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SUSCEPTIBILITY OF CERTAIN TOMATO CULTIVARS TO INFESTATION WITH *TUTA ABSOLUTA* (MEYRICK) (LEPIDOPTERA: GELECHIIDAE) IN RELATION TO QUANTITATIVE VARIATIONS OF LEAVES CHEMICAL COMPONENTS.

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Abstract

The susceptibility of eight tomato cultivars to infestation with tomato leafminer in relation to leaves chemical composition was studied during the years 2018-2019 under Egyptian field condition. Four tomato cultivars; 714, 53, Alissia and G.S.12 were planted in early-summer plantation, while the four cultivars namely 86, 036, Fayrouz and Omnia were planted in nili plantation. Survey of eggs, larvae, mines and % of infested leaflets were estimated for all mentioned cultivars, whereas, the quantitative variations of the metabolites components applied for healthy and infested plants. Results indicated that, seasonal abundance of this pest was higher in early summer plantation than nili one. Moreover, the pest population decreased in 2019 than that recorded in year 2018 in both plantations. The most susceptible cultivars to the infestation were G. S. 12 and Omnia in early-summer and nili plantations, respectively. On contrary, 714 and 86 cultivars appeared to be more resistant ones in both selected plantations. There were significant differences between tested compounds in all cultivars in healthy and infested plants and remarkable decrease of these compounds in infested plants, except for α-esterase. Knowledge of the extent of durability of cultivars to a pest on a crop is one of the fundamental components of integrated pest management (IPM) programs for any crop.

Key words: *Tuta absoluta*, cultivars susceptibility, chemical composition, seasonal abundance**.**

Introduction

Tomato*, Lycopersicon esculentum* Mill. is one of the most important vegetable crop around the world with more than 700 varieties (El-Badawy *et al*., 2017). According to the Egyptian Ministry of Agriculture and Land Reclamation in 2013, Tomato crop is the first vegetable crop in Egypt, it is grown in four rotations and covers about 3% of Egypt's total planted area and the production increased to 16,636 tons/feddan (Anonymous, 2013 and FAOSTAT, 2014). Egypt is classified as the 5th country around the world and second around the Mediterranean countries in production and exportation of tomato (WPTC, 2011), with the largest areas located in Beheira, Fayoum, Sharkia and Qena governorates.

The tomato leaf miner, *Tuta absoluta* (Meyrick) is one of the most important pests of tomato all over the world. It has been notified in Egypt since 2009, quickly becoming one of the major pests of the tomato crop. Tomato plants can be attacked by this insect at any developmental stage, from seedlings to mature plants, having 10-12 generations per year (Darbain *et al.,* 2016). Females lay about 250 eggs. Larvae are the most destructive stage, which last for 12 to 15 days, as it mines leaves, fruits, flowers, buds and stems. The damage occurred when the larvae feed on the leaf mesophyll expanding mines, thus affecting the photosynthetic capacity of the crop. Subsequently, injury made directly to the fruits reduce both yield (Colomo and Berta, 2006) and fruit quality.

Tomato (*Solanum lycopersicum*) is considered the primary host of this pest, therefor no tomato cultivars are entirely resistant to this insect, but not all cultivars are equally susceptible (Borgorni *et al*., 2003; Oliveira *et al*., 2009 and De Oliveira *et al*., 2012).

Plants confront the herbivores attacks both directly and indirectly (Howe and Jander, 2008). Direct defenses, with immediate a negative impact, may prevent herbivores

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from feeding via physical barriers (e.g., hairs, trichomes, thorns, spines and thicker leaves) or chemical ones, with secondary metabolites such as terpenoids, alkaloids, anthocyanins and phenols that either prevent or retard the development of the herbivores (Hanley *et al.,* 2007). Plants, when damaged by herbivorous insects, produce increased amounts of antinutritive, toxic proteins and secondary metabolites that impede oviposition, feeding, digestion and absorption of essential nutrients of insects (Smith and Clement, 2012). Defensive components in tomato cultivars in relation to *T. absoluta* infestation were clarified in previous reports likewise, Pereira *et al.,* (2008) and Adam *et al.,* (2011).

Choosing of less susceptible tomato cultivars is important in controlling this pest, beside reducing the number of sprayings. So, in the present study, the susceptible of eight tomato cultivars to leafminer infestation was illustrated in relation to the natural defensive components of each cultivar leaves in case of infestation and uninfestation.

Materials and Methods

Susceptibility of certain tomato cultivars to the infestation by *Tuta absoluta*

• Field experiment:

This study was carried out during two successive seasons 2018 & 2019 under open field conditions at Diarb Negm city, Sharkia Governorate, Egypt. This experiment contained eight tomato cultivars separated into two planting dates (early-summer and nili), four tomato cultivars were planted in each planting date as follow:

♦ 714 & 53 & Alissia & G.S.12 were cultivated in early summer plantation.

♦ 86 & 036 & Fayrouz & Omnia were cultivated in nili plantation.

The above-mentioned cultivars are the major tomato cultivars in Sharkia Governorate. Seedlings obtained from El-Adham nursery in El-Salhia city, Sharkia Governorate. Four weeks after sowing date, seedlings of nili tomato cultivars were cultivated on 15th July and 35 days after seed sowing, early summer cultivars seedlings were cultivated on 15th February during the two successive seasons.

A randomized block design with three replicates (for each of the eight tested cultivars) was applied for two seasons, each replicate contained one experimental plot, the plot area was 18 m^2, each plot consisted of three rows (one row for the leaflets weekly samples and two rows for estimating the yield parameters). Each row was five meters length and 120 cm width, plants distance was 40 cm. The normal agricultural practices (mechanical weed control, fertilizers and irrigation) were done as followed commonly in the district according to the Ministry of Agriculture recommendations with no insecticidal treatments during the study period.

• Samples technique:

One week after cultivation, weekly randomized samples of 75 leaflets (25 leaflets × 3 replicates) for each cultivar were picked early in the morning and kept in tightly closed paper bags, labeled and transferred to the laboratory. The upper and lower surfaces of leaflets were inspected for counting the pest eggs, alive larvae and mines (alive and dead) by aid of a stereomicroscope. The mean numbers of eggs, larvae, mines (alive and dead) and % of infested leaflets were estimated per 25 leaflets in each cultivar.

Effect of leaf chemical components on infestation rate by *Tuta absoluta*

The purpose of this study is to estimate certain phytochemical components (primary and secondary plant metabolites and defense enzymes) in dry leaflets of the same previously eight tomato cultivars in infested and coated (healthy) plants to clarify the relationship between infestation by *Tuta absoluta* and leaf components of the investigated cultivars. Samples of tested cultivars in each of early-summer and nili plantations were collected after 60 days of seedlings cultivation. Six plant samples were collected randomly for each cultivar (three from healthy leaves and three from infested leaves) from the fourth leaf (with the same size) at the main branch from the top of the plant. Then, the samples kept in a labeled polyethylene bag, left to be air dried at the laboratory and grinded into powdered form. Finally, the powder is kept for extraction and evaluation by spectrophotometric method.

The analysis of leaflets samples were conducted in department of physiology, plant protection Institute, Agricultural Research Center.

• Determination of primary and secondary plant metabolites:

Determination of primary metabolites: The main groups of primary metabolites, total soluble carbohydrates and total soluble proteins were extracted and determined as follows:

Total soluble carbohydrates in tomato leaflets were quantified by the method described by Krishnaveni *et al*., (1984). Total soluble proteins were determined by the method of Bradford, (I976).

Determination of secondary plant metabolites: The

Table 1. Weekly mean numbers of *Tuta absoluta* stages and infestation percentages /25 leaflets of four tomato cultivars during early-summer plantation 2018.

Samp-ling date	714					53					Alissia					GS.12				
	Egg	Larve	Mines		% infested leaflets	Egg	Larve	Mines		% infested leaflets	Egg	Larve	Mines		% infested leaflets	Egg	Larve	Mines		% infested leaflets
			Alive	Dead				Alive	Dead				Alive	Dead				Alive	Dead	
Feb. 23	0.00	1.00	1.00	0.00	4.00	0.00	1.67	1.67	2.67	13.33	0.00	2.33	2.33	2.00	17.33	0.00	2.00	2.00	1.33	13.33
02/03	0.00	1.00	1.00	2.00	12.00	0.00	3.00	3.00	2.00	20.00	1.67	4.33	4.33	2.00	22.67	4.67	5.00	5.00	1.33	24.00
09/03	2.67	1.00	1.00	2.67	14.67	2.33	3.00	3.00	3.33	24.00	4.00	7.00	7.00	3.00	32.00	2.67	.33	7.33	3.67	36.00
16/03	1.67	2.67	2.67	5.00	30.67	3.00	1.67	1.67	5.33	24.00	6.33	9.00	9.00	4.67	42.67	6.67	10.00	10.00	4.67	42.67
23/03	2.67	3.00	3.00	6.33	33.33	3.67	4.67	4.67	5.00	36.00	6.33	6.00	6.00	5.00	33.33	.00	12.67	12.67	3.00	45.33
30/03	4.67	3.67	3.67	3.33	26.67	7.33	6.00	6.00	5.00	36.00	9.33	8.33	8.33	7.33	45.33	9.67	7.00	7.00	5.33	37.33
06/04	4.00	5.00	5.00	5.67	37.33	12.00	8.33	7.00	4.00	37.33	13.00	11.00	11.00	9.00	56.00	14.33	8.00	6.00	7.00	40.00
13/04	7.00	7.67	7.67	3.67	42.67	10.33	9.00	8.00	8.67	53.33	13.00	14.00	14.00	11.67	65.33	12.00	10.00	7.67	9.00	45.33
20/04	8.33	8.33	8.33	7.00	50.67	9.00	9.33	9.00	7.00	41.33	11.00	14.33	14.33	10.33	64.00	14.33	11.33	11.00	6.00	52.00
27/04	12.00	9.33	9.33	9.33	57.33	7.33	11.00	9.67	8.33	50.67	14.00	17.00	17.00	8.33	68.00	17.33	14.00	12.33	7.67	62.67
04/05	12.00	9.33	9.33	10.67	54.67	9.33	14.00	13.67	9.67	6267	16.67	15.00	13.00	10.00	57.33	21.00	16.00	16.00	5.67	60.00
11/05	9.00	6.00	6.00	6.67	2.67	5.00	13.67	13.00	6.67	56.00	13.33	13.33	10.67	11.33	62.67	16.33	12.33	12.33	4.67	45.33
18/05	12.00	6.33	6.33	7.00	48.00	6.00	9.00	9.00	9.33	53.33	10.00	9.00	9.00	10.00	54.67	14.00	9.00	9.00	5.67	40.00
25/05	8.00	4.33	4.33	4.33	30.67	3.67	6.67	6.67	7.00	38.67	6.33	7.00	7.00	6.33	42.67	9.00	10.33	10.33	7.00	50.67
01/06	4.00	2.00	2.00	4.33	25.33	3.67	3.33	3.33	6.00	32.00	4.00	5.00	5.00	8.00	37.33	5.67	6.00	6.00	7.33	36.00
08/06	2.33	2.00	2.00	5.00	28.00	2.67	4.67	4.67	6.00	34.67	5.00	5.33	5.33	8.33	40.00	4.33	4.00	4.00	7.67	33.33
General means	5.65c	4.54c	4.54c	5.20c	33.67d	5.33c	6.81b	6.50b	6.00b	38.58c	8.37b	9.25a	8.96a	7.33a	46.33a	10.06a	9.06a	8.67a	5.44c	41.50b
L.S.D.	**Eggs = 0.713**					**Larve = 0.794**					**Alive Mines = 0.759**					**Dead Mines = 0.558**				**% of infestation = 2.780**

secondary component was divided into Phenolic components (Simple phenols, Flavonoids and polyphenolic components (Tannins), Nitrogen-containing components (Alkaloids) and Terpenoids (included Monoterpenes, Sesquiterpenes and Diterpenes) according to Schoonhoven *et al.,* (2005).

Phenolic components

As for Simple phenols: Extraction was performed as described by kβhkônen *et al.,* (1999). The amount of Simple phenols in extracts was estimated by Folin-Ciocateu method as modified by Singelton and Rossi, (1965). Total flavonoids were determined according to Sakanaka *et al.,* (2005). Determination of tannins in tomato cultivars was carried out according to Van-Buren and Robinson, (1981).

Nitrogen compounds

Total alkaloids was estimated according to (Li *et al.,* 2014). Determination of terpenoids was carried out according to (Dai *et al.,* 1999).

- **Determination of defense enzymes.**

Peroxidase activity was determined according to Vetter, (I958), while Phenoloxidase activity was determined according to a modification of Ishaaya, (I971), β-glucosidase activity was measured by assaying glucose liberated by enzymatic hydrolysis of salicin as described by Lindorth, (1988).

Non specific esterases

Alpha esterases and beta esterases (α & β) were determined according to Van Asperen, (I962) using α-naphthyl acetate or β-naphthyl acetate as substrates, respectively.

Statistical analysis between cultivars for each parameter was performed by a randomized complete block ANOVA by Statistix 9 program using Least Significant Differences (L.S.D.) test at 0.05 level of probability (Waller and Duncan, 1969). Simple correlation between chemical components of infested plants and infestation percentage (the infestation at 60 days and the general mean of infestation)

Table 2. Weekly mean numbers of *Tuta absoluta* stages and infestation percentages /25 leaflets of four tomato cultivars during early-summer plantation 2019.

Samp-ling date	714					53					Alissia					G.S.12				
	Egg	Larve	Mines		% infested leaflets	Egg	Larve	Mines		% infested leaflets	Egg	Larve	Mines		% infested leaflets	Egg	Larve	Mines		% infested leaflets
			Alive	Dead				Alive	Dead				Alive	Dead				Alive	Dead	
Feb. 23	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.33	1.33	0.00	1.67	1.67	1.33	12.00	0.00	2.00	2.00	1.67	14.67
02/03	0.33	1.33	1.33	0.67	8.00	0.00	1.00	1.00	0.00	4.00	1.00	2.67	2.67	1.00	14.67	2.67	4.67	4.67	1.33	24.00
09/03	2.33	2.67	2.67	0.67	13.33	2.33	3.00	3.00	1.00	16.00	3.33	4.67	4.67	1.33	22.67	5.67	6.67	6.67	1.67	25.33
16/03	1.67	4.00	4.00	2.67	24.00	2.33	3.67	3.67	1.67	21.33	6.67	7.00	7.00	3.00	33.33	7.67	10.00	10.00	5.00	37.33
23/03	4.33	5.33	5.33	5.00	36.00	6.00	5.00	5.00	4.67	37.33	4.00	8.67	8.67	3.33	40.00	10.00	12.67	12.67	7.33	52.00
30/03	7.33	5.00	5.00	5.33	34.67	6.00	8.00	8.00	5.00	42.67	9.33	9.00	9.00	4.67	44.00	10.67	10.00	10.00	9.00	48.00
06/04	10.00	8.00	8.00	3.00	37.33	9.33	9.33	9.33	8.00	52.00	11.00	12.67	12.67	3.00	46.67	13.00	10.00	10.00	10.67	56.00
13/04	10.00	10.33	10.33	3.00	42.67	11.00	12.00	9.00	9.33	54.67	14.33	9.33	9.33	4.33	45.33	16.00	13.00	13.00	5.33	48.00
20/04	13.67	12.00	12.00	3.00	46.67	12.33	13.33	13.33	7.00	61.33	14.67	9.33	9.33	4.67	48.00	16.33	13.00	10.00	5.33	36.00
27/04	11.00	10.33	8.00	5.00	37.33	10.00	10.00	10.00	5.00	45.33	16.00	7.00	7.00	6.33	44.00	13.00	10.33	10.33	8.33	57.33
04/05	16.00	8.00	6.00	8.33	44.00	8.33	8.33	8.33	5.33	45.33	10.00	12.00	10.00	9.00	57.33	10.67	14.67	14.67	9.00	62.67
11/05	14.33	6.67	6.67	5.33	36.00	10.67	7.00	7.00	3.00	40.00	20.00	11.00	8.67	11.00	62.67	10.00	17.00	17.00	8.33	65.33
18/05	9.67	4.00	4.00	6.00	32.00	10.00	5.33	5.33	3.33	30.67	15.33	9.33	6.00	4.67	37.33	7.67	14.33	10.33	10.00	45.33
25/05	8.33	6.00	6.00	7.67	38.67	10.33	4.00	4.00	5.33	33.33	12.00	11.67	11.67	4.67	53.33	7.00	13.00	10.00	11.00	56.00
01/06	4.00	6.33	6.33	6.00	40.00	8.00	7.00	7.00	5.00	42.67	8.00	8.00	8.00	5.00	42.67	9.00	9.00	9.00	11.33	50.67
08/06	4.00	4.33	4.33	4.67	28.00	5.67	3.00	3.00	2.67	22.67	6.00	5.00	5.00	6.00	36.00	5.00	8.68	8.68	7.67	48.00
15/06	0.00	3.00	3.00	3.00	24.00	2.33	1.67	1.67	1.33	12.00	3.00	3.67	3.67	3.67	26.67	4.33	4.33	4.33	7.00	30.67
22/06	0.00	1.00	1.00	4.33	21.33	0.00	0.00	0.00	1.33	5.33	3.67	0.00	0.00	3.67	14.67	4.00	4.33	4.33	6.00	30.67
General means	6.50b	5.46c	5.22c	4.09bc	30.22c	6.37c	5.65c	5.48c	3.85c	31.56c	8.80a	7.37b	6.95b	4.48b	37.85b	8.48a	9.87a	9.32a	7.11a	43.78a
L.S.D.	**Eggs = 0.637**				**Larve = 0.958**				**Alive Mines = 0.936**				**Dead Mines = 0.541**				**% of infestation = 4.057**			

were applied by IBM SPSS Statistics 19.

Results and Discussion

Susceptibility of certain tomato cultivars to infestation of *T. absoluta*:

Results of seasonal abundance of *T. absoluta* population density on the eight tomato cultivars are represented in tables 1-4.

Early summer plantation 2018 and 2019

The data in table 1 summarized the fluctuating changes in infestation symptoms of early-summer cultivars in season 2018. It is showed that the number of eggs started to appear 2 weeks after cultivation in both G.S.12 and Alissia *cvs*, however in 53 and 714 *cvs*, oviposition observed 3 weeks after cultivation. The egg number increased gradually in all tested cultivars with the increase of the plant age to reach the highest peak on 1st of May in G.S.12, Alissia and 714 (21.00, 16.67 and 12.00 eggs/25 leaflets, respectively), while 53 recorded its first and highest peak (12.00 eggs/25 leaflets) on the first of April. In season 2019, the deposited eggs also started with slight numbers (Table 2), then increased gradually reaching to the first and only peak (around mid of rotation) in 3rd week of April for G.S.12 and 53 *cvs*, while Alissia and 714 *cvs* showed the maximum numbers of eggs in 2nd week of May and first of May, respectively. Then the egg number decreased gradually until the end of the rotation in both seasons. It is appeared that G.S.12 in 2018 was significantly more attractive to *T. absoluta* for oviposition with highest general mean of eggs around the rotation by 10.06 eggs/25 leaflets ($F = 121.09$ at $df = 3$, $P = 0.000$), while Alissia appears to be more attractive for oviposition in season, 2019 with highest general mean being 8.80 eggs/25 leaflets ($F = 48.46$ at $df = 3$, $P = 0.0001$) as compared to other cultivars.

Table 3. Weekly mean numbers of *Tuta absoluta* stages and infestation percentages /25 leaflets of four tomato cultivars during nili plantation 2018.

Samp-ling date	86					036					Fayrouz					Omnia				
	Egg	Larve	Mines		% infested leaflets	Egg	Larve	Mines		% infested leaflets	Egg	Larve	Mines		% infested leaflets	Egg	Larve	Mines		% infested leaflets
			Alive	Dead				Alive	Dead				Alive	Dead				Alive	Dead	
July 21	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.33	1.33	0.00	0.00	0.00	0.00	0.00	0.00	1.33	1.33	0.67	8.00
28/07	0.00	0.00	0.00	1.00	4.00	0.00	0.00	0.00	0.00	0.00	0.00	0.67	0.67	2.33	12.00	0.00	0.00	0.00	167	6.67
04/08	1.67	0.00	0.00	1.00	4.00	1.33	1.00	1.00	1.67	10.67	0.67	2.00	2.00	1.67	14.67	1.33	2.67	2.67	2.00	18.67
11/08	0.33	1.67	1.67	0.00	6.67	2.00	1.33	1.33	1.33	10.67	2.33	3.67	3.67	1.00	18.67	2.67	3.33	3.33	1.67	18.67
18/08	1.67	2.67	2.67	2.00	18.67	3.33	3.67	3.67	3.00	26.67	2.00	2.33	2.33	2.33	17.33	2.67	4.00	4.00	1.67	22.67
25/08	3.33	4.00	4.00	2.67	25.33	4.00	2.67	2.67	1.67	17.33	2.67	3.67	3.67	3.00	24.00	1.33	5.00	5.00	1.67	22.67
01/09	4.67	3.33	3.33	2.67	20.00	3.67	1.67	1.67	0.00	6.67	4.33	2.67	2.67	3.00	22.67	3.67	5.00	4.00	2.00	24.00
08/09	3.67	2.00	2.00	3.33	21.33	5.00	3.33	3.00	2.00	18.67	5.00	4.33	4.33	3.33	28.00	4.67	4.00	3.00	2.67	20.00
15/09	3.33	3.00	3.00	3.67	24.00	4.33	4.33	4.33	2.33	26.67	3.33	6.00	5.67	3.67	34.67	4.00	4.67	3.00	4.33	26.67
22/09	2.00	3.33	3.33	1.67	20.00	2.33	5.67	4.33	2.67	28.00	4.67	5.00	5.00	5.00	37.33	3.67	3.33	3.33	4.67	30.67
29/09	5.00	5.00	5.00	1.33	25.33	4.00	3.33	3.33	1.00	17.33	4.67	4.33	4.33	3.67	32.00	5.67	3.67	3.67	5.33	36.00
06/10	5.67	7.00	7.00	2.00	33.33	6.33	5.67	5.67	4.00	34.67	7.33	5.00	5.00	4.00	34.67	8.33	8.67	8.67	5.67	50.67
13/10	7.00	5.33	5.33	3.00	32.00	8.00	5.00	5.00	4.33	30.67	6.67	6.33	6.33	4.00	37.33	6.67	8.00	8.00	5.33	46.67
20/10	6.67	5.00	5.00	3.33	30.67	7.67	6.00	6.00	2.67	26.67	6.33	7.67	7.67	5.33	38.67	5.33	6.33	6.33	6.00	41.33
27/10	6.00	6.67	6.67	4.33	38.67	9.33	7.33	7.00	3.33	26.67	7.00	9.67	9.67	6.00	48.00	9.00	9.33	9.33	7.00	50.67
03/11	7.67	7.67	7.00	4.67	38.67	8.67	7.33	7.00	3.00	30.67	8.33	8.00	6.67	4.67	37.33	9.33	9.67	9.00	8.00	54.67
10/11	8.33	6.00	5.00	5.00	30.67	7.00	6.67	6.67	4.67	37.33	8.33	7.00	7.00	7.67	40.00	11.67	10.67	10.67	7.00	52.00
General means	3.94b	3.69c	3.59b	2.45b	21.96b	4.53b	3.82c	3.69b	2.24b	20.63b	4.33b	4.61b	4.51a	3.69a	28.08a	4.71a	5.27a	5.02a	3.96a	31.22a
L.S.D.	Eggs = 0.734					Larve = 0.596					Alive Mines = 0.585					Dead Mines = 0.735				% of infestation = 4.099

In the meantime, larvae in both seasons reported in the beginning of inspection but the infestation fluctuated in small numbers, except for G.S.12 *cv* recorded its first peak on 23, March. Whereas, larvae incidence began noticeably to reached the maximum numbers in samples collected around the middle of the rotation. In season 2018, highest peak of G.S.12, 53 and 714 *cvs* occurred on 1st May (16.00, 14.00 and 9.33 larvae, respectively), while Alissia presented highest number (17.00 larvae) on 4th week of April. In season 2019, G.S.12 and Alissia reached to the maximum numbers in mid of May and first of April, respectively, while 53 and 714 cultivars introduced the maximum numbers of larvae on 20, April. Then larvae in both seasons continued decreasing until the last collected samples. Resulted data showed that G.S.12 and Alissia *cvs* are more susceptible to infestation with larvae in both seasons. As the highest general mean of larvae in 2018 was 9.25 larvae/25 leaflets in Alissia (F= 92.99 at df = 3, P = 0.000) and in 2019 was 9.87 larvae in G.S.12 (F= 54.53 at df = 3, P = 0.0001).

As for mines, alive mines numbers coincided with the numbers of larvae except for a slight decrease in few samples in each cultivar when the mine contained more than one larva. While dead mines fluctuated in this rotation, beginning with decreased numbers followed by remarkable increase in the middle of the rotation, then terminated with slight decrease. Alive mines in G.S.12 *cv* in 2018 recorded lower numbers than that recorded in larvae during April that coincided with the highest registered numbers of dead mines around the rotation, while in 2019, alive mines differed in three samples, situated in April and in May. This cultivar in 2019 recorded the highest general mean of alive mines (F=48.03 at df = 3, P = 0.0001) and dead mines (7.11mines/25 leaflets) (F=92.89 at df

Table 4. Weekly mean numbers of *Tuta absoluta* stages and infestation percentages /25 leaflets of four tomato cultivars during nili plantation 2019.

Samp-ling date	86					036					Fayrouz					Omnia				
	Egg	Larve	Mines		% infested leaflets	Egg	Larve	Mines		% infested leaflets	Egg	Larve	Mines		% infested leaflets	Egg	Larve	Mines		% infested leaflets
			Alive	Dead				Alive	Dead				Alive	Dead				Alive	Dead	
July 21	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
28/07	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.67	2.67	0.00	0.00	0.00	2.00	8.00
04/08	0.00	0.00	0.00	1.33	5.33	0.00	1.33	1.33	1.67	12.00	0.00	3.00	3.00	2.00	20.00	0.00	3.00	3.00	1.00	16.00
11/08	0.00	0.00	0.00	1.67	6.67	2.00	0.00	0.00	2.33	9.33	2.00	3.00	3.00	2.67	22.67	2.33	2.67	2.67	2.33	20.00
18/08	1.33	0.33	0.33	2.00	9.33	1.33	2.67	2.67	3.67	21.33	4.00	3.00	3.00	3.33	25.33	4.00	2.33	2.33	1.67	16.00
25/08	1.00	2.00	2.00	2.00	16.00	3.00	2.67	2.67	5.00	25.33	2.00	4.00	2.67	6.00	34.67	3.33	4.00	4.00	0.00	16.00
01/09	2.33	2.00	2.00	3.67	21.33	4.00	1.67	1.67	5.67	26.67	3.33	4.67	3.33	7.00	36.00	3.00	4.67	4.67	0.00	18.67
08/09	2.67	4.33	4.33	4.33	29.33	2.67	4.67	4.67	4.67	32.00	6.33	5.00	5.00	8.00	44.00	6.00	5.67	5.67	2.00	30.67
15/09	3.67	3.67	3.67	5.00	26.67	5.33	4.00	4.00	5.33	3.33	6.00	3.67	3.67	5.00	30.67	6.00	3.67	3.67	2.00	21.33
22/09	4.67	3.00	3.00	5.67	30.67	7.33	4.00	4.00	3.67	28.00	4.00	3.00	3.00	4.33	29.33	6.33	5.00	4.00	3.00	28.00
29/09	7.67	6.33	6.33	7.00	41.33	8.00	7.00	7.00	7.00	42.67	5.00	6.33	6.33	6.67	45.33	5.67	8.00	8.00	3.33	41.33
06/10	7.00	5.67	5.67	8.33	44.00	5.00	8.67	8.67	7.00	46.67	8.67	7.33	7.33	7.67	50.67	9.00	6.33	6.33	3.67	36.00
13/10	6.33	7.00	7.00	8.00	44.00	9.33	6.00	6.00	5.33	38.67	10.67	9.00	9.00	7.00	53.33	6.67	8.00	8.00	4.67	44.00
20/10	8.67	8.00	8.00	9.33	48.00	10.00	7.33	7.33	8.00	45.33	9.33	7.00	6.00	9.00	50.67	8.00	10.00	8.67	5.33	46.67
27/10	6.00	4.67	4.67	7.33	41.33	9.00	8.67	8.67	9.00	46.67	7.00	3.67	3.67	9.33	41.33	10.00	9.00	9.00	6.33	49.33
03/11	3.00	2.67	2.67	5.33	30.67	4.33	5.00	5.00	7.33	36.00	7.67	5.00	5.00	10.00	45.33	10.00	5.67	5.67	7.67	42.67
General means	3.40b	3.10v	3.10b	4.44b	24.67b	4.46a	3.98b	3.98a	4.73b	27.75b	4.75a	4.23b	4.00a	5.54a	33.25a	5.02a	4.88a	4.73a	2.81c	27.17b
L.S.D.	Eggs = 0.780				Larve = 0.847					Alive Mines = 0.865					Dead Mines = 1.044				% of infestation = 3.364	

= 3, P = 0.000) among tested cultivars. In Alissia *cv*, Alive mines in 2018 decreased in first two weeks of May compared to larvae number, while in 2019, alive mines number differed than larvae during May beside recording the maximum number of dead mines during 2nd week of the same month. Alive mines in 53 *cv* in 2018 differed than larvae number from first April to mid May, with highest estimated number of dead mines in first May. Whereas in 2019, alive mines decreased only in sample collected 8 weeks after cultivation with highest recorded number of dead mines. Investigated alive mines numbers were equal with the larvae numbers in 714 *cv* during all collected samples in 2018 and the maximum value of dead mines was detected in first May.

While in 2019, the decline in 714 *cv* alive mines occurred in late April and first May with higher incidence of dead mines in the second half of rotation. Data presented in table 1 showed that the highest general mean of alive mines (F= 88.66 at df = 3, P = 0.000), dead mines (F= 35.44 at df = 3, P = 0.0003) occurred in Alissia *cv*. The maximum infestation percentages around the rotation in 2018 registered on 27, April in G.S.12, Alissia and 714 *cvs* and on 4, May in 53 *cv* with highest general mean in Alissia (F= 43.64 at df = 3, P = 0.0002). On the other hand, highest records of infestation percentages in 2019 represented in mid May in both G.S.12 and Alissia *cvs* and in 3rd week of April in both 53 and 714 *cvs*, however the highest general mean introduced significantly by G.S.12 (F=28.38 at df = 3, P = 0.0006).

Nili plantation 2018 and 2019

Data in table 3 and 4 gave a brief statement of *T. absoluta* surveyed parameters in nili cultivars during seasons 2018 and 2019. In season 2018, oviposition did not observed in the first two weeks after transplanting in all tested cultivars, as well as, survey did not recorded any eggs in the first few weeks after cultivation in season 2019. Eggs started and fluctuated in a few numbers in both seasons until reach in 2018 to first small peak on late of August and first of September. Then fluctuated in the same season again to record the last and highest peak at the end of the rotation represented by 11.67, 8.33, 9.33 and 8.33 eggs in case of Omnia, Fayrouz, 036 and 86, respectively. In 2019, egg also fluctuated to arrive the maximum number around the rotation end being 10 eggs, 10.67 eggs, 10 eggs and 8.67eggs/25 leaflets in Omnia, Fayrouz, 036 and 86, respectively. These data showed that the cultivar coded as Omnia appeared to be more preferable and attraction to *T. absoluta* moths in both seasons, as the general mean of eggs around the rotation in 2018 (4.71 eggs/25 leaflets) was insignificant higher than that recorded in other cultivars (F= 2.39 at df = 3, P = 0.1677). Also in 2019, it recorded the highest significant general mean (5.02 eggs/25 leaflets) (F=9.95 at df = 3, P = 0.0096).

Similar results were obtained with the larvae, mines and % of infestation as the data given in table 3 and 4 indicated that the infestation symptoms raised around the end of season. As regard to larvae, in both seasons, all cultivars started with weak incidence of larvae, then larvae increased and fluctuated passing by few ascending peaks to arrive the maximum number around the rotation end. The highest significant general mean of larvae introduced in Omnia *cv* in both 2018 by 5.27 larvae (F=18.42 at df = 3, P = 0.0020) and 2019 by 4.88 larvae/ 25 leaflets (F= 8.96 at df= 3, P= 0.0123).

It is clear that alive mines introduced a slight decrease in the general mean than larvae in all cultivars in 2018, while in 2019, only Omnia and Fayrouz appeared the slight decrease in the general mean of alive mines than larvae, but in 036 and 86, alive mines equal with larvae in the general mean. General mean of alive mines followed the same order of larvae general mean in both seasons. Statistical analysis showed significant differences in the general mean of alive mines around the rotation in 2018 (F=16.41 at df = 3, P = 0.0027) and 2019 (F=7.09 at df = 3, P = 0.0213).

Obviously, the increase in the number of dead mines and % of infestation were connected with an increase of the deposited eggs, hatched larvae and plant age. So, the maximum number of dead mines and highest infestation percentage were recorded at the end of the rotation. The highest general mean of dead mines (F=16.68 at df = 3, P = 0.0026) and infestation percentage (F=17.96 at df = 3, P = 0.0021) around the rotation in 2018 recorded in Omnia *cv*, nevertheless in 2019, Fayrouz *cv* appeared the highest general mean of dead mines (F=14.38 at df = 3, P = 0.0038), as well as infestation percentage (F=13.85 at df = 3, P = 0.0042).

It appears that tomato cultivars, Alissia and G.S.12, were more susceptible to infestation as compared to 714 and 53 *cvs* in the early-summer plantation of both seasons. In the nili plantation, Omnia *cv* was more susceptible to infestation as compared to the resistant cultivars 86 and 036 and the moderate resistant one, Fayrouz. These findings clearly viewed the variation in the susceptibility of the most dominant tomato cultivars cultivated in Egypt. The declined population of *T. absoluta* at nili plantation than early-summer plantation is due to the unsuitable climatic conditions (high temperature) that kill the neonate larvae and decreased the moths activity, especially the first month of the plantation. Resistance levels of some tomato cultivars to *T. absoluta* have been previously reported by several researchers like Oliveira *et al.,* (2009) in Brazil, evaluated resistance of three commercial cultivars (Santa clara, Moneymaker and TOM-601). Allal *et al.,* (2011) in France, found that the most susceptible varieties to larval attacks were “Doucen, Zahra and Kartier” whereas “CLX” and “Pietro” were the least ones. Shawir *et al.,* (2014) in Egypt, stated that tomato varieties, Fyrouz and H9780 were the most susceptible followed by Alissa, Hadir and Elbasha 1077. Bottega *et al.,* (2015) found that the tomato genotypes, *Lycopersicon esculentum* and *Lycopersicon hirsutum* had the most negative effect on *T. absoluta* in comparison to *Lycopersicon pimpine*. Darbain *et al.,* (2016) in Egypt, mentioned that the most susceptible cultivars were Alissa F1 and Super strain B while Logain cultivar was the least susceptible one. Ghaderi *et al.,* (2017) in Iran, indicated that Cal JN3 cultivar was the most susceptible to infestation and Primo Early and Early Urbana Y were the most resistant ones. Sohrabi *et al.,* (2017) in Netherland, revealed that the cultivars:

Berlina, Golsar, Poolad and Zaman were less suitable cultivars. Azadi *et al.,* (2018) in Iran, mentioned that the descending order of cultivars susceptibility was Primo early cultivar, CaljN3, Petomek, Rio grande, Early urbana and Super 2270. Al-Antary *et al.,* (2019) in Jordan, reported that the most resistant cultivar was Dafnis followed by Newton and Shams in Al Baqa.

Effect of the main primary and secondary metabolites as well as, defensive enzymes on *T. absoluta* in the tested tomato cultivars

Primary metabolites, secondary metabolites and defensive enzymes in leaflets of healthy and infested plants collected 60 days from seedling were determined in eight tomato cultivars divided into two plantations.

Early-summer plantation

- **Primary metabolites:**

Table 5: Relationship between the content of some primary metabolites in tested early-summer cultivars (healthy and infested) at 60 days of seedling and infestation percentages of *Tuta absoluta* larvae/ 25 leaflets during season, 2019.

Cultivars	Primary metabolites compounds: Total soluble carbohydrate (mg/g dry weight)		Total soluble Protein (mg/g dry weight)		Infestation percentage at 60 days (%)	General mean of infestation percentage
	Healthy	Infested	Healthy	Infested		
714	37.68b	32.45a	87.04a	30.27b	42.67b	30.22c
53	35.17b	27.16b	51.83b	41.70a	54.67a	31.56c
Alissia	47.14a	22.60c	81.70a	21.16c	45.33b	37.85b
GS.12	25.03c	18.07d	34.77c	22.93c	48.00ab	43.78a
F. value	58.74**	34.66**	113.13**	23.43**	4.47ns	28.38**
L.S.D.	4.1	3.62	8.07	6.67	8.43	4.06
Simple correlation (r) at 60 days	-	-0.07	-	0.49	-	-
Simple correlation (r) with general infestation percentage	-	-0.74**	-	-0.61*	-	-

The same letter in the same column represents no significant differences (p<0.05).
*,** and ns indicate significance at 0.05 and 0.01 levels and insignificancy of differences, in respective order.

Data given in table 5 illustrated that the amount of total soluble protein and total soluble carbohydrates were differed between cultivars in significant groups diversed according to type of the determined component. The total soluble carbohydrate content in healthy plants was significantly higher in Alissia *cv* being 47.14 mg/g of leaflets, followed by moderate amounts in both 714 and 53, while G.S.12 *cv* showed the lowest significant amount (25.03 mg/g) as compared to other cultivars. In case of infestation, all cultivars content of soluble carbohydrate decreased, with highest significant amount in 714 *cv* by 32.45 mg/g which contained the least infestation at 60 days (42.67%) and in general (30.22%). While the lowest significant amount (18.07 mg/g) was recorded in G.S.12 with infestation percentage of 48% at 60 days and significant highest percentage of 43.78% in general. The same table revealed that 714 and Alissia were also the highest in total soluble protein, with no significant difference, with obtained amounts of 87.04 and 81.70 mg/g, respectively and the least significant amount was also recorded in G.S.12 by 34.77 mg/g. Total soluble protein decreased in infested leaflets in all cultivars being significantly higher in 53 *cv* with 41.70 mg/g that introduced highest infestation rate at 60 days (54.67) and low general infestation rate (31.56%). While, Alissia showed the least amount of this component (21.16 mg/g) with moderate infestation rates at 60 days by 45.33% and in general by 37.85%. Statistical analysis revealed that the correlation between infestation rate and total soluble carbohydrates was insignificant negative (0.07) at 60 days and highly significant negative

Table 6: Relationship between the content of some phenolic compounds in tested early-summer cultivars (healthy and infested) at 60 days of seedling and infestation percentages of *Tuta absoluta* larvae/ 25 leaflets during season, 2019.

Cultivars	Phenolic compounds: Simple phenols (mg/g dry weight)		Tannins (mg/g dry weight)		Flavonoids (mg/g dry weight)		Infestation percentage at 60 days (%)	General mean of infestation percentage
	Healthy	Infested	Healthy	Infested	Healthy	Infested		
714	8.12b	21.33a	0.52a	0.87a	3.76b	4.03b	42.67b	30.22c
53	1.72d	14.52b	0.31b	0.71a	7.17a	7.84a	54.67a	31.56c
Alissia	11.08a	12.11b	0.08c	0.12b	0.27c	1.01c	45.33b	37.85b
GS.12	3.74c	5.85c	0.03c	0.07b	0.62c	0.91c	48.00ab	43.78a
F. value	144.96**	18.64**	110.59**	81.56**	162.27**	138.98**	4.47ns	28.38**
L.S.D.	1.21	5.13	0.08	0.16	0.87	0.96	8.43	4.06
Simple correlation (r) at 60 days	-	-0.03	-	-0.06	-	0.56	-	-
Simple correlation (r) with general infestation percentage	-	-0.64*	-	-0.85**	-	-0.59*	-	-

The same letter in the same column represents no significant differences (p<0.05).
*,** and ns indicate significance at 0.05 and 0.01 levels and insignificancy of differences, in respective order.

(0.74) in general rate of infestation, respectively. Whereas, total soluble proteins gave an insignificant positive and a significant negative correlations with both levels of infestation with "r value" of 0.49 and -0.61, respectively.

• **Secondary metabolites:**

The mentioned results in table 6 showed that phenolic components such as simple phenols, tannins and flavonoids were significantly accumulated in all tested cultivars leaflets. The highest significant amount of simple phenols in healthy plants was introduced in Alissia with obtained value of 11.08 mg/g, whereas 714 showed a moderate content. However, G.S.12 and 53 reached to significant lower values being 3.74 and 1.72 mg/g, respectively. The infestation increased the amount of simple phenols in all cultivars recording the maximum significant amount in the resistant cultivar against *T. absoluta* coded 714 that sharply increased in its content in infestation condition which associated with the lowest infestation rates. The only G.S. 12 *cv* significantly represented the lowest amount of simple phenols being the highest susceptible with high incidence of infestation rates. Tannins contain was significantly higher in the most resistant cultivars (714 and 53) than in the most susceptible cultivar (G.S.12). Similar result was obtained in infestation circumstance, as the increase of tannin amounts and general infestation percentages followed the same trend. It is obvious that flavonoids amount also increased in all infested leaflets, 53 *cv* remarkably occupied the first in containing flavonoids in healthy plants with 7.17 mg/g and in infested plants with 7.84 mg/g.

On contrary, Alissia contained the lowest significant amount of flavonoids in healthy plants (0.27 mg/g), yet G.S.12 recorded the significant lower content (0.91 mg/g) in infested plants. Statistical analysis revealed that there is an insignificant correlation between all phenolic compounds and the infestation at 60 days, however flavonoids gave a positive correlation, yet both phenols and tannins gave negative correlations. While in case of general infestation rate, the correlation was significant negative in both flavonoid and phenols, but highly significant in tannins.

Data in table 7 revealed that there were differences in amounts of alkaloids and terpenoid components in all cultivars, with remarkable increase in their amounts of infested plants. The alkaloids and terpenoids amounts in healthy plants were significantly higher in 714 *cv* (resistant one) (11.14 and 31.00 mg/g, respectively) than the most reduced amount in G.S.12 by 2.45 and 15.08 mg/g, respectively. 714 *cv* was significantly more effective in increasing both compounds in infested leaflets being 19.15 and 45.60 mg/g, respectively with lowest infestation rates, yet the lowest increased amounts of both compounds occurred in Alissia, that infested with moderate rates. Insignificant negative correlations were recorded between infestation and both alkaloids (-0.12) and terpenoids (-0.09) at 60 days, while general percent of infestation showed an insignificant negative correlation with alkaloids (-0.48) and a highly significant negative correlation with terpenoids (-0.72).

Table 7: Relationship between the content of alkaloids and terpenoids in tested early-summer cultivars (healthy and infested) at 60 days of seedling and infestation percentages of *Tuta absoluta* larvae/ 25 leaflets during season, 2019.

Cultivars	Alkaloids (mg/g dry weight)		Terpenoids (mg/g dry weight)		Infestation percentage at 60 days (%)	General mean of infestation percentage
	Healthy	Infested	Healthy	Infested		
714	11.14a	19.15a	31.00a	45.60a	42.67b	30.22c
53	7.44b	10.22b	29.28a	39.54b	54.67a	31.56c
Alissia	5.37c	5.82c	20.11b	24.70c	45.33b	37.85b
GS.12	2.45d	6.41c	15.08b	27.66c	48.00ab	43.78a
F. value	119.44**	47.09**	21.79**	52.84**	4.47ns	28.38**
L.S.D.	1.16	3.1	5.6	4.69	8.43	4.06
Simple correlation (r) at 60 days	-	-0.12	-	-0.09	-	-
Simple correlation (r) with general infestation percentage	-	-0.48	-	-0.72**	-	-

The same letter in the same column represents no significant differences ($p<0.05$). *,** and ns indicate significance at 0.05 and 0.01 levels and insignificancy of differences, in respective order.

Defensive enzymes (antioxidant enzymes) evaluation

Table 8 viewed the differences in all defensive enzymes activities in all cultivars, beside the significant increase in infested plants except for, α-esterase that decreased in case of infestation. The cultivar, 53 recorded the highest significant activity of peroxidase (916.00ΔO.D.405/min/g dry weight) in healthy plants as well as infested plants (930.67ΔO.D.405/min/gdw), while

Table 8: Relationship between the content of some defensive enzymes in tested early-summer cultivars (healthy and infested) at 60 days of seedling and infestation percentages of *Tuta absoluta* larvae/ 25 leaflets during season, 2019.

Cultivars	Defensive enzymes										Infestation percentage at 60 days (%)	General mean of infestation percentage
	Peroxidase (ΔO.D.405/min/g dry weight)		Phenolxidase (O.D. units/min/g dry weight)		β-glucosidase (ug/glucose/min/ g dry weight		Alpha esterase (ug α-naphthol/ min/g dry weight		Beta esterase (ug β-naphthol/ min/g dry weight			
	Healthy	Infested	Healthy	Infested	Healthy	Infested	Healthy	Infested	Healthy	Infested		
714	780.33b	902.67a	146.00a	161.33a	284.00a	463.33a	370.33c	277.67c	446.00ab	500ab	42.67b	30.22c
53	916.00a	930.67a	120.67b	130.33ab	261.33a	280.00c	544.33b	327.00b	498.67a	517.00ab	54.67a	31.56c
Alissia	460.33c	550.00b	80.33c	137.67ab	173.67b	201.33d	722.00a	516.33a	425.67b	596.00a	45.33b	37.85b
G.S.12	284.67d	365.00c	89.33c	104.67b	292.67a	415.67b	331.33d	318.67bc	458.67ab	465.67b	48.00ab	43.78a
F. value	210.45**	374**	18.26**	3.73ns	8.93*	106.23**	777.82**	58.23**	3.86ns	3.76ns	4.47ns	28.38**
L.S.D.	68.98	49.37	24.36	41.82	63.08	40.55	22.23	48.29	54.23	98.49	8.43	4.06
Simple correlation (r) at 60 days	-	0.14	-	-0.24	-	-0.21	-	-0.11	-	0.25	-	-
Simple correlation (r) with general infestation percentage	-	-0.83**	-	-0.37	-	-0.01	-	0.29	-	0.08	-	-

The same letter in the same column represents no significant differences ($p<0.05$).
*,** and ns indicate significance at 0.05 and 0.01 levels and insignificancy of differences, in respective order.

G.S.12 recorded the lowest significant activity in infestation and uninfestation conditions. The highest significant activity of phenoloxidase in healthy plants was found in 714 *cv* (146.00 O.D. units/min/gdw) and the lower activity was found in Alissia (80.33 O.D. units/ min/gdw), whereas in infestation case, 714 *cv* also gave the highest increase of phenoloxidase, while G.S.12 gave the lowest increase of this compound. β-glucosidase activity in absence of infestation was higher in G.S.12 *cv* (292.67 ug glucose/min/gdw), but 714 *cv* significantly came in the first in increasing β-glucosidase activity in the infestation case (463.3367 ug glucose/min/gdw). Even though Alissia registered the significant least activity in both healthy and infested plants. As regard to esterases, the maximum significant activity of α-esterase recorded in Alissia by 722.00 ug α-naphthol/min/gdw and the lowest significant one recorded in G.S.12 by 331.33 ug α-naphthol/min/gdw. This enzyme activity decreased in infested plants representing the highest activity in Alissia and the lowest one in 714. Beta esterase activity was significantly higher in 53 *cv* (498.67 ug β-naphthol/min/ gdw) and lower in Alissia (425.67 ug β-naphthol/min/ gdw). While in infestation, this enzyme activity increased to give the highest increase in Alissia and lowest increase in G.S.12. Infestation at 60 days gave insignificant positive correlations with beta esterase and peroxidase, but insignificant negative correlations with the other enzymes. General infestation rate recorded insignificant positive correlations with α and β-esterase, insignificant negative correlations with β-glucosidase and phenoloxidase and a highly significant negative correlation with peroxidase.

Nili plantation

- **Primary metabolites:**

Data in table 9 concluded that the amount of primary metabolism compounds in nili tomato cultivars were differed according to the cultivars susceptibility to infestation. It is obvious that the amounts of these substances decreased in infested plants. The total soluble carbohydrates were significantly higher in 86 *cv* and lower in Fayrouz *cv* being 92.90 and 48.53 mg/g, respectively. While 036 and Omnia cultivars recorded the highest and the lowest amounts of this component in infested plants by 46.60 and 37.73 mg/g with moderate general infestation rates of 27.75% and 27.17%, respectively. The total soluble proteins was found in a decreased amount in 036 and moderate amounts in 86 and Omnia, while the highest significant amount was found in the moderate resistant Fayrouz.

On contrary, 86 *cv* recorded the maximum significant value of this component in infested plants with the least incidence of infestation rates (29.33% and 24.67%), however Omnia reduced the amount to the minimum value. Insignificant negative correlations were obtained between infestation and the two primary metabolites at 60 days (-0.05 and -0.27, respectively). While, the

Table 9: Relationship between the content of some primary metabolites in tested nili cultivars (healthy and infested) at 60 days of seedling and infestation percentages of *Tuta absoluta* larvae/ 25 leaflets during season, 2019.

Cultivars	Primary metabolites compounds				Infestation percentage at 60 days (%)	General mean of infestation percentage
	Total soluble carbohydrate (mg/g dry weight)		Total soluble Protein (mg/g dry weight)			
	Healthy	Infested	Healthy	Infested		
86	92.90a	38.30b	45.10b	39.40a	29.33b	24.67b
036	63.73c	46.60a	38.20c	37.27ab	32.00b	27.75b
Fayrouz	48.53d	40.47b	50.57a	35.10b	44.00a	33.25a
Omnia	86.13b	37.73b	44.17b	30.80c	30.67b	27.17b
F. value	254.36**	12.26**	14.62**	11.30**	10.62**	13.85**
L.S.D.	4.43	4.01	4.58	3.79	7.17	3.36
Simple correlation (r) at 60 days	-	-0.05	-	-0.27	-	-
Simple correlation (r) with general infestation percentage	-	0.21	-	0.03	-	-

The same letter in the same column represents no significant differences (p<0.05).
*,** and ns indicate significance at 0.05 and 0.01 levels and insignificancy of differences, in respective order.

correlation in case of general infestation was insignificant positive (0.21 and 0.03, respectively).

• **Secondary metabolites:**

The obtained results in table 10 indicated that investigated secondary metabolites signified in all cultivars and increased in case of infestation. The highest significant amounts of simple phenol in healthy and infested plants were found in the resistant cultivar 86 with lower infestation rates, while the lowest amount in healthy and infested plants were found in the susceptible cultivar Omnia and the moderate resistant one Fayrouz (which opposite to the highest infestation rates being 44% and 33.25%), respectively. Tannins in healthy plants was estimates with higher amounts in the most resistant cultivars 036 and 86 and lower amount in the susceptible cultivar Omnia. Increased amounts of tannins in case of infestation tracked the same trend of its amounts in healthy plants. The highest incidence of flavonoids was found in 036, 86 and Fayrouz without significant differences, nevertheless, the lowest incidence recorded in Omnia. In infested plants, 86 *cv* caused the highest increase in flavonoid and Omnia showed the least amount. In general, all phenolic compounds recorded insignificant negative correlations with infestation at 60 days (-0.50, -0.34 and -0.35) and with general infestation (-0.36, -0.10 and -0.13) for phenols, tannins and flavonoids, respectively.

The results in table 11 illustrated that the content of alkaloids and terpenoids in tomato cultivars healthy leaflets were higher in 036 and 86 *cvs* with obtained values of

Table 10: Relationship between the content of some phenolic compounds in tested nili cultivars (healthy and infested) at 60 days of seedling and infestation percentages of *Tuta absoluta* larvae/ 25 leaflets during season, 2019.

Cultivars	Phenolic compounds						Infestation percentage at 60 days (%)	General mean of infestation percentage
	Simple phenols (mg/g dry weight)		Tannins (mg/g dry weight)		Flavonoids (mg/g dry weight)			
	Healthy	Infested	Healthy	Infested	Healthy	Infested		
86	15.00a	18.40a	0.77a	1.57b	12.73a	19.40a	29.33b	24.67b
036	10.07b	13.23b	0.80a	2.82a	13.23a	14.07b	32.00b	27.75b
Fayrouz	10.67b	10.80b	0.68a	0.77c	11.97a	13.60b	44.00a	33.25a
Omnia	9.13b	11.04b	0.38b	0.59c	6.97b	11.93b	30.67b	27.17b
F. value	4.45ns	16.80**	6.93*	44.56**	5.48*	6.49*	10.62**	13.85**
L.S.D.	4.27	2.98	0.25	0.53	4.26	4.39	7.17	3.36
Simple correlation (r) at 60 days	-	-0.50	-	-0.34	-	-0.35	-	-
Simple correlation (r) with general infestation percentage	-	-0.36	-	-0.10	-	-0.13	-	-

The same letter in the same column represents no significant differences (p<0.05).
*,** and ns indicate significance at 0.05 and 0.01 levels and insignificancy of differences, in respective order.

Table 11: Relationship between the content of alkaloids and terpenoids in tested nili cultivars (healthy and infested) at 60 days of seedling and infestation percentages of *Tuta absoluta* larvae/ 25 leaflets during season, 2019.

Cultivars	Alkaloids (mg/g dry weight)		Terpenoids (mg/g dry weight)		Infestation percentage at 60 days (%)	General mean of infestation percentage
	Healthy	Infested	Healthy	Infested		
86	4.73a	7.27a	8.20a	16.11a	29.33b	24.67b
036	4.93a	6.60ab	3.42b	5.00b	32.00b	27.75b
Fayrouz	4.27ab	4.73c	0.61c	4.45b	44.00a	33.25a
Omnia	3.70b	5.90bc	1.37c	2.42c	30.67b	27.17b
F. value	4.05ns	7.87*	167.06**	200.91**	10.62**	13.85**
L.S.D.	0.94	1.34	0.91	1.51	7.17	3.36
Simple correlation (r) at 60 days	-	-0.69*	-	-0.35	-	-
Simple correlation (r) with general infestation percentage	-	-0.54	-	-0.43	-	-

The same letter in the same column represents no significant differences ($p<0.05$). *,** and ns indicate significance at 0.05 and 0.01 levels and insignificancy of differences, in respective order.

4.93 and 8.20 mg/g, respectively. Conversely, Omnia and Fayrouz exhibited the lowest values of 3.70 and 0.61 mg/g, respectively. Infested plants witnessed significant highest increase in 86 being 7.27 and 16.11mg/g for alkaloids and terpenoids, respectively, while Fayrouz and Omnia also showed the lowest increase of both components in infested plants.

The correlation between infestation rate and alkaloids was a significant negative (-0.69) at 60 days and an insignificant negative in general (-0.54), while the correlation with terpenoids proved to be an insignificant negative at both infestation rates with r values of -0.35 and -0.43, respectively.

Defensive enzymes evaluation

Tabulated data in table 12 cleared that there are significant differences between contents of all defensive enzymes in this plantation cultivars, beside the significant increase of their activities in infested plants except for α-esterase, as its activity decreased in all cultivars with a slight increase in 86 *cv*. Cultivar 86 contained the highest significant activity of peroxidase (1396 ΔO.D.405/min/gdw) in healthy plants, while 036 showed highest increase of this enzyme activity (1870.67 ΔO.D.405/min/gdw) in infestation case. On contrary, Omnia contained the least activity of peroxidase in both uninfestation and infestation. Phenoloxidase presented with higher activity in moderate resistant Fayrouz (91.33 O.D. units/min/gdw) and with lower activity in Omnia (70.67 O.D. units/min/gdw) without significant differences between all tested cultivars, but its activity in infestation was higher in resistant 86 and lower in Fayrouz. β-glucosidase activity in healthy plants was significant higher in resistant 86 (850 ug glucose/min/gdw), while in infested plants, it was significant higher in Fayrouz (978 ug glucose/min/gdw) that infested with highest rates, on the other hand, Omnia represented the significant lower activity in both healthy and infested plants. As for esterases enzymes, the highest significant activity of α-esterase was recorded in susceptible Omnia in healthy and infested plants (925.67 and 850 ug α-naphthol/min/gdw, respectively). Whereas the highest activity of β-esterase was recorded in 036 in healthy and infested plants, however Fayrouz introduced the least activity of both enzymes in infestation and uninfestation. The correlation between infestation rate and each of peroxidase, phenoloxidase and beta esterase was an insignificant negative at 60 days and in general. Whereas, the correlation was significant negative in alpha esterase and insignificant positive in β-glucosidase at both level of infestations.

From the previous data, it could be concluded that there was a decrease in metabolic contents in all tested resistant and susceptible tomato cultivars in uninfested plants (coated) than infested plants (open field) during early-summer and nili plantations except for adversative result in α-esterase. This result may be attributed to the reduction of photosynthesis process in tomato plants under the absence of insect infestation stress which stimulate the evolution of biochemical mechanism that serving the production of secondary metabolism substance (Allelochemicals).

These findings were consistent with the reports that related to primay metabolites contents as a result to infestation like Tomczyk and Krompczyñska, (1985) who stated the reduction of total soluble protein in the injured tomato leaflet with mite, Adam *et al.,* (2011) who mentioned that induced changes in primary metabolism were important for plant responses to herbivory, providing energy and metabolic precursors for defense compounds and Helmi and Mohamed, (2016) in illustrating the

Table 12: Relationship between the content of some defensive enzymes in tested nili cultivars (healthy and infested) at 60 days of seedling and infestation percentages of *Tuta absoluta* larvae/ 25 leaflets during season, 2019.

Cultivars	Defensive enzymes										Infesta-tion per-centage at 60 days (%)	General mean of infesta-tion- pe-rcentage
	Peroxidase (ΔO.D.405/min/g dry weight)		Phenolxidase (O.D. units/min/g dry weight)		β-glucosidase (ug/glucose/min/ g dry weight		Alpha esterase (ug α-naphthol/ min/g dry weight		Beta esterase (ug β-naphthol/ min/g dry weight			
	Healthy	Infested	Healthy	Infested	Healthy	Infested	Healthy	Infested	Healthy	Infested		
86	1396.00a	1566.00b	75.33a	149.67a	850.00a	920.67a	705.33b	720.67b	444.67a	486.33b	29.33b	24.67b
036	1196.67b	1870.67a	81.00a	99.00b	552.00b	570.33b	581.33c	545.67c	457.67a	570.00a	32.00b	27.75b
Fayrouz	1051.67c	1184.00c	91.33a	93.67b	578.33b	978.00a	505.67d	470.00d	392.67b	424.33c	44.00a	33.25a
Omnia	720.33d	840.67d	70.67a	114.00b	456.33c	486.00c	925.67a	850.00a	415.33ab	468.67b	30.67b	27.17b
F. value	98.65**	218.72**	1.23ns	8.64*	123.42**	178.22**	280.61**	223.83**	4.62ns	50.43**	10.62**	13.85**
L.S.D.	99.18	104.97	27.75	29.7	52.61	63.95	37.93	39.67	47.09	29.71	7.17	3.36
Simple correlation (r) at 60 days	-	-0.22	-	-0.54	-	0.46	-	-0.63*	-	-0.51	-	-
Simple correlation (r) with general infestation percentage	-	-0.22	-	-0.42	-	0.28	-	-0.58*	-	-0.31	-	-

The same letter in the same column represents no significant differences ($p<0.05$).
*,** and ns indicate significance at 0.05 and 0.01 levels and insignificancy of differences, in respective order.

accumulation of soluble proteins and sugars as defense compounds in the resistant tomato cultivar (GS). As for secondary metabolites, Goffreda *et al.,* (1990) suggested that the glycoalkaloid α-tomatine is a possible resistance factor in tomatoes to beet armyworm, *S. exigua*, Gregory *et al.,* (1998) explained that the mechanical wounding of tomato leaves increased phenolic compounds by 10 fold, which have a role in defense responses of tomato plant, Stamp and Osier, (1998) showed the adverse effects of phenolic compounds and tomatine (alkaloid) on insect herbivores performance, Bialczyk *et al.,* (1999) mentioned that tannins reduced the numbers of whitefly on tomato, Freitas *et al.,* (2002) showed the role of sesquiterpene in resistant tomato cultivars, Kennedy, (2003) reported that phenolics are growth inhibitors of *H. zea* and *S. exigua* larvae in tomato foliage, Chris *et al.,* (2007) mentioned the induced olefinic terpenes by spider mite-infestation in tomato, Pereira *et al.,* (2008) proved the role of allelochemicals of resistant tomato plants against *T. absoluta*, Kang *et al.,* (2010) concluded that the basis leaves of tomato accumulate only trace levels of monoterpenes, sesquiterpenes and flavonoids and these defensive compounds influence host plant selection and Zeiss *et al.,* (2018) who described 41 metabolites in four resistant tomato cultivars. In concern to defensive enzymes, Han *et al.,* (2009) showed that resistant wheat cultivars against cereal aphid *Sitobion avenae* (F) showed greater constitutive polyphenol oxidase (PPO) activity in the tillering, stem elongation and flag leaf stages, while aphid infestation induced peroxidase (POD) activity in all cultivars, especially in susceptible ones, Gulsen *et al.,* (2010) mentioned that the POD and PPO are the important defensive enzymes in response to insect herbivory, War *et al.,* (2012) recorded that the resistant three groundnut lines ICGV86699 against *Spodoptera litura* showed greater elevation in POD and PPO activities and in phenolic than TMV2 (susceptible line) and Helmi and Mohamed, (2016) represented that the activity of POD and PPO in leaves increased significantly in the resistant cultivar of tomato (GS) than in the other cultivars.

Resulted variation between cultivars in pest population and chemical components could be confirmed by some researchers such as Letourneau *et al.*, 1996, Picanço *et al.*, 1998 and Leite *et al.,* 1999a who illustrated that variation may be a result to several morphological and chemical factors of plants, that influenced the pest population. Also, Fery and Kennedy, 1987 and Leite *et al.,* 2001 reported that the possible effect of trichomes on insects can result from chemical and/or mechanical factors; the chemical factor could be due to secretions produced by glandular trichomes which contain compounds that are toxic to insects. Other potential resistance factors are mechanical barriers, density, length and form of trichomes (Leite *et al.,* 1999a, b). The crystals that presented in the leaves is another factor that can interfere with insects feeding (Franceschi and Horner Júnior, 1980 and Leite *et al.,* 1999c).

References

Adam, D.S., S. Gómez, S. Osorio, A.R. Fernie and C.M. Orians (2011). Herbivore-induced Changes in Tomato (*Solanum lycopersicum*) Primary Metabolism. *A Whole Plant Perspective, J. Chem. Ecol*., **37:** 1294-1303.

Al Antary, T.M., A.S. Alhawamdeh and A.M. Katbeh-Bader (2019). The susceptibility of three tomato cultivars and the efficacy of three insecticides in controlling the broad tomato leafminer, *Tuta absoluta* (Meyrick) (Lepidoptera: Gelechiidae) in the high lands of Jordan. *Fresenius Environmental Bulletin*, **28(11A):** 8694-8701.

Allal, B.L., M. Bellatreche, F. Bounaceur, G. Tail and H. Mostefaoui (2011). Distribution of the infestations and larval generations of the tomato moth on five tomato varieties in greenhouse: is there a varietal resistance? [French] Les Cochenilles: ravageur principal ou secondaire. 9eme Conference Internationale sur les Ravageurs en Agriculture, SupAgro, Montpellier, France, 25-27 October 2011, **335**.

Anonymous (2013). Agricultural Statistics Bulletin. Central Administration of Economic. Ministry of Agriculture, Egypt, 170.

Azadi, F., A. Rajabpour, A.L.J. Abadi and M. Mahjoub (2018). Resistance of tomato cultivars to *Tuta absoluta* (Lepidoptera: Gelechiidae) under field condition. *Research Article. J. Crop Prot*., **7(1):** 87-92.

Bialczyk, J., Z. Lechowski and A. Libik (1999). The protective action of tannins against glasshouse whitefly in tomato seedlings. *The Jour. of Agricult. Science*, **133(2):** 197-201.

Borgorni, P.C., R.A. Da Silva and S.G. Carvelho (2003). Leaf mesophyll consumption by *Tuta absoluta* (Meyrick, 1971) (Lepidoptera: Gelechiidae) in three cultivars of *Lycopersicon esculentum* MILL. *Ciencia Rural*, **33(1):** 7-11.

Bottega, D.B., A.L. Boica Junior, B.H.S. Souza and A.L. Lourencao (2015). Biological aspects of *Tuta absoluta* (Lepidoptera: Gelechiidae) reared on leaves of different tomato genoypes. *Revista de Ciencias Agrarias*, **38(2):** 139-148.

Bradford, M.M. (1976). A Rapid and Sensitive Method for the Quantitation of Microgram Quantities of Protein Utilizing the Principle of Protein-Dye Binding. *Analytical Biochemistry*, **72:** 248-254.

Chris, C.N., V. Schie, M.A. Haring and R.C. Schuurink (2007). Tomato linalool synthase is induced in trichomes by jasmonic acid, *Plant Mol. Biol*., **64(3):** 251-263.

Colomo, M.V. and D.C. Berta (2006). First record of a member of the Exoristini (Diptera: Tachinidae) in *Tuta absoluta* (Lepidoptera, Gelechiidae). *Acta Zoologica Lilloanna Argentina*, **50(1):** 123-124.

Dai, X., G. Wang, D. Yang, Y. Tang, P. Broun, M. Marks, L. Sumner, R. Dixon and P. Zhao (1999). Trichome: a comparative omics database for plant trichomes. *Plant Physiol*., **152:** 44-54.

Darbain, S., A.K. Emam, A. Helmi, S.S. El-Badawy and S. Moussa (2016). Susceptibility of certain tomato cultivars to infestation with *Tuta absoluta* (Meyrick) (Lepidoptera: Gelechiidae) in relation to leaflet trichomes. *Egypt. J. Agric. Res*., **94(4):** 829-840.

De Oliveira, C.M., V.C. De-Andrade Junior, W.R. Maluf, I.P. Neiva and G.M. Maciel (2012). Resistance of tomato strains to the moth Tuta absoluta imparted by allelochemicals and trichome density. *Ciência e Agrotecnologia*, **36(1):** 45-52.

El-Badawy, S., A.K. Emam, S. Moussa, H.A. Al-Ghanam and S. Darbin (2017). Interpretation of Susceptibility Phenomenon of Four Tomato Cultivars to *Tuta absoluta* (Meyrick) (Lepidoptera: Gelechiidae). *Egypt Acad. J. Biolog. Sci.*, **10(3):** 17-28.

FAOSTAT (2014). Egypt Country Profile:http:// faostat.fao.org/ Country Profiles/Country_Profile/ Direct.aspx?lang=en &area =59 visited in March 2014.

Fery, R.L. and G.G. Kennedy (1987). Genetic Analysis of 2-tridecanone concentration, leaf trichome characteristics and tobacco hornworm resistance in tomato. *Journal of the American Society for Horticultural Science, Alexandria*, **112(5):** 886-891.

Franceschi, V.R. and H.T. Horner Junior (1980). Calcium oxalate crystals in plants. *Botanical Review, NewYork*, **46(1):** 361-427.

Freitas, J., W. Maluf, M.G. Cardoso, L. Gomes and E. Bearzotti (2002). Inheritance of foliar zingiberene contents and their relationship to trichome densities and whitefly resistance in tomatoes. *Euphytica*, **127:** 275-287.

Ghaderi, S, Y. Fathipour and S. Asgari (2017). Susceptibility of Seven Selected Tomato Cultivars to *Tuta absoluta* (Lepidoptera: Gelechiidae): Implications for its Management. *J. Econ. Entomol.*, **110(2):** 421-429.

Goffreda, J.C., E.J. Szymkowiak, I.M. Sussex and M.A. Mutschler (1990). Chimeric tomato plants show that aphid resistance and triacylglucose production are epidermal autonomous characters. *The Plant Cell*, **2:** 643-649.

Gregory, P., P.A. Marchand, J. Griswold, N.G. Lewis and C.A. Ryan (1998). Accumulation of feruloyltyramine and p-coumaroyltyramine in tomato leaves in response to wounding. *Phytochemistry,* **47(4):** 659-664.

Gulsen, O., T. Eickhoff, T. Heng-Moss, R. Shearman, F. Baxendale, G. Sarath and D. Lee (2010). Characterization of peroxidase changes in resistant and susceptible *warmseason turfgrasses* challenged by *Blissus occiduus*. *Arthropod Plant Interact*., **4:** 45-55.

Han, Y., Y. Wang, J.L. Bi, X.Q. Yang, Y. Huang, X. Zhao, Y. Hu and Q.N. Cai (2009). Constitutive and induced activities of defense-ralated enzymes in aphid-resistant and aphid-susceptible cultivars of wheat. *Journal of Chemical Ecology,* **35:** 176-182.

Hanley, M.E., B.B. Lamont, M.M. Fairbanks and C.M. Rafferty (2007). Plant structural traits and their role in antiherbivore defense. *Plant Ecol. Evol. Syst*., **8:** 157-178.

Helmi, A. and H.I. Mohamed (2016). Biochemical and

Ultrastructural Changes of Some Tomato Cultivars after Infestation with *Aphis gossypii* Glover (Hemiptera: Aphididae) at Qalyubiyah, Egypt. *Gesunde Pflanzen*, **68:** 41-50.

Howe, G.A. and G. Jander (2008). Plant immunity to insect herbivores. *Ann. Rev. Plant Biol*., **59:** 41-66.

Ishaaya, I. (1971). Observations on the phenoloxidase system in the armored scales *Aonidiella aurantii* and *chrysomphalus aonidum. Comp. Biochem. physiol*., **39:** 935-943.

Kβhkônen, M.P., A.I. Hopia, H.J. Vuorela, J.P. Rauha, K. Pihlaja, T.S. Kujala and M. Heinonen (1999). Antioxidant activity of plant extracts containing phenolic compounds. *J. Agric, food chem*., **47:** 3954-3962.

Kang, J., F. Shi, A. Jones, M. Marks and G. Howe (2010). Distortion of trichome morphology by the hairless mutation of tomato affects leaf surface chemistry. *J. Exp. Bot*., **61:** 1053-1064.

Kennedy, G.G. (2003). Tomato, pests, parasitoids and predators tritrophic interactions involving the genus *Lycopersicon*. *Annu Rev Entomol*., **48:** 51-72.

Krishnaveni, S., T. Balasubramanian and S. Sadasivam (1984). Determination of reducing sugars, *Food chem*., **15:** 229.

Leite, G.L.D., M. Picanço, A.A. Azevedo and A.H.R. Gonring (1999a). Efeito de tricomas, aleloquímicos e nutrientes na resistência de *Lycopersicon hirsutum* à traça-do-tomateiro. *Pesquisa Agropecuaria Brasileira, Brasília*, **34(11):** 2059-2064.

Leite, G.L.D., M. Picanço, L. Della and M.D. Moreira (1999b). Role of canopy height in the resistance of *Lycopersicon hirsutum f. glabratum to Tuta absoluta* (Lep.; Gelechiidae). *Journal Applied of Entomology, Berlin*, **123(8):** 459-463.

Leite, G.L.D., M. Picanço, R.N.C. Guedes and L. Skowronski (1999c). Effect of fertilization levels, age and canopy height of *Lycopersicon hirsutum* on the resistance to *Myzus persicae* Entomologia Experimentalis et Applicata, *Dordrecht*, **91(2):** 267-273.

Leite, G.L.D., M. Picanço, R.N.C. Guedes and J.C. Zanuncio (2001). Role of plant age in the resistance of *Lycopersicum hirsutum* f. glabratum to the tomato leafminer *Tuta absoluta* (Lepidoptera: Gelichiidae). *Scientia Horticulturae, Amsterdam*, **89(2):** 103-113.

Letourneau, D.K., L.E. Drinkwater and C. Shennan (1996). Effects of soil management on crop nitrogen and insect damage in organic vs conventional tomato fields. *Agriculture, Ecosystems & Environment, College Park*, **57(2-3):** 179- 187.

Li, W., W. Long, X. wan, Q. Ding, F. Zhang and D. Wan (2014). Studies on quantitative determination of total alkaloids and Berberine in five origins of crude medicine "Sankezhen". *J. chromatographic Sci*., 1-5.

Lindroth, R.L. (1988). Hydrolysis of phenolic glycosides by mid gut β-glucosidases in *Papilo glaucus* subspecies. *Insect biochem*., **18:** 789-792.

Oliveira F.A., D.J. Da Silva, G.L.D. Leite, G.N. Jham and M. Picanco (2009). Resistance of 57 greenhouse-grown accessions of *Lycopersicon esculentum* and three cultivars to *Tuta absoluta* (Meyrick). (Lepidoptera: Gelechiidae). *Science Horticulture*, **119:** 182-187.

Pereira, G.V.N., W.R. Maluf, L.D. Gonçalves and I.R. Nascimento (2008). Seleção para alto teor de acilaçúcares em genótipos de tomateiro e sua relação com a resistência ao αcaro vermelho (*Tetranychus evansi*) e à traça (*Tuta absoluta*). *Ciên.Agrotec.*, **32:** 996-1004.

Picanço, M., G.L.D. Leite, R.N.C. Guedes and E.E.A. Silva (1998). Yield loss in trellised tomato affected by insecticidal sprays and plant spacing. *Crop Protection, London*, **17(5):** 447-452.

Sakanaka, S., Y. Tachibana and Y. Okada (2005). Preparation and antioxidant properties of extracts of Japanese persimmon leaf tea (*kakinoha-cha*), *Food Chemistry*, **89:** 569-575.

Schoonhoven, M.L., J.A. Loon and M. Dicke (2005). Insect-Plant Biology, Published in the United States by Oxford University, 48-57.

Shawir, M.S., A. El-bakary, S.A.M. Abdelgaleil and G.R.M. Ramadan (2014). Susceptibility of five tomato varieties to *Tuta absoluta* infestation in insecticide treated fields. *Alexandria Science Exchange Journal*, **35:** 249.

Singleton, V.L. and J.A. Rossi (1965). Colorimetry of total phenolics with phosphomolybdic-phosphotungstic acid reagents. *Am. J. Enol. Vitic*., **16:** 144-158.

Smith, C.M. and S.L. Clement (2012). Molecular bases of plant resistance to arthropods. *Ann. Rev. Entomol*., **57:** 309-328.

Sohrabi, F., H.R. Nooryazdan, B. Gharati and Z. Saeidi (2017). Plant resistance to the moth *Tuta absoluta* (Meyrick) (Lepidoptera: Gelechiidae) in tomato cultivars. *Neotropical Entomology*, **46(2):** 203-209.

Stamp, E.N. and T.L. Osier (1998). Response of five insect herbivores to multiple allelochemicals under fluctuating temperatures, You have full text access to this content, *Entomologia Experimentalis et Applicata*, **88(1):** 81-96.

Tomczyk, A. and D. Krompczyñska (1985). Effects on the host plant. *Elsevier*, **5:** 317-329.

Van Asperen, K. (1962). A study of house fly esterase by means of sensitive colourimetric method. *J. Insect physiol*., **8:** 401-416.

Van-Buren, J.P. and W.B. Robinson (1981). Formation of Complexes between Protein and Tannic Acid, J*ournal of Agric. Food Chemistry*, **17:** 772- 777.

Vetter, D.S. (1958). Quantitative determination of peroxidaese in sweet corn. *Agric. and food chem*., **6(1):** 39-41.

Waller, R.A. and D.P. Duncan (1969). A bays rule for symmetric multiple comparison problem. *Am. Stat. Assoc. J*., **64:** 1485-1503.

War, A.R., M.G. Paulraj, M.Y. War and S. Ignacimuthu (2012). Herbivore-induced resistance in different groundnut germplasm lines to Asian army worm, *Spodoptera litura* (Fab.) (Lepidoptera: Noctuidae). *Physiol. Plant*., **34:** 343.

WPTC (2011). Report of World Processing Tomato Council. 10.

Zeiss, D.R., M.I. Mhlongo, F. Tugizimana, P.A. Steenkamp and I.A. Dubery (2018). Comparative Metabolic Phenotyping of Tomato)*Solanum lycopersicum*) for the Identification of Metabolic Signatures in Cultivars Differing in Resistance to *Ralstonia solanacearum. International Journal of Molecular Sciences*, **19(9):** 2558 (17).