

Efficacy of Exogenous Elicitors against *Tuta Absoluta* on Tomato

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Abstract: Plant defensive systems against herbivores such as leafminers can be induced by application of biotic and abiotic elicitors. In this study we examined the effect of some elicitor treatments on the response of tomato hybrid cultivar Gold Stone against (*Tuta absoluta*). Also, their effects on the growth characteristics of tomato were studied in the successive summer seasons of 2011 and 2012. The treatments were salicylic acid (SA) at 200 ppm, L-ascorbic acid (L-AA) at 200 ppm and at 500 ppm, benzothiadiazole (BTH) at 200 ppm, effective microorganisms (EM) at 5m/L., ethanol (solvent) at 1m/L. and tap water (control). The application were treated three times in three stages of growth. L-AA at 200 ppm followed by BTH at 200 ppm were significantly reduced the percentage of (*Tuta absoluta*) density population and significantly reduced the percentage of infested leaflets on tomato. Also, most of growth characteristics were responded. SA and L-AA at 200 ppm as well as EM treatments enhanced significantly L-ascorbic acid (vitamin C). Moreover, SA treatment at 200 ppm significantly decreased tomato yield in both seasons.

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1. Introduction

Tomato, suffers damage from a large numbers of insect pests. Induced resistance to insect pests and plant pathogens has been documented in several crops (Kahl et al., 2000; Omer et al., 2001). Several investigators have proposed the use of elicitors of induced pest resistance as a means of controlling arthropod pests and diseases in agriculture (Thaler et al., 1999; Boughton et al., 2006). This new control approach arise because insect pests are serious constraints to increase productivity and expansion of crops (Verhagen et al., 2006; Buonaurio et al., 2009). Radman et al. (2003) classified these elicitors to two groups depending on their origin which include physical or chemical, biotic or abiotic agent. In a broad sense, "elicitors", for a plant defense refer to chemicals from various sources that can trigger physiological and morphological responses and phytoalexin accumulation (Mejia-Teniente et al., 2010). The chemical structure of elicitors is including glycoprotein, polypeptides, oligosaccharides, polysaccharides, lipid compounds or others (OđjacoVa and Hadjiivanova, 2001). Two pathways have been implicated in plant response to insect pests; the first is JA-dependent wound pathway, and the second is JA-independent wound pathway as reported by Reymond and Farmer (1998). They also should that both pathways are primarily associated with insects feeding and concluded that salicylic acid (SA) and jasmonic acid (JA) are seen as the key

signals for defense gene expression. The ability of plants to produce or perceive members of the jasmonate family of regulators is essential for their defence against tobacco hornworm (Reymond et al., 2000). Other signals and stimuli also lead to the expression of genes in wounded plant tissues are found such as ethylene (Rojo et al., 1999), abscisic acid and electrical signals (Wildon et al., 1992). However, jasmonic acid "JA" or methyl jasmonate "MJ" application increased plant resistance to insect pests by reducing insect preference, performance, and reproduction (Stout and Duffey, 1996 and Thaler et al., 1996). In tomato, foliar application of jasmonic acid and other elicitors may be valuable pest management tools under high densities of insect pests that can reduce yield (Thaler, 1999). Decreasing of populations of many common pests by different elicitors in tomato field were detected as reported by Thaler et al., 2002) and Boughton et al., (2006). These pests were *Frankliniella occidentalis* Pergrande (thrips), *Spodoptera exigua*, *Trichoplusia ni* Hubner (noctuid caterpillars), *Epitrix hirtipennis* Melsheimer (flea beetles), *Macrosiphum euphrbiae* Thomas, and *Muzus persical* Sulzer (aphis). Howe et al., (1996) showed that a tomato mutant that was deficient in the capacity to induce defense genes, through the octadecanoid pathway, was very susceptible to damage by *Manduca sexta*. On the other hand, a large variations among different crops in their growth and yield response to the application

of elicitors were reported by Walker et al., (2004). The application of various doses from the elicitor Chitosan resulted in yield increase of nearly 20% in two out of three tomato trials but insignificant differences were detected in average yield of cucumber, capsicum or peas from any treatment. In this experiment, four elicitors were evaluated to identify their impact on the population densities of *Tuta absoluta* tomato pest as well as their effects on the growth and yield of tomato cv. Golden stone.

2. Materials and Methods

Seeds of tomato hybrid Golden Stone were planted in trays under the green plastic house conditions using the standard nursery culture practices in Egypt, during the summer seasons of 2011 and 2012. Seven treatments were applied with hand sprayer to plants at the 4-leaf stage. Neighboring plants in the nursery were shielded from the spray with a large sheet of plastic. The studied treatments were as follows:

1. Salicylic acid "SA" at 200 ppm
2. Ascorbic acid "AA" at 200 ppm
3. Ascorbic acid "AA" at 500 ppm
4. Benzothiadiazole "BTH" at 200 ppm
5. Effective Microorganisms "EM" at 5m/L. (EM fertilizer : consists of around 80 species of selected beneficial microorganisms including lactic acid , yeast , photosynthetic bacteria and actinomycetes among other types microorganisms such as fungi (Xu, 2000). EM were obtained from Minia University – Agriculture college) .

6. Ethanol 95 at 1ml/L.

7. Tap water

The salicylic acid was dissolved in 1 ml of ethanol 95% before dispersed in one liter of tap water. Ascorbic acid and benzothiadiazole and dispersed in one liter of tap water.

The nursery treated plants were transplanted in the experimental open field after 45 days from sowing on 28th May of 2011 and the 20th May of 2012. The first season was conducted at Experimental Farm of Faculty of Agriculture, Minia University. The second season was done at private farm at Talla village, El Minia governorate. The experiment in both seasons were arranged in a Complete Randomized Block Design (CRBD) with three replications. Each plot was three rows 4.5 meters long and one meter width. The transplants were spaced 45 cm within each row. The total numbers of tested plants per replicate for each treatment were approximately 30 plants. After 40 and 55 days from transplanting, tomato plants were retreated with the previously mentioned treatments. All agricultural

practices were carried out according to the recommendations of the Egyptian Ministry of Agriculture for commercial tomato production (Mohamad and Desouky, 2005). Hand weeding was carried out when needed and no pesticides were used throughout the experiment.

A. Data collection

The data were recorded in the field and in the laboratory under binocular microscope. The percentage of reduction was calculated according to Henderson and Tilton formula (1955) with some modification as follows:

% of reduction = $[1 - \text{Number of insect in specific treatment} / \text{number of insect population in control}] * 100$.

Also, data were recorded for the following growth, fruit and yield characteristics:

Above growth:

Dry weight of 250 g. of above ground growth as well as from mature fruits were determined in the second season. The samples were dried for 5 to 6 hours at 70°C until constant weight and the fresh/dry ratio of the sample were calculated as follows:

% of dry weight = $(\text{sample dry weight} / 250) * 100$

B. Chemical constituents of fruits:

- Total soluble solids TSS was determined by a hand refractometer (Carlizeiss Jena 1 DDR 783255) in a fruit juice obtained by squeezing the flesh after cutting the fruit crosswise.

- L-Ascorbic acid content was determined using 2, 4-Dichlorophenolindophenol blue dye (Cox and Person, 1962) and expressed as mg/100g fruit fresh weight.

- pH of tomato juice was measured using pH digital instrument model Hi 98127-HANNA- as described by Dilmacunal et al.(2011).

- Number of locules/Fruit. (Ten fruits in each plot were calculated).

- Average fruit weigh: (In each treatment from 3 replicates / treatment after each picking).

- Shape index: (The shape index = $\frac{\text{diameter}}{\text{width}}$ of fruit).

- Thickness of pericarp: (Thickness of flesh was determined by dermis tool).

- Percentage of Insect-infested fruit: $(\frac{\text{Insect-infested fruit}}{\text{Total fruits}} * 100)$

- Yield (tones/Feddan). (Total weight of fruits per plot were determined and converted to tons/feddan).

C. Data analysis:

Data were analyzed using the MSTAT statistical software (MSTAT Inc., USA), with comparison of means using Duncan's means separation test.

Mean of field temperatures and relative humidity on two seasons (2011 & 2012) were recorded in Table (1).

Table (1): Mean of field temperatures and relative humidity on two successive seasons (2011 &2012)

Season		2011			2012		
Month	Day	Mean of Field temperature		Mean of Relative humidity	Mean of Field temperature		Mean of Relative humidity
		Maxi.	Mini.		Maxi.	Mini.	
April	20-30	39.4	10.3	59.7	46.1	11.5	54.0
May	1-15	41.2	12.8	49.4	44.9	14.0	42.8
	16-31	44.8	15.0	44.3	45.0	16.9	41.3
June	1-15	41.8	17.8	47.7	47.2	17.9	39.5
	16-30	43.9	17.6	50.4	48.7	20.3	42.4
July	1-15	45.5	19.0	43.6	49.5	20.3	46.9
	16-31	46.4	19.4	47.0	48.1	21.1	51.7
August	1-15	44.0	19.5	50.7	48.5	19.9	52.1
	16-31	40.5	18.3	51.9	45.7	17.9	58.2
September	1-15	43.9	17.5	54.8	42.3	18.1	61.7

Source: Agricultural Meteorology Station of Mallawy.

3. Results

Foliar damage:

In the first season, the results on efficacy of elicitors obtained after second spray are presented in Table (2) and Fig (1). At 39 DAC (Day after cultivation), L-AA (200) ppm recorded the lowest percentage of *T. absoluta* infested plants followed by BTH and SA. Whereas all remaining treatments were found on par with each other. The reduction percentage of the total number of mines per plant were 75.28 and 39.00 % in 2011 and 73.19 and 57.10 % in the second season for L-AA at 200 ppm and BTH treatments, respectively. After the first spray, numbers of mines of *T. absoluta* per plant was ranged from 2.93 to 11.87. Among the tested treatments, the lowest values was recorded in plots treated with L-

AA (200) ppm followed by BTH treatment. At 48 DAC, all the treatment differed significantly over untreated control in reducing the population density of infested plants with *T. absoluta*. Observation showed that the plots treated with L-AA at 200 ppm, BTH and SA were recorded the lowest population of *T. absoluta* 11.2 and 20.80 stages per plant. EM recorded 26.20 stages which was significantly lower than untreated control (41.40) stages / plant. Similar treated was observed in the second season. However, the pest population was lower that the first one. Treatments with different elicitors had significant effects on *Tuta absoluta* mines at 64 days after cultivation.

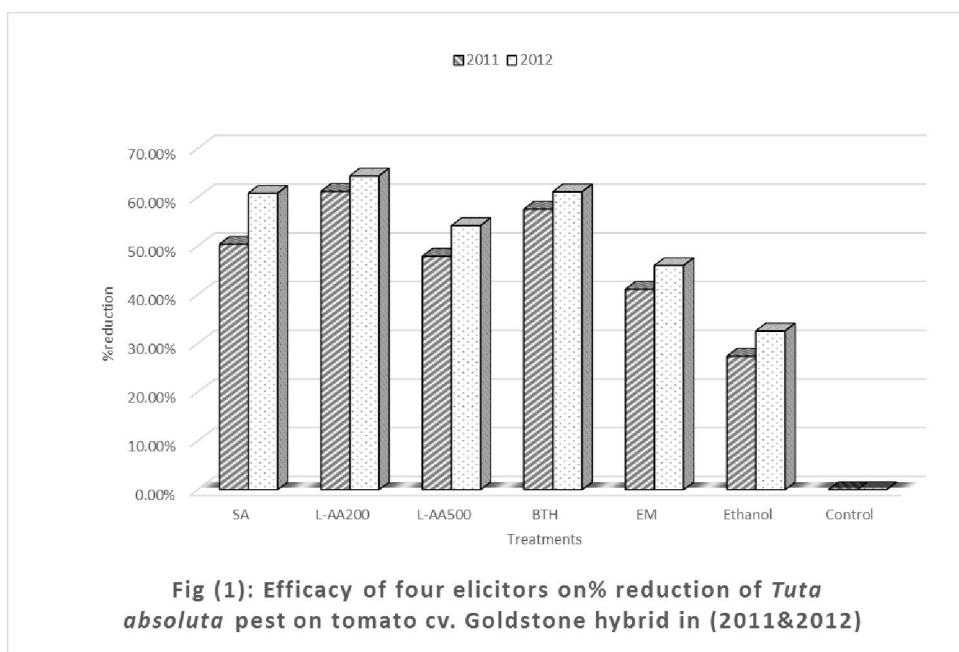


Table (2) Efficacy of four elicitors against *Tuta absoluta* pest on tomato cv. Goldstone hybrid in 2011.

Tr.	Dose(ml/L.)	2nd spray		3rd spray				4th spray			
		39 DAC	%Red.	48 DAC	64 DAC	Mean	%Red.	75 DAC	89 DAC	Mean	%Red.
SA	200	8.13 BC	31.51%	20.80 C	31.60 CD	26.20	49.71%	33.13 CD	33.47 CDE	33.30	50.35%
L-AA	200	2.93 D	75.32%	11.20 D	23.60 E	17.40	66.60%	25.80 E	26.27 E	26.03	61.18%
L-AA	500	10.00 ABC	15.75%	22.73 BC	33.27 CD	28.00	46.26%	34.47 CD	35.40 CD	34.93	47.91%
BTH	200	7.13 C	39.93%	18.73 C	27.47 DE	23.10	55.66%	28.40 DE	28.54 D	28.47	57.55%
EM	5	10.73 AB	9.60%	26.20 BC	37.53 C	31.87	38.84%	39.33 C	39.67 C	39.50	41.10%
Ethanol	1	10.33 AB	12.97%	29.20 B	45.73 B	37.47	28.09%	48.33 B	49.07 B	48.70	27.39%
Control	-	11.87 A	-	41.40 A	62.80 A	52.10	-	66.67 A	67.47 A	67.07	-

Means followed by a common letter are not significantly different at 5% level.

Table (3) Efficacy of four elicitors against *Tuta absoluta* pest on tomato cv. Goldstone hybrid in 2012.

Tr.	Dose (ml/L.)	2nd spray		3rd spray				4th spray			
		39 DAC	%Red.	48 DAC	64 DAC	Mean	%Red.	75 DAC	89 DAC	Mean	%Red.
SA	200	2.33 BC	37.5%	5.00 A	7.13 C	6.07	58.46%	7.40 C	8.80 C	8.10	60.80%
L-AA	200	1.00 C	73.1%	4.00 B	6.00 C	5.00	65.75%	6.20 C	8.53 C	7.37	64.36%
L-AA	500	3.20 B	14.2%	7.07 B	8.27 BC	7.67	47.47%	9.27 BC	9.67 BC	9.47	54.17%
BTH	200	1.60 BC	57.10%	4.13 B	7.87 BC	6.00	58.90%	8.00 C	8.07 C	8.04	61.12%
EM	5	2.65 BC	28.95%	6.27 B	9.67 BC	7.97	45.41%	10.00 BC	12.33 BC	11.17	45.97%
Ethanol	1	3.53 B	5.36%	7.73 AB	12.47 B	10.10	30.82%	13.47 B	14.40 B	13.94	32.57%
Control	-	5.73 A	-	11.07 A	18.13 A	14.60	-	19.80 A	21.53 A	20.67	-

Means followed by a common letter are not significantly different at 5% level.

The number of mines per plant 23.60 and 27.47 for L-AA and BTH compared to 45.73 and 62.80 stages per plant in the ethanol and water control, respectively. Mean mines counts per plant were not significantly differed on plants receiving SA and L-AA (500 ppm) than counts on plants receiving EM treatment. Although the populations were much lower, the results trend were similar in the season reading. (Table 3) and Fig (1). At 75 days total number of mines was significantly affected by elicitor treatments (table 1). Means of mined leaves per plant were significantly lower on L-AA and BTH-treated plants (25.8 and 28.4 mines /plant) than on control-treated plants (66.67 mines). However, mines on L-AA – treated plants were about two and half times more than that on water control-treated plants. Insignificant differences of pest population per plant were detected among SA, L-AA 200 and L-AA 500, BTH and EM treatments in the second season at this stage of growth. The population ranged from 6.20 to 10.00 mines / plant compared to 13.47 and 19.80 mines in ethanol and water-control, respectively.

Laboratory examination:

The post spray data recorded after the first field spray at 48 days from cultivation in the first season and second one, respectively are presented in Table (4). In the first season, the percentage of infested leaflets obtained from samples taken on the first

sampling date in all treatments were insignificantly less than in the untreated control. EM, BTH and SA treatments gave the less values in descending order. (Table 4). In samples from the second sampling dates, EM, BTH and L-AA 200 treatments significantly reduced the percentage of infested leaflets compared to the control. Also, in samples from the fourth sampling dates, all treatments significantly reduced the percentage of infested leaflets compared to the control. The population densities of *Tuta absoluta* were low on the third and fourth sampling dates (Table 4). EM showed minimum (9%) followed by BTH (13%) and SA (15%) compared to 28% in the water-treated plants. In the second season, all elicitors provided insignificant reductions of infested leaflet percent on the first sampling date when compared with the water-treated control. In addition, all elicitors treatments significantly reduced percentage of infested leaflets on tomato in the samples collected after 55 and 64 days from cultivation (Table 4). The most effective elicitors were SA, L-AA 200, L-AA 500 and BTH and the least effective was EM.

In the first season, the *Tuta absoluta* was high with about 28% of the fruit in the control plots being damaged (Table 5). All treated plots yielded more no damaged fruit than the control plots, treated with EM, L-AA 200, SA and BTH yielded insignificantly more healthy fruits than water-treated control.

In the second season, the *Tuta absoluta* population was low about 25% of the fruit in the control plots being damage (Table 6). Compared to the water-treated control, SA, L-AA 200, L-AA 500

and BTH treatments resulted in significantly less *Tuta absoluta* – damaged fruits.

Table (4) Efficacy of four elicitors on % infested leaflets and population of *Tuta absoluta* in two successive seasons 2011 and 2012 after 48, 55, 64 and 75 days
From planting tomato cultivar Gold stone.

Treatment/DA C	2011																			
	After 48 days					After 55 days					After 64 days					After 75 days				
	% infested Leaflets	Population				% infested Leaflets	Population				% infested Leaflets	Population				% infested Leaflets	Population			
Mine		Egg	Larvae	Total	Mine		Egg	Larvae	Total	Mine		Egg	Larvae	Total	Mine		Egg	Larvae	Total	
SA	15	5.67	0.67	0.33	6.67	3 A	0.67	-	-	0.67	-	-	-	-	-	4 AB	1.00	0.67	0.33	2.00
L-AA200	19	6.33	4.00	0.33	10.66	1 A	0.33	-	0.33	0.66	-	-	-	-	-	5 AB	1.33	-	1.00	2.33
L-AA500	27	10.33	1.33	0.67	12.33	3 A	0.67	-	-	0.67	3	0.67	-	-	0.67	4 A	1.00	-	-	1.00
BTH	13	6.33	1.33	1.00	8.66	1 A	0.33	-	0.33	0.66	1	0.33	-	0.33	0.66	4 AB	1.00	-	-	1.00
EM	9	3.67	-	0.67	4.34	1 A	1.00	-	-	1.00	3	0.67	-	-	0.67	4 AB	1.00	-	-	1.00
Ethanol	21	10.00	0.67	0.67	11.34	11 AB	2.67	-	0.33	3.00	-	-	-	-	-	5 AB	1.33	-	0.33	1.66
Control	28	22.33	1.67	1.00	25.00	15 B	10.33	-	0.67	11.00	5	1.33	-	0.33	1.66	13 B	3.67	-	0.67	4.34
Treatment/DA C	ns					**					ns					**				
2012																				
SA	17	2.00	-	-	2.00	3 A	0.33	0.33	-	0.66	- A	-	-	-	-	10	-	1.00	-	1.00
L-AA200	30	4.33	0.33	-	4.66	3 A	0.67	-	-	0.67	- A	-	-	-	-	3	0.33	0.33	-	0.67
L-AA500	30	10.33	0.67	-	11.00	3 A	0.67	0.67	-	1.34	3 A	-	0.33	-	0.33	7	0.33	0.33	-	0.67
BTH	23	3.00	-	-	3.00	3 A	-	0.67	-	0.67	3 A	0.33	-	-	0.33	13	0.67	1.67	-	2.33
EM	10	1.33	0.67	0.33	2.33	7 A	-	1.33	-	1.33	10 A	1.00	0.33	-	1.33	7	-	1.00	-	1.00
Ethanol	13	1.67	0.33	0.33	2.33	10 A	0.67	1.67	-	2.34	10 A	1.00	0.33	-	1.33	10	0.67	1.33	-	2.00
Control	50	7.00	1.00	0.67	8.67	33 B	4.67	2.67	-	7.34	23 B	2.33	1.00	-	3.33	10	1.00	4.00	-	5.00
Significance at 0.05 level	ns					**					**					ns				

Means followed by a common letter are not significantly different at 5% level.

Table (5) Determination of infection in 25 fruits /plot treated with elicitors in season 2011.

Treatment	Healthy	%Healthy	Infected			
			Tuta	Mines/fruit	Bollworm	Mines/fruit
SA	20.67	82.66	1.33	1.33	3.00	2.00
L-AA200	19.33	77.32	2.67	2.67	3.66	3.00
L-AA500	19.67	78.66	1.00	1.00	4.33	4.00
BTH	18.67	74.68	1.67	1.67	4.67	4.67
EM	19.67	78.68	1.33	1.33	4.00	4.00
Ethanol	20.33	81.32	2.33	2.33	2.66	2.33
Control	18.00	72.00	5.00	5.00	2.33	2.00
Significance at 0.05 level		ns				

Means followed by a common letter are not significantly different at 5% level.

Table (6) Determination of infection in 25 fruits /plot treated with elicitors in season 2012.

Treatment	Healthy	%Healthy	Infected			
			Tuta	Mines/fruit	Bollworm	Mines/fruit
SA	22.67	90.67 A	2.00	1.44	0.67	0.67
L-AA200	22.33	89.33 A	2.00	1.00	0.67	0.33
L-AA500	23.00	92.00 A	2.00	1.92	0.33	0.33
BTH	22.00	88.00 A	3.00	2.00	0.00	0.00
EM	21.33	85.33 A	2.67	2.33	2.00	1.33
Ethanol	21.67	86.67 A	2.33	4.08	1.67	1.17
Control	18.67	74.67 B	4.67	2.37	2.33	1.67
Significance at 0.05 level		*				

Means followed by a common letter are not significantly different at 5% level.

Table (7) Effect of Some elicitors on tomato fruit characteristics of hybrid cultivar Gold stone in two successive seasons.

Treatment/Season	Fresh weight (gm)		Shape index		TSS (°Brix)		No. of locules		Thickness of pericarp		L-Ascorbic acid mg/100g		pH	
	2011	2012	2011	2012	2011	2012	2011	2012	2011	2012	2011	2012	2011	2012
SA	98.68	93.00	1.05	1.03	3.78	2.94	5.43	5.22	0.64	0.64	22.64A	25.76A	4.47	4.50
L-AA200	95.20	89.53	1.05	1.04	3.72	3.11	5.33	5.11	0.62	0.61	24.91A	26.88A	4.47	4.47
L-AA 500	100.52	109.27	1.09	1.04	3.56	2.67	4.66	4.89	0.63	0.61	14.51B	14.19C	4.40	4.70
BTH	107.76	95.27	1.10	1.02	3.80	2.78	5.28	5.00	0.66	0.69	24.88A	21.28B	4.33	4.70
EM	101.60	90.40	1.05	1.02	3.47	2.78	4.83	5.00	0.63	0.63	23.41A	28.00A	4.40	4.63
Ethanol	100.08	86.00	1.10	1.02	3.33	2.89	4.76	4.56	0.64	0.61	15.12B	16.05C	4.57	4.40
Control	91.60	78.44	1.05	1.03	3.44	2.89	4.89	4.89	0.58	0.60	12.61B	13.81C	4.57	4.60
Significance at 0.05 level	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns	**	**	ns	ns

Means followed by a common letter are not significantly different at 5% level.

Data recorded on fruit characteristics are presented in table (7). Fruits in the tested treatments did not differ statistically in the fruit weight, fruit shape index, TSS, number of locules, pericarp wall thickness and pH in both seasons. On the other hand, the treated plants produced fruits with higher contents of ascorbic acid. The increase in the ascorbic acid in tomato fruits produced by treated plants was significantly more pronounced in the L-AA at 200 ppm and BTH treatments in the first season and in the L-AA at 200 ppm and EM treatments in the second season. However, the control plants gave the lowest contents in both seasons (Table 7).

Data presented in Table (8) and Fig (2) show that application of various elicitors affected significantly the total yield compared to the control treatments. The yield ranged from 19.95 to 25.58 Ton /Feddan in the first season and from 17.75 to 22.25 Ton / Feddan in the second one. Salicylic acid at 200

ppm was the most effective treatments in decreasing fruit yield of tomato cv. Goldstone. On the other hand, the highest yield occurred in ethanol treatment in the first season followed insignificantly by EM, L-AA at 200 ppm and BTH treatments in the first season. In the second season, L-AA at 200 ppm treatment produced the highest yield followed by EM treatment without significant different among these treatments. In the second season, BTH treatment significantly increased the percentage of dry weight of fruits followed by SA treatment, while Ethanol, L-AA 500 and L-AA 200 treatments significantly decreased the percentage of dry weight of fruits compared to control. On the other hand, the insignificantly highest percentage of dry weight of vegetative growth occurred in EM treatment followed by L-AA at 500 ppm compared to control.

Table (8) Efficacy of four elicitors on yield in two successive seasons (2011 & 2012).

Treatment Season /	Dry weight/250 gm. of fruits	% of dry weight of fruits	Dry weight /250 gm. of vegetative growth	% of dry weight of vegetative growth	Yield (Ton/Feedan)			
					2011		2012	
SA	16.71	6.68 AB	87.00	34.80	19.95 C	17.75 C		
L-AA200	10.61	4.24 C	87.07	34.83	23.10 B	22.25 A		
L-AA500	10.73	4.29 C	89.87	35.95	24.15 AB	19.39 BC		
BTH	18.91	7.56 A	84.90	33.96	23.10 B	19.03 BC		
EM	14.08	5.63 BC	91.02	36.41	22.77 B	21.94 A		
Ethanol	11.05	4.42 C	82.09	32.84	25.58 A	21.13 AB		
Control	15.14	6.06 B	84.22	33.69	24.82 AB	20.10 AB		
Significance at 0.05 level		*		ns	**	*		

Means followed by a common letter are not significantly different at 5% level.

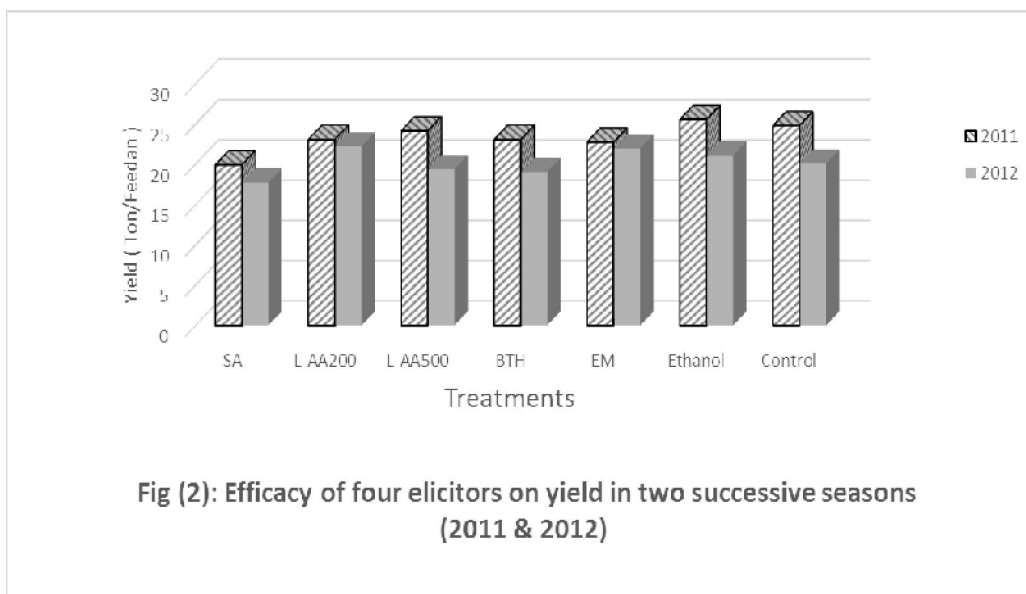


Fig (2): Efficacy of four elicitors on yield in two successive seasons (2011 & 2012)

4. Discussion

Tuta absoluta have become important pest in tomato. Damage is inflicted by punctures in the leaves, stem and fruits made by larvae for either feeding or oviposition. The larvae mine through the tissues of tomato plants and reduce the photosynthetic capacity of the plant as well as causing defoliation. In recently invaded areas, if no control measures are taken, then the *Tuta absoluta* pest can cause up to 80-100% yield losses in tomato crops and may pose a threat to both greenhouse and open-field tomato production (Desneux et al., 2010). In addition, resistance development has been reported against many pesticides (Siqueira et al. 2000, 2001 and Lietti et al., 2005) in different countries of South America. Chemical insecticide control has been the most common method for this control of tomato insect pests. Although, this method has effective against many insects, it has serious drawbacks and continued reliance on it is not a sustainable pest control strategy. This study aims to screen the response of tomato plants to some elicitors under open field conditions in order to minimize using pesticide and its side effect in the consumer health. Jasmonic acid induced resistance against leaf miner (*Liriomyza trifolii*) in Celery (Black et al., 2003) and in Sweet pepper (Tebayashi et al., 2007). Reduction of percentage of *T. absoluta* was obtained when tomato plants were treated with four elicitors in this study. Plant response to elicitors showed that the effects of the four elicitors were significantly different from the control treatments, but in various directions. The best was ascorbic acid (L-AA) at 200 ppm. However, the endogenous level of AA has recently been suggested to be important in the regulation of developmental senescence and plant

defense against pests (Pastor et al., 2003; Barth et al., 2004 and Pavet et al., 2005). Molecular and genetic studies suggested that cross talk between AA and various plant hormones are existed. It includes alteration in the electrophilic secondary metabolites in plants (Taber and Stevens; 2011). In addition, it acts directly to neutralize superoxide radicals (O_2^-), singlet oxygen ($O^$) or hydroxyl radical ($OH^$) simply by acting as a secondary antioxidant during reductive recycling of the oxidized form of α -tocopherol (Noctor and Foyer, 1998). L-AA serves as a Co-factor for many enzymes (Arrigioni and De-Tullio., 2000) and it contributes to the detoxification of reactive oxygen species (ROS) (Smirnoff and Wheeler, 2000; Conklin, 2001; Conklin and Barth, 2004). BTH followed by SA reduced pest population and mines / plant compared to control. Foliar application of BTH and SA was used to induce SA-dependent defenses (Cooper et al., 2004). Treatment with the SA and BTH induced both SA - and JA elicited genes (Heidel and Baldwin, 2004). The kinetics of SA and JA production varies greatly in both quantity and timing. SA and JA play a primary role in the orchestration of the plants defence response, but other regulatory mechanisms such as pathway cross- talk or additional attacker- induced signals, eventually shape the highly complex attacker- specific defence response (Vos et al., 2005 and Oosten, 2007). Whereas, it has been reported that SA and JA act antagonistically, where SA inhibits the activity of JA and vice versa (Maffei et al., 2007 and Rayapuram and Baldwin, 2007). The microorganisms elicitors (EM) also, has effectiveness on the reduction percentage of *Tuta absoluta*. It suggested that the effectiveness of microbially induced SAR and ISR against herbivore feeding such as *Spodoptera exigua*,

is associated with enhanced defense - related gene expression (Oosten, 2007). In laboratory examination the data recoded that, all elicitor treatments reduced the percentage of infested leaflets on tomato. The effective elicitors were SA, L-AA and BTH. Results obtained by Inbar et al. (1998) showed that BTH application reduced the density of leaf miner (*Liriomyza trifolii*) (adult host preference) in tomatoes but not larval survival. BTH induced local resistance and it seems that the negative effect of the SAR induced by BTH on insect herbivores should vary among plants and insect species (Inbar et al., 2001 and Nombela et al., 2005). Also, acquired resistance and R-gene mediated resistance can interact for enhanced suppression of insect herbivores (Cooper et al., 2004). Moreover, SA signaling molecule is involved in local defence as well as in induction of systemic resistance as reported by Peng et al., 2004. H₂O₂ induced by SA in treated plants defend them against various insect pest since H₂O₂ activity damages the digestive system of insects (Peng et al., 2004 and Maffei et al., 2007). Furthermore, SA signals release of plant volatiles that attract natural enemies of insect pests in tomato plants (De Boer et al., 2004). The effect of elicitors on fruit damage resulted in less *Tuta absoluta* – damaged fruits. Also, the obtained results indicated that all elicitor treatments insignificantly increased fresh weight, TSS and pH. On the other hand, some treatments enhanced significantly the L- Ascorbic acid (vitamin C). Similar results were found when SA was applied on tomato plants by Yildirim and Dursun (2009) and Glala et al. (2005). The four elicitors haven't affect the cultivar dependent characteristics; shape index, number of locules and thickness of pericarp. All elicitor treatments were insignificantly increased sample dry weight of vegetative growth. These results agree with those obtained by Glala et al. (2005) and Yildirim and Dursum (2009) when tomato plants treated with SA. However, BTH and SA treatments significantly increased dry weight of fruits. The same results were recorded when SA was foliarly applied by Glala et al. (2005) and Yildirim and Dursun (2009). Although SA treatment in this study was significantly reduced total yield compared to water- treated, Iverson et al. (2001), Yildirim and Dursun (2009) reported that yield of tomato was significantly influenced by foliar SA application and the highest yield occurred in 0.50 mM SA treatment. Yield response to application of various elicitors could be partially explain the difference between these results and the results reported by other researchers. From the preceding results and discussion, it can be concluded that foliar application on tomato cultivar Gold stone with L- ascorbic acid

at 200 ppm dose and BTH at 200 ppm dose improved tomato growth and reduced *Tuta absoluta* damage.

References

1. Arrigioni O. and De Tullio M.C. (2000). The role of ascorbic acid in cell metabolism: between gene directed functions and unpredictable chemical reactions. *Journal of Plant Physiology*. 157: 481-488.
2. Barth C., Moeder W., Klessing D.F. and Conklin P.L. (2004). The timing of senescence and response to pathogens is altered in the ascorbate-deficient Arabidopsis mutant vitamin C-1. *Plant Physiology*. 134:1784-1792.
3. Black C.A., Karban R., Godfrey L.D., Granett J. and Chaney W.E. (2003). Jasmonic acid: Avaccine against leafminers (Diptera: Agromyzidae) in Celery. *Envirom. Entomol.* 32 (5): 1196-1202.
4. Boughton A.J., Hoover K., and Felton G.W. (2006). Impact of chemical elicitor applications on greenhouse tomato plants and population growth of the green peach aphid, *Myzuzs persicae*. *Entomologia Experimentalis et Applicata* 120:175-188.
5. Buonauro R., Lriti M., and Romanazzi. G. (2009). Induced resistance to plant diseases caused by Oomycetes and Fungi. *Petria*, 19(3):130-148.
6. Conklin P.L. (2001). Recent advances in the role and biosynthesis is of ascorbic acid in plants. *Plant, Cell and Environment*. 24:383-394.
7. Conklin P.L. and Barth C. (2004). Ascorbic acid, a familiar small molecule intertwined in the response of plants to ozone, pathogens and the onset of senescence. *Plant, Cell and Environment*. 27: 959-971.
8. Cooper W.C., Jia L. and Goggin F.L. (2004). Acquired and R-gene-mediated resistance against the potato aphid in tomato. *Journal of Chemical Ecology*. 30 (12): 2527-2542.
9. De Boer, J.G., Posthumus, M.A. and Dicke, M. (2004). Identification of volatiles that are used in discrimination between plants infested with prey or nonprey herbivores by a predatory mite. *J Chem. Ecol.*, 30:2215-30.
10. Desneux N., Wajnberg E., Wyckhuys K.A.G., Burgio G., Arpaia S., Narva/ez-Vasquez C.A., Gonzalez-Carera J., Ruescas D.C., Tabone E., Fradon J., Pizzol J., Poncet C., Cabello T., and Urbaneja A. (2010). Biological invasion of European tomato crops by *Tuta absoluta* : ecology, geographic expansion and prospects for biological control. *J. Pest. Sci.* 83: 197-215.

11. Dilmacunal T., Koyuncu M.A., Aktas H. and Bayindir D. (2011). The effect of several postharvest treatments on shelf life quality of bunch tomatoes. *Not. Bot. Horti. Agrobi.* 39 (2):209-213.
12. Glala A.A., Hoda A.M. and Fawzi Z.F. (2005). Improving tomato plant growth, health, earliness, productivity and fruit quality by chemically induced systematic resistance. *Journal of Applied sciences Research*.1 (5): 362-372.
13. Heidel A.J. and Baldwin I.T. (2004). Microarray of salicylic acid- and jasmonic acid-signaling in responses of *Nicotiana attenuata* to attack by insects from multiple feeding guilds. *Plant, Cell and Environment*. 27(11): 1362-1373.
14. Henderson C.F. and W. Tilton (1955). Tests with acaricides against the brown wheat mite. *J. Econ. Entomol.* 48:157-161.
15. Howe G.A., Lightner J., Browse J. and Ryan C.A. (1996). An octadecanoid pathway mutant (JLS) of tomato is compromised in signaling for defense against insect attack. *Plant Cell*.8:2067-77.
16. Inbar M., Doostdar H., Sonoda R.M., Leibe G.L. and Mayer R.T. (1998). Elicitors of plant defensive systems reduce insect densities and disease incidence. *Journal of Chemical Ecology* 24:135-149.
17. Inbar M., Doostdar H., Gerling D., and Mayer R.T. (2001). Induction of systemic acquired resistance in cotton by BTH has a negligible effect on phytophagous insects. *Entomologia Experimentalis et Applicata*. 99: 65-70.
18. Iverson A.L., Iverson L.R. and Eshita S. (2001). The effects of surface-applied jasmonic acid and salicylic acids on caterpillar growth and damage to tomato plants. *OHIO. J. Sci.* 101 (5): 90-94.
19. Kahl J., Siemens D.H., Aerts R.J., Gabler R., Kuhnemann F., Preston C.A., Baldwin I.T. (2000). Herbivore-induced ethylene suppresses a direct defense but not a putative indirect defense against an adapted herbivore. *Planta* 210:336-342.
20. Lietti M.M.M., Botto E. and Alzogaray R.A. (2005). Insecticide resistance in Argentine population of *Tuta absoluta* (Meyrick) (Lepidoptera: Gelechiidae). *Neotrop. Entomol.* 34: 113-119.
21. Maffei M.E., Mithofer A. and Boland W. (2007). Insects feeding on plants: rapid signals and responses preceding the induction of phytochemical release. *Phytochemistry*. 68: 2946-59.
22. Mejia-Teniente, L., Torres-Pacheco I., Gonzalez-Chavira M.M., Ocampo-Velazquez R.V., Herrera-Ruiz G., Chapa-Oliver A.M., Guevara-Gonzalez R.G. (2010). Use of elicitors as an approach for sustainable agriculture. *Afr. J. Biotech.* 9, 9155-9162.
23. Mohamad M.A. and Desouky S.M. (2005). Producing and trading tomatoes. *Technical Bulletin No.14*. Issued by the General Administration of Agriculture Culture.
24. Noctor G. and Foyer C.H. (1998). Ascorbate and glutathione; Keeping active oxygen control. *Annual Review of Plant Physiology and Plant Molecular Biology*. 49: 249-279.
25. Nombela G., Pascual S., Aviles M. Guillard E. and Muniz M. (2005). Benzothiadiazole induces local resistance to *Bamisia tabaci* (Hemiptera: Aleyrodidae) in tomato plants. *J. Econ. Entomol.* 98 (6): 2266-2271.
26. Odjacova M. and Hadjiivansva C. (2001). The complexity of pathogen defense in plants. *Bulg. J. Plant. Physiol.* 27:101-109.
27. Oosten V. Van (2007). Induced pathogen and insect resistance in Arabidopsis: transcriptomics and specificity of defense. *Induced. Pathogen. And. Insect. Resistance. In. Arabidopsis: Transcriptomics. And. Specificity. Of. Defense.* 155pp.
28. Omer A.D., Granet J., Kabran R. and Villa E. (2001). Chemically-induced resistance against multiple pests in cotton. *Int. J. Pest Manag.* 47 (1) 49-54.
29. Pastor G.M., Kiddle G., Antoniw J., Bernard S., Veljovic-Jovanic S., Verrier P.J., Noctor G. and Foyer C.H. (2003). Leaf vitamin C contents modulate plant defense transcripts and regulate genes that control development through hormone signaling. *Plant Cell*. 15: 939-951.
30. Pavet V., Olmos E., Kiddle G., Mowla S., Kumar., Antoniw J., Alvarez M.E. and Fayer C.H. (2005). Ascorbic acid deficiency activates cell death and disease resistance responses in Arabidopsis. *Plant Physiology*. 139: 1291-1303.
31. Peng J., Deng X., Huang J., Jia S., Miao X. and Huang Y. (2004). Role of salicylic acid in tomato defense against cotton bollworm, *Helicoverpa armigera* Hubner. *Z Naturforsch C*. 59:856-62.
32. Radman R.T., Sae Z., Buck C., and Keshavarz T. (2003). Elicitation of plants and microbial cell systems. *Biotechnol. Applied Biochem.* 37:91-102.
33. Rayapuram C. and Baldwin I.T. (2007). Increased SA in NPR1-silenced plants antagonizes JA and JA-dependent direct and indirect defenses in herbivore-attacked

- Nicotiana attenuata* in nature. Plant Journal. 52: 700-15.
34. Reymond P. and Farmer E.E. (1998). Jasmonate and salicylate as global signals for defense gene expression. Current Opinion in Plant Biology. 1(5) 404-411.
 35. Reymond P. Weber H., Damond M. and Farmer E.E. (2000). Differential gene expression in response to mechanical wounding and insect feeding in Arabidopsis. Plant Cell, 12:707-720.
 36. Rojo E., Leon J. and Sanchez-Serrano J.J. (1999). Crosstalk between wound signaling pathways determines local versus systemic gene expression in *Arabidopsis thaliana*. Plant Journal. 20, 135-142.
 37. Siqueira H.A.A., Guedes R.N., and Picanço M.C. (2000). Insecticide resistance in populations of *Tuta absoluta* (Lepidoptera: Gelechiidae). Agric. For. Entomol. 2: 147-153.
 38. Siqueira H.A.A., Guedes R.N.C., Frangoso D.B., and Magalhaes L.C. (2001). Abamectin resistance and synergism in Barazilian population of *Tuta absoluta* (Meyrick) (Lepidoptera: Gelechiidae). Int. J. Pest Manage. 47: 247-251.
 39. Smirnoff N. and Wheeler G.L. (2000). Ascorbic acid in plants: biosynthesis and function. Crit. Rev. Biochem. Mol. Biol.35: 291-314.
 40. Stout M.J. and Duffey S.S. (1996). Characterization of induced resistance in tomato plants. Entomologia Experimentalis et Applicata. 79:273-283.
 41. Taber M.G. and Steven J.F. (2011). Vitamins C and E: Beneficial effects from a mechanistic perspective. Free Radic.Biol. Med., (in press).
 42. Tebayashi S-i., Horibata Y., Mikagi E., Kashiwagi T., Mekuria D.B., Dekebo A., Ishihara A. and Kim C.S. (2007). Induction of resistance against the leafminer, *Liriomyza trifolii*, by jasmonic acid in sweet pepper. Biosci. Biotechol. Biochem. 71 (6): 1521-1526.
 43. Thaler J.S. (1999). Jasmonate-inducible plant defences cause increased parasitism of herbivores. Nature 399,686-688.
 44. Thaler J.S., Fidantsef A.L., Duffey S.S. and Bostock R.M. (1999). Trade-offs in plant defense against pathogen and herbivores: a field demonstration of chemical elicitors of induced resistance. J Chem Ecol 25:1597-1609.
 45. Thaler J.S., Stout M.J., Karban R. and Duffey S.S. (1996). Exogenous jasmonates simulate insect wounding in tomato plants (*Lycopersicon esculentum*) in the laboratory and field. Journal of Chemical Ecology. 22, 1767-1781.
 46. Thaler J.S., Karban R., Ullman D.E., Boege K. and Bostock R.M. (2002). Cross-talk between jasmonate and salicylic plant defense pathways: effects on several plant parasites. Oecologia 131,227-235.
 47. Verhagen B.W.M., Van Loon L.C. and Pieterse C.M.J. (2006). Induced disease resistance signaling in plants. In: Floriculture Ornamental and Plant Biotechnology.(3)334-343. Advances and topic issues. Global Science books. ISSN:978-4-06-1.
 48. Vos M.de., Oosten V.R.Van., Poecke R.M.P.Van., Pelt J.A.Van., Pozo M.J., Muller M.J., Buchala A.J., Metrax J.P., Loon L.C.Van., Dicke M. and Pieterse C.M.J. (2005). Signal signature and transcriptome changes of Arabidopsis during pathogen and insect attack. Molecular. Plant. Microbe. Interactions. 18 (9): 923-937.
 49. Walker R., Morris S., Brown P. and Gracie A. (2004). Evaluation of potential for chitosan to enhance plant defense. Publication No.4 of Rural Industries Research and Development Corporation. Australia pp.55.
 50. Wildon DC, Thain JF, Minchin PEH, Gubb IR, Reilly AJ, Skipper YD, Doherty HM, O'Donnell PJ, Bowles DJ. 1992. Electrical signalling and systemic proteinase inhibitor induction in the wounded plant. Nature 360: 62-65.
 51. Xu, H. 2000. Soil-root interface water potential in sweet corn as affected by organic fertilizer and a microbial inoculant. In Xu, H.; Parr, J.F.; Umemura, H. (eds) Nature Farming and Microbial Applications. Pp139-156. The Haworth Press Inc. New York.
 52. Yildirim E. and Dursun A. (2009). Effect of foliar salicylic acid applications on plant growth and yield of tomato under greenhouse conditions. Acta. Hort. 807:395-400.