 seeds (56.38 and 57.56 g), fresh pod yield /plant (152.87 and 158.06 g) and fresh yield/feddan (4.43 and 4.58 ton) were achieved from Progress 9 cultivar in both seasons respectively, however, Sweet 2 showed (116.46 and 121.9 g) for the weight of fresh pod yield/plant and (3.38 and 3.53 ton) for fresh yield/ feddan as the lowest values in studied seasons while the lowest means of green 100 seeds weight were obtained by On Ward 37.67 and 38.19 g in two seasons, respectively.

Table 1: Effect of pea cultivars on vegetative growth and pod traits as well as fresh pod yield during 2021/2022 and 2022/2023 seasons.

Item	2021/2022 season					2022/2023 season				
	Balmoral	Sweet 2	Progress 9	On Ward	L.S.D. 0.05	Balmoral	Sweet 2	Progress 9	On Ward	L.S.D. 0.05
Flowering date	62.5	57	62.75	61.25	3.27	60.2	56.93	61.25	60.08	1.04
Stem length	96.82	95.96	105.88	101.75	2.31	86.65	85.76	94.23	87.01	0.91
No. of branches/plant	3.47	3.6	4.18	3.85	0.46	3.88	3.68	4.34	3.93	0.36
Pod length	8.02	10.57	11.04	7.69	0.64	8.4	11.1	11.08	8.32	0.51
No. of seeds/pod	7.39	9.27	7.07	6.88	0.87	7.53	9.15	6.96	6.88	0.66
Shellout percentage	58.53	53.13	48.44	57.28	2.44	59.48	54.46	49.76	58.43	1.97
No. of pods/plant	44.51	26.86	41.1	45.61	1.86	46.98	27.89	42.3	47.03	3.34
Green 100 seeds wt.	45.36	47.65	56.38	37.67	2.12	46.5	48.72	57.56	38.19	1.96
Pod yield/plant(g)	143.66	116.46	152.87	119.4	5.2	148.81	121.9	158.06	122.97	3.96
Fresh yield/fed (ton)	4.17	3.38	4.43	3.46	0.14	4.32	3.53	4.58	3.53	0.15

3.2. Anti-oxidants foliar spray effects:

It is clearly illustrated that all foliar spray applications significantly increased earliness and all other studied traits in both seasons except ABA on stem length which was not significant in 1st season compared to the control. The earliest flowering date was recorded by SA (59 and 57.56 days in 1st and 2nd seasons, respectively). It is worth noted that, no significant differences were observed between the three antioxidants for flowering date and pod length in both seasons as well as no. of seeds/pod and fresh yield/fed in 1st and 2nd seasons, respectively. Also, data tabulated in (Table 2) reveal that the differences between foliar spray treatments were significant in both seasons compared to untreated pea plants. The heaviest weight of green 100 seeds (50.88 and 51.81 g), fresh pod yield/plant (149.68 and 154.19 g) and fresh pod yield/feddan (4.34 and 4.47 ton) were found in SA treatment in both seasons, respectively.

Treated plants with the different antioxidants showed that 200 ppm of SA exhibited a high significant increment in most studied traits in both seasons, *i.e*., earliness, number of branches, pod length, seed number, and fresh pod yield per feddan as well as shellout percentage, number of pods, 100-seeds weight and pod yield per plant by 8.5%, 45.1%, 11.3%, 20.3% and 46.3% as well as 13.6%, 46.7%, 22.3%and 45.5%, respectively in the average of both seasons over the corresponding untreated plants (control) followed by ABA in earliness, no. of branches, pod length, seed number, pod number, pod yield/plant and pod yield /fed.

Table 2: Effect of foliar spray treatments with antioxidants on vegetative growth and pod traits as well as fresh pod yield during 2021/2022 and 2022/2023 seasons.

Item	2021/2022 season					2022/2023 season				
	ABA	SA	CHI	Control	L.S.D. 0.05	ABA	SA	CHI	Control	L.S.D. 0.05
Flowering date	60.5	59	60.75	63.25	1.81	58.45	57.56	58.33	64.12	1.12
Stem length	98.76	101.04	102.14	98.47	2.93	89.24	90.63	90.86	82.92	0.38
No. of branches/plant	4.02	4.34	3.74	3	0.45	4.42	4.44	3.91	3.05	0.45
Pod length	9.65	9.66	9.29	8.74	0.53	10.04	10.11	9.73	9.03	0.41
No. of seeds/pod	8.06	8.2	7.58	6.76	0.46	7.75	8.19	7.72	6.86	0.53
Shellout percentage	54.84	57.2	55.09	50.25	1.5	56.13	58.22	56.47	51.32	1.05
No. of pods/plant	41.5	44.85	41.2	30.54	1.27	43.15	46.57	42.7	31.78	1.88
Green 100 seeds wt.	45.91	50.88	48.71	41.58	1.57	47.32	51.81	49.43	42.41	2.45
pod yield/plant(g)	143.14	149.68	137.21	102.36	3.17	148.17	154.19	142.91	106.46	3.44
Fresh yield/fed (ton)	4.15	4.34	3.98	2.97	0.9	4.29	4.47	4.14	3.05	0.11

Our results have coincided with those of Gad El-Hak *et al.* (2012), El-Sayed *et al.* (2014), Abd Elkader, (2016), Abdelmageed *et al.* (2020), and Ragab *et al.* (2021). They stated that the beneficial

effects of the applied treatments individually or in combination with different genotypes may be also explained due to their functional roles where they found that the foliar spray application by SA impacted the yield and quality of pea plants and productivity because of these compound has a favorable impact on the plant to high photosynthetic rate, therefore, may be the cause of the observed increase in vegetative growth and thus returned to the productivity.

3.3. Interaction effects:

Table 3 shows the abovementioned studied traits of pea plants sprayed with different antioxidants interacting with some cultivars. It is clearly noted that all anti-oxidant treatments combined with cultivars gave statistically equivalent or increased values in all vegetative growth traits compared to the corresponding control treatments, indicating the efficient role of the studied antioxidants to plant enhancement.

Table 3: Effect of interaction between pea cultivars and foliar spray treatments on flowering date, stem length, no. of branches /plant, pod length, number of seeds/pod, shellout %, no. of pods/plant, 100 seeds weight, pod yield/plant and pod yield/feddan during 2021/2022 and 2022/2023 seasons.

Item		F days	SL (cm)	BN	PL (cm)	SN	Sh (%)	PN	100-SW (g)	PY/P (g)	PY/fed (ton)
2021/2022 season											
Balmoral	**ABA**	63	95	3.67	8.23	7.75	58.14	43.2	45.31	157.1	4.55
	SA	61	96.47	4	8.16	7.52	60.83	48.77	49.97	161.42	4.68
	CHI	62	97.7	3.5	7.97	7.28	59.68	47.04	47.01	150.36	4.36
	Control	64	94.11	2.72	7.71	7	55.45	39.04	39.17	105.75	3.08
Sweet 2	**ABA**	57	94.03	4	11	9.64	54.56	27.52	47.04	123.72	3.58
	SA	55	99.41	4.36	11.2	10.11	54.5	31.7	50.8	131.61	3.81
	CHI	56	96.92	3.55	10.59	9	52.51	25.15	49.72	118.53	3.43
	Control	60	93.49	2.5	9.5	8.33	50.96	23.06	43.04	91.97	2.67
Progress 9	**ABA**	62	105.72	4.5	11.43	7.56	48.48	46.04	54.22	167.05	4.85
	SA	61	104.39	4.72	11.23	7.44	54.03	46.78	62.51	170.23	4.94
	CHI	63	108.2	4	11	7.06	51.31	41.57	58.53	152.39	4.43
	Control	65	105.22	3.5	10.5	6.22	39.92	30.03	50.27	121.42	3.52
On Ward	**ABA**	60	100.28	3.92	7.93	7.28	58.16	49.23	37.07	124.67	3.62
	SA	59	103.91	4.28	8	7.72	59.44	52.15	40.24	135.48	3.93
	CHI	62	105.76	3.92	7.58	7	56.85	51.03	39.56	127.16	3.69
	Control	64	97.06	3.28	7.27	5.5	54.67	30.04	33.83	90.3	2.62
L.S.D. 0.05		3.62	5.86	0.89	1.06	0.92	3.01	2.55	3.14	6.34	0.18
2022/2023 season											
Balmoral	**ABA**	60	86.61	4.34	8.62	7.68	59.27	45.66	47.51	163.47	4.74
	SA	57.9	86.56	4.36	8.79	7.89	61.25	51.96	50.89	165.57	4.8
	CHI	58	89.42	3.81	8.47	7.56	60.9	49.33	47.44	155.72	4.52
	Control	64.9	84.02	3	7.73	7	56.51	40.96	40.17	110.46	3.21
Sweet 2	**ABA**	54.9	93.33	4.34	11.42	9.33	55.9	28.26	48.44	129.31	3.75
	SA	54.9	90.22	4.38	11.48	10	55.96	32.91	51.89	136.22	3.94
	CHI	56	80.28	3.5	11.17	9	53.64	26.19	50.44	125.5	3.63
	Control	61.9	79.22	2.5	10.34	8.28	52.33	24.21	44.1	96.58	2.8
Progress 9	**ABA**	61.9	94.34	5	11.5	7	50.12	47.21	55.44	170.69	4.94
	SA	58.1	93	4.7	11.32	7.44	55.39	48	63.89	175.64	5.09
	CHI	60	98.45	4.33	11	7.03	53.35	43	59.72	159.15	4.62
	Control	65	91.11	3.31	10.5	6.38	40.19	31	51.17	126.75	3.68
On Ward	**ABA**	57	82.69	4	8.6	7	59.21	51.46	37.89	129.22	3.75
	SA	59.33	92.72	4.34	8.87	7.44	60.28	53.42	40.56	139.31	4.04
	CHI	59.33	95.3	4	8.28	7.28	57.99	52.27	40.1	131.28	3.8
	Control	64.67	77.33	3.38	7.52	5.79	56.23	30.96	34.2	92.07	2.52
L.S.D. 0.05		2.23	0.76	0.9	0.82	1.06	2.11	3.76	4.9	6.87	0.23

Upon spraying of the Progress 9 cv plants with SA treatment, the highest value in the 100-seed weight , pod yield/plant, and pod yield/fed as well as medium or over medium values in all other studied traits was observed (Table 3) in both seasons, resulting in an increment percentage Fig. 1 (as the average of both seasons) by 0.5%, 7.4%, 8.4%, 18.1%, 24.6%, 36.6%, 38.3%, 39.3%, 39.4%, and 55.3% in ascending order for stem length (SL), pod length (PN), earliness, no. of seeds/pod (SN), 100-seed

weight (100-SW), shellout % (Sh), number of branches (BN), pod yield/fed (PY/fed), pod yield /plant (PY/P) and no.of pods/plant (PN) over the corresponding control (Fig. 1) followed by Progress 9 × ABA which has the highest for no. of branches/ plant (BN) and pod length (PL) as well as medium or over medium values in all other studied traits except the no. of seeds/pod (SN) and shellout percentage(Sh), resulting in an increment percentage (as the average of both seasons) by 1.9%, 4.7%, 8.1%, 9.2%, 15.6%, 23.1%, 36.0%, 36.1%, 39.5% and 52.8% in ascending order for stem length(SL), earliness,100-seed weight (100-SW), pod length(PL), no. of seeds/pod (SN), shellout % (Sh), pod yield/fed (PY/fed), pod yield /plant (PY/P), no. of branches/plant (BN) and no. of pods/plant (PN) followed by Sweet 2 × SA which was the earliest cultivar and has the highest number of seeds and medium or over medium values in all other studied traits except number of pods/plant, resulting in an increment percentage (as average of both seasons) by 6.9%, 9.8%, 9.8%, 14.3%, 17.8%, 21.1%, 36.7%, 41.7%, 42.0% and 74.8% in ascending order for shellout % (Sh), earliness, stem length (SL), pod length (PL), 100-seed weight (100-SW), no. of seeds/pod (SN), no. of pods/plant (PN), pod yield/fed (PY/fed), pod yield /plant (PY/P) and no. of branches/plant (BN). Moreover, Balmoral × SA, Progress 9× CHI, and On Ward × (SA or CHI) exhibited the highest values in shellout % (Sh), stem length (SL), and no. of pods/plant (PN), respectively, and medium or over medium in most other traits.

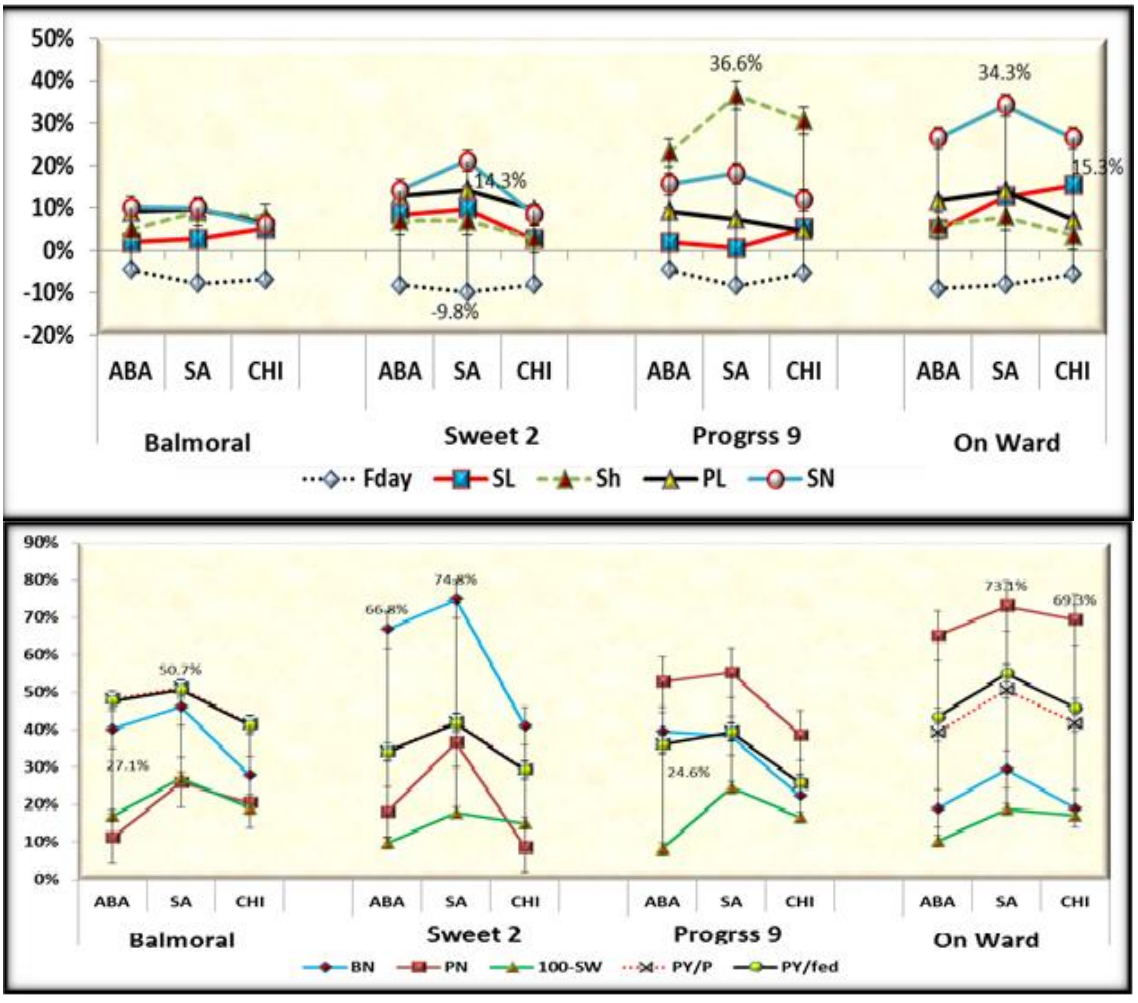

Fig. 1: Changes in percentage for vegetative growth and pod traits as well as fresh pod yield as affected by the interaction between cultivars and antioxidants foliar spray on pea plants in the average of 2021/2022 and 2022/2023 seasons both seasons.

The significant increments in the obtained characters over control may be due to the protective and recovered specific transporter enzymes and/or the whole machinery under stress conditions (Palta,

2000) where, foliar spray applications plants, have beneficial effects on the metabolic potential for synthesis of amino acids, proteins, sugars, and carbohydrates, as well as, their antioxidant defensive function, corresponding with normal growth and high yielding capacity (Fathy and Khedr, 2005). Nevertheless, the beneficial effects of the different cultivars may be explained due to the genetic structure greatly affecting their ability to adapt to adverse environmental conditions. Moreover, the internal physiological disturbances and the accompanied agronomical depression affected control plants were greatly ceased by all the applied antioxidant treatments, which succeed in alleviating the deleterious effects of the insect's infestations, due to their antioxidant roles in quenching formed reactive oxygen radicals or activating enzymes related to scavenging and removing the toxic and degradable ROS away from the center of the active metabolic machinery of plant tissues i.e. peroxidase, superoxide dismutase and catalase (Noctor and Foyer, 1998). Moreover, the active roles of ABA, SA, and CHI which act as antioxidants that protect the cell from oxidative processes that are due to environmental stresses, impede the growth process and affect the yield.

3.4. Insect infestation:

3.4.1. Cultivar effects:

The susceptibility of the four tested pea cultivars to the infestation of pea plants by *A. craccivora*, *T. tabaci* and *L. trifolii* is shown in Table 4. It is clear that the differences between the four pea cultivars were significant in both seasons of the study. Data in Table 4 show that the lowest mean number of aphid was observed in Balmoral cultivar with 23.83 and 28.42 aphids/10 leaves in the 1st and 2nd seasons, respectively, followed insignificantly by Sweet 2 and Progress 9 cvs in the 1st season. While, the On Ward pea cv recorded the highest mean number of aphid (31.91 and 34.97 aphids/10 leaves in the 1st and 2nd seasons, respectively). Moreover, Sweet 2 and On Ward recorded the lowest mean number of thrips in 2021/2022 and 2022/2023 seasons, respectively, by insignificant difference between them in the 1st season, with mean numbers of 6.60 and 6.76 thrips/ 10 leaves, respectively, in the 1stseason, and with 6.83 and 5.74 thrips/ 10 leaves, respectively, in the 2nd season. However, the highest mean number was observed on Progress 9 with 7.40 and 6.88 thrips/ 10 leaves in the two seasons, respectively, by insignificant differences with Balmoral in both seasons and with Sweet 2 in the 2nd season only. As for leaf miners, data in Table 4 show that Progress 9 (6.58 and 6.86 mines/10 leaves) and On Ward (6.76 and 6.60 mines/10 leaves) pea cultivars exhibited the lowest mean number of miners with no significant differences between them in both seasons were observed. While, the highest mean number was observed in Balmoral cultivar in both seasons, with 8.86 and 8.97 mines/ 10 leaves in the two seasons, respectively.

In previous studies, many investigators reported that pea cultivars differed in their susceptibility to insect infestation (Pobozniak and Koschier, 2014; Khan *et al.*, 2015 and Omar *et al.*, 2023), they added that may due to differences in some morphological and chemical characters.

Table 4: Effect of pea cultivars and foliar spray treatments with abscisic acid, salicylic acid and chitosan on infestation with *Aphis craccivora*, *Thrips tabaci* and *Liriomyza trifolii* during 2021/2022 and 2022/2023 seasons.

	Mean number/ 10 leaves					
	Aphis craccivora		***Thrips tabaci***		***Liriomyza trifolii***	
	2021/2022 season	**2022/2023 season**	**2021/2022 season**	**2022/2023 season**	**2021/2022 season**	**2022/2023 season**
Pea cultivar						
Balmoral	23.83	28.42	7.06	6.83	8.86	8.97
Sweet 2	26.27	30.90	6.60	6.60	7.83	7.72
Progress 9	26.21	31.09	7.40	6.88	6.58	6.86
On Ward	31.91	34.97	6.76	5.74	6.76	6.60
L.S.D.	3.0753	1.8004	0.3983	0.4456	0.6427	0.3845
Foliar treatment						
ABA	27.52	29.99	6.47	7.24	6.49	7.64
SA	20.01	25.06	5.04	4.46	5.37	5.76
CHI	25.55	29.41	4.94	4.26	6.38	6.43
Control	35.13	40.91	11.37	10.09	11.80	10.32
L.S.D.	2.6626	1.6989	0.5550	0.3626	0.5211	0.6445

3.4.2. Anti-oxidant foliar spray effects:

As shown in Table 4, the foliar application with ABA, SA and CHI decreased significantly the infestation by *A. craccivora*, *T. tabaci* and *L. trifolii* compared to the control in both seasons of the study. For *A. craccivora*, the lowest infestation was recorded with the application of SA (20.01 and 25.06 aphids/10 leaves in the 1st and 2nd seasons, respectively), followed by CHI (25.55 and 29.41 aphids/10 leaves in the 1st and 2nd seasons, respectively) and ABA (27.52 and 29.99 aphids/10 leaves in the 1st and 2nd seasons, respectively), compared to 35.13 and 40.91 aphids/10 leaves in the 1st and 2nd seasons, respectively in untreated plots. However, the lowest *T. tabaci* infestation was recorded in CHI with 4.94 and 4.26 thrips/10 leaves in the two seasons, respectively, followed insignificantly by salicylic acid with 5.04 and 4.46 aphids/10 leaves in the two seasons, respectively, compared to 6.47 and 7.24 thrips/10 leaves in the two seasons, respectively, in ABA and with 11.37 and 10.09 thrips/10 leaves in the two seasons, respectively, in untreated plots. On the other hand, the lowest mean number of mines due to *L.trifolii* larvae was recorded in SA with 5.37 and 5.76 mines/10 leaves in the two seasons, respectively, followed by CHI with 6.38 and 6.43 mines/10 leaves in the two seasons, respectively, with insignificant differences between them in the second season. However, ABA acid recorded 6.49 and 7.64 mines/10 leaves, in 2021/2022 and 2022/2023 seasons, respectively, compared with 11.80 and 10.32 mines/10 leaves for control in the two seasons, respectively. As for the average of the two seasons (Fig. 2), it is clear that the spray applications by SA gave the highest reduction in the infestation of pea plants with *A. craccivora*, *T. tabaci* and *L. trifolii* by 40.89%, 55.75 and 49.34%, respectively, followed by CHI with 27.69%, 57.18% and 41.80% for the three previous insect pests, respectively, while, ABA recorded average numbers of reduction of 24.18%, 35.68% and 35.46% for the three previous insect pests, respectively. Our results are in wide agreement with El-Khawas (2012) Elhamahmy *et al.* (2016), Chapman *et al.* (2018), Hammam *et al.* (2019) and Ahmad *et al.* (2022), they found that the foliar application by ABA, SA and CHI decreased significantly the infestation by aphid, thrips or leafminer compared to untreated plots.

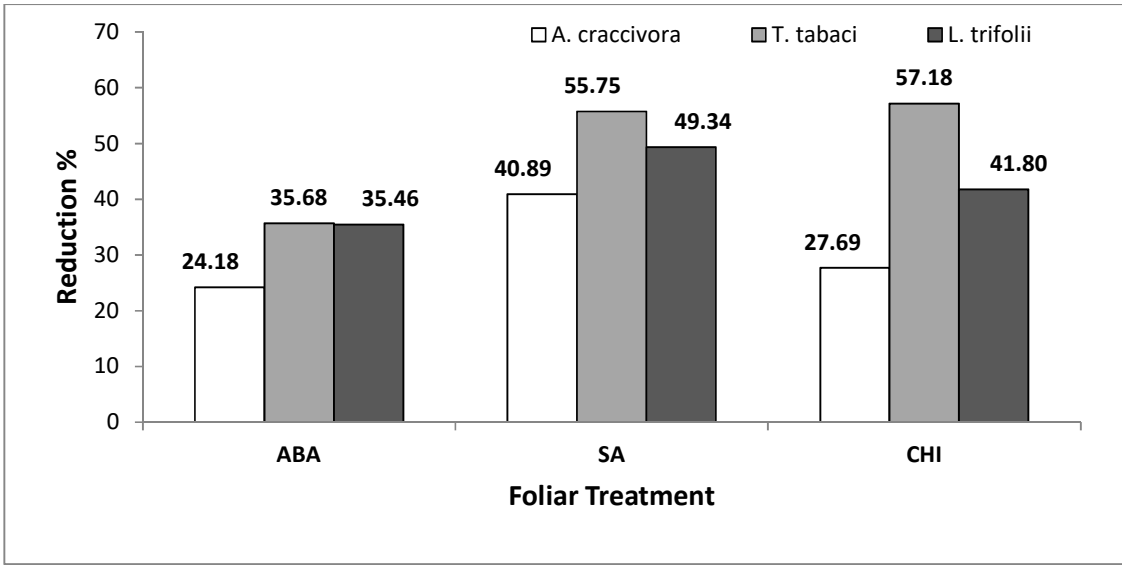

Fig. 2: Effect of abscisic acid (ABA), salicylic acid (SA) and chitosan (CHI) on infestation with *A craccivora*, *T. tabaci* and *L. trifolii* in average of both 2021/2022 and 2022/2023 seasons.

3.4.3. Interaction effects:

Data in Table 5 show the effect of interaction between the four pea cultivars and the four foliar spray applications on the infestation of pea plants by *A. craccivora*, *T. tabaci* and *L. trifolii*, it is clear that the interaction between them was significant in both seasons.

For *A. craccivora*, Balmoral sprayed by SA received the lowest infestation with 17.80 and 21.76 aphids/ 10 leaves in 2021/2022 and 2022/2023 seasons, respectively, with insignificant differences with Balmoral x CHI, Sweet2 x ABA, Sweet 2 x SA, Progress 9 x CHI and On Ward x SA in the first season, and with Progress 9 x SA in both seasons. The highest infestation of 36.73 and 46.40 aphids/ 10 leaves

was recorded in untreated On Ward plots in the two seasons, respectively, with insignificant differences with Balmoral x control, Sweet 2 x control, Progress 9 x control and On Ward x CHI in the first season only (Table 5). For *T. tabaci*, Balmoral x SA and Sweet 2 x CHI recorded the lowest infestation in the two seasons, respectively, with 3.73 and 3.76 mines/ 10 leaves, respectively, in the first season, and with 3.93 and 3.71 mines/ 10 leaves, respectively, in the second season. No significant differences were observed between them on the side and Sweet 2 x SA on the other side in both seasons, also, the two combinations did not differ significantly with Progress 9 x CHI and On Ward x CHI in the second season. On the other hand, the combination of Sweet 2 x control received the highest infestation in both seasons with 13.33 and 11.89 thrips/ 10 leaves in the two seasons, respectively. In regard to *L. trifolii*, the lowest mean number of mines was recorded in Progress 9 x SA with 3.49 and 3.69 mines/ 10 leaves in the two seasons, respectively, followed insignificantly by Progress 9 x CHI in both seasons of the study, however, the highest one was recorded in Balmoral x control in both seasons with 15.24 and 12.87 mines/ 10 leaves in the two seasons, respectively. As shown in Fig. 3, the reduction level differed according to the type of cultivar, foliar spray application and insect pest. All cultivars gave the highest response to SA followed by CHI and ABA was the least in the case of *A. craccivora*, except for Sweet 2. However, in the case of *T. tabaci*, CHI was the highest one, followed by SA except for Balmoral. Also, SA gave the highest reduction of *L. trifolii* for all cultivars except for On Ward. In previous studies, many authors found that the interaction between the anti-oxidant foliar spray and plant cultivars was significant, also, they added that the plant cultivars differ in their response to different foliar treatments **(**Thaler and Bostock, 2004; Mony *et al.,* 2017 and Ragab *et al.*, 2021).

Data in the average of both seasons (Table 5 and Fig. 4) indicated that the gradual reduction of infestation % was observed as a result of Genotypes × antioxidants interactions. Upon spraying of the Balmoral and Progress 9 cvs plants with SA treatment, the highest decreasing % in aphid and combined insects, as well as medium or over medium % in thrips and leafminer, was observed (Table 5 and Fig. 4) as average seasons, resulting in an enhancing percentage (as the average of both seasons) by 65.4%, 63.1%, 58.1%, and 45.9% in descending order for the effects of Balmoral on thrips, leafminers, whole insects and Aphid over the corresponding control followed by Progress 9 × SA which has the highest reduction for leafminers (70.1%) and medium or over medium % in other insects. On the other hand, Sweet 2 x CHI or SA gave the highest reduction of thrips (70.4 and 68%). All these reduction percentages in insect levels were along with increases in yield.

Table 5: Effect of the interaction between pea cultivars and foliar spray treatments with ABA, SA and CHI on infestation with *Aphis craccivora*, *Thripstabaci* and *Liriomyza trifolii* during 2021/2022 and 2022/2023 seasons.

Pea cultivar	Foliar treatment	Mean number/ 10 leaves					
		Aphis craccivora		*Thrips tabaci*		*Liriomyza trifolii*	
		2021/2022 season	2022/2023 season	2021/2022 season	2021/2022 season	2022/2023 season	2021/2022 season
Balmoral	**ABA**	23.38	28.76	7.18	7.98	8.56	10.60
	SA	17.80	21.76	3.73	3.93	5.00	5.36
	CHI	17.91	26.31	5.36	5.24	6.64	7.07
	Control	36.22	36.84	11.98	10.18	15.24	12.87
Sweet 2	**ABA**	22.53	26.44	5.09	6.96	5.93	7.22
	SA	20.16	25.42	4.22	3.84	6.22	6.29
	CHI	26.98	32.20	3.76	3.71	8.58	8.76
	Control	35.40	39.53	13.33	11.89	10.60	8.62
Progrss 9	**ABA**	28.71	31.49	6.82	8.33	5.98	7.71
	SA	20.89	22.67	5.49	5.20	3.49	3.69
	CHI	23.04	29.36	5.00	3.89	4.33	4.56
	Control	32.18	40.87	12.29	10.09	12.53	11.47
On Ward	**ABA**	35.44	33.29	6.78	5.71	5.49	5.04
	SA	21.20	30.40	6.73	4.84	6.78	7.69
	CHI	34.27	29.78	5.64	4.20	5.96	5.36
	Control	36.73	46.40	7.89	8.22	8.82	8.31
L.S.D.		5.5272	3.4406	1.0389	0.7677	1.1047	1.1793

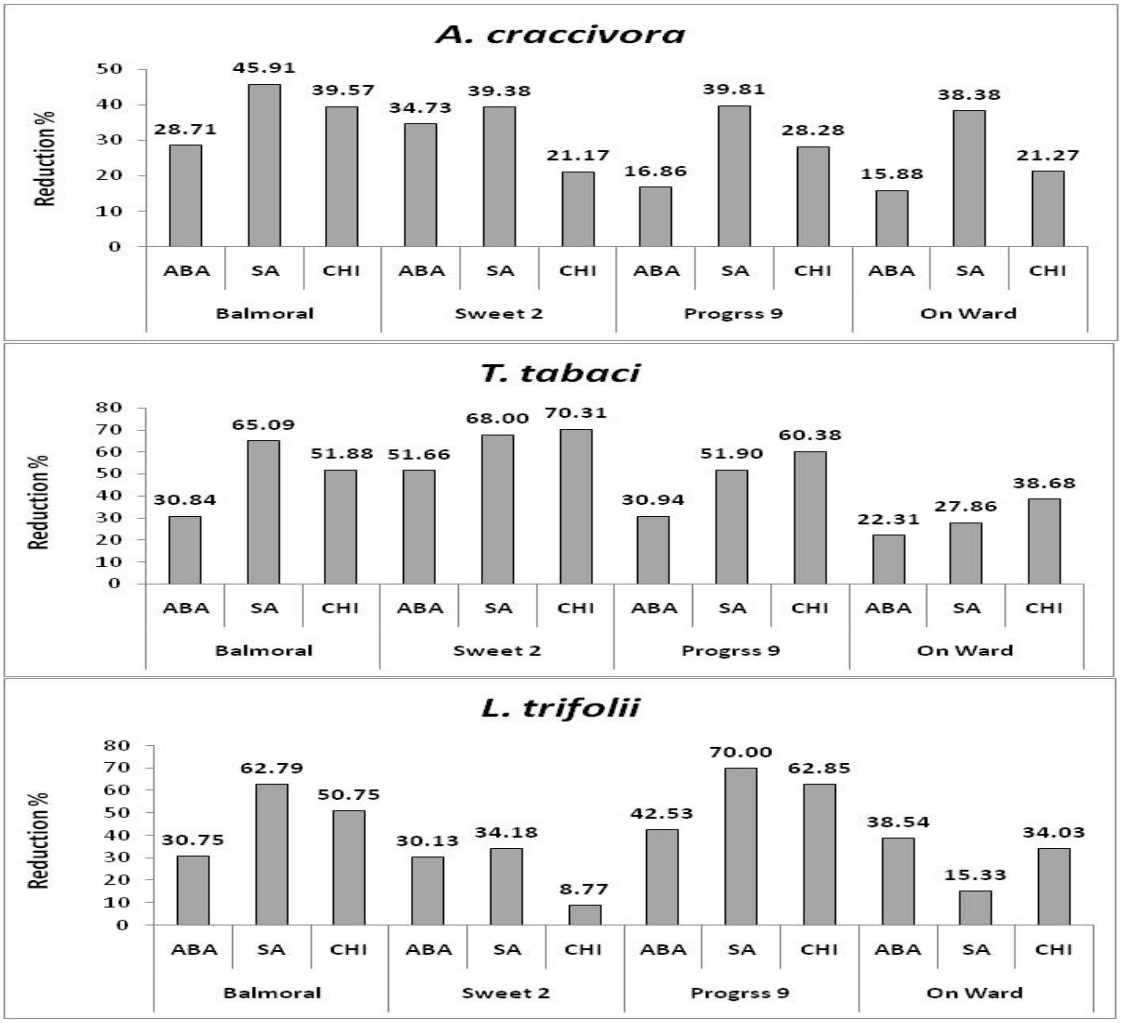

Fig. 3: Effect of the interaction between pea cultivars and foliar spray treatments with ABA, SA and CHI on infestation with *A. craccivora*, *T. tabaci* and *L. trifolii* in average of both 2021/2022 and 2022/2023 seasons.

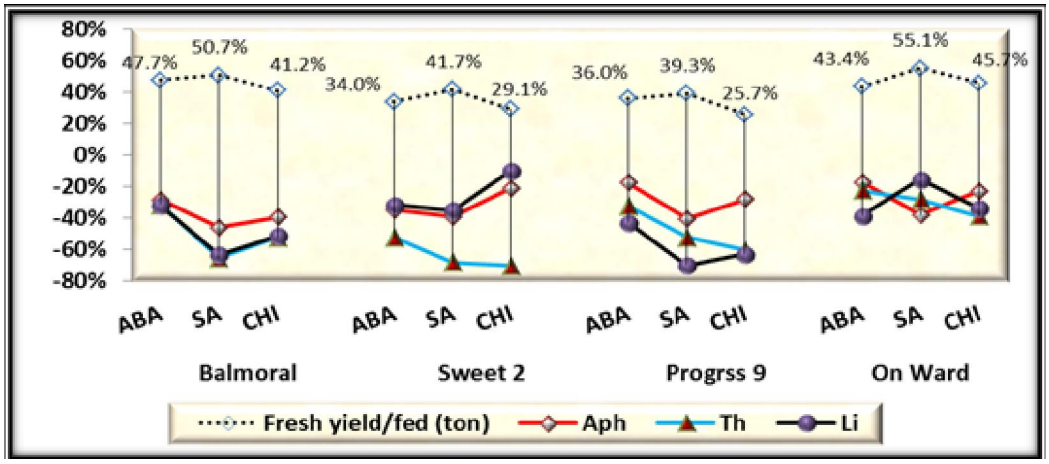

Fig. 4: Changes in percentage in aphid (Aph), thrips (Th) and leafminers (Li) along with increasing in yield/fed as affected by the interaction between cultivars and anti-oxidants foliar spray on pea plants in the average of 2021/2022 and 2022/2023 seasons.

4. Conclusion

The previous results concluded that the foliar spray application with ABA, SA and CHI increased the production of pea green pods yield and decreased the infestations with *A. craccivora*, *T. tabaci* and *L. trifolii* compared to control. In almost, SA was the best foliar spray application in regard to pea production and insect pest control. Pea cultivars varied in their response to the foliar spray application with the previous materials and they need more studies.

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