International Journal of Agricultural Research

ISSN 1816-4897

Academic Journals Inc.

www.academicjournals.com

International Journal of Agricultural Research 9 (4): 210-218, 2014
ISSN 1816-4897 / DOI: 10.3923/ijar.2014.210.218

Effect of Certain Low Toxicity Insecticides Against Tomato Leaf Miner, *Tuta absoluta* (Lepidoptera: Gelechiidae) with Reference to Their Residues in Harvested Tomato Fruits

Y.A. Mahmoud, H.A. Salem, Sh. E.M. Shalaby, A.S. Abdel-Razak and I.M.A. Ebadah
Department of Pests and Plant Protection, National Research Centre, Dokki, Cairo, Egypt

Corresponding Author: Y.A. Mahmoud, Department of Pests and Plant Protection, National Research Centre, Dokki, Cairo, Egypt

ABSTRACT

Tomato leaf miner *Tuta absoluta* (Meyrick) is present throughout the crop duration, larvae can infest leaves, flowers, stem and fruits that causing important losses in tomatoes. So, this study was carried out to evaluate the efficiency of four low toxicity insecticides against this insect under field conditions, as well as the dissipation of coragen and aljambo residues in harvested tomato fruits were determined. Results indicated that the differences between the numbers of alive larvae ranged from low significant as in avant and superlambada to highly significant as in coragen and aljambo insecticides in relation to control at all observation periods and the percent reduction in infestation with tomato leaf miner decreased with time elapsed. Coragen and aljambo affected strongly the number of eggs laid by *T. absoluta* females where highly significant decrease in the number of deposited eggs was observed. At all tested periods, there were highly significant reductions in the number of tunnels in the leaves treated with coragen and aljambo insecticides. On the other hand, the initial deposits of coragen and aljambo on tomato fruits were 11.4 and 9.6 ppm, respectively. The residue loss of both insecticides continued on over time. Washing process caused significant decrease in both compounds residue. Generally, coragen insecticide was the most toxic against this pest followed by aljambo and superlambda while, avaunt was the lowest toxic compound.

Key words: Insecticides, toxicity, residues, tomato, infestation, *Tuta absoluta*

INTRODUCTION

Tomato, *Solanum lycopersicum* (*Lycopersicon esculentum* (Mill.) is one the most important economic vegetables in Egypt so far as the area under vegetables and commercial value of the crop is concerned. Tomato is considered as one of the few cultures for which pests and diseases are equally important, being a host plant to about 200 species of arthropods (Anonymous, 2001). Recently, tomato leaf miner, *Tuta absoluta* (Meyrick) (Lepidoptera: Gelechiidae), has assumed the status of the most important pest in Egypt (De Medeiros *et al*., 2005; Shalaby *et al*., 2012).

This pest is present throughout the crop duration, larvae can infest leaves, flowers, stems and fruits causing important losses in tomatoes (Molla *et al*., 2011). The leaf miner injury to the host plant is manifested in the form of reduction of leaf surface area responsible for photosynthetic

activity. It prevents newly emerged leaves from fully expanding and causes leaves to be curled, twisted and eventually necrotic (Knapp *et al*., 1994). Therefore, both yields and fruits quality can significantly be reduced by direct feeding of *T. absoluta* and pave way for the entry of secondary pathogens through the wounds made by the insect (Colomo *et al*., 2002).

Tomato crop is treated with pesticides in order to control pest infestation. Residues after pesticide application on vegetable crops need to be determined and the waiting period between application and harvest accordingly be recommended to ensure that the product is free from residues before it reaches market (Shalaby *et al*., 2012). Therefore, present study was undertaken with the objective to evaluate the efficacy of four low toxicity insecticides from diverse pesticide groups against *T. absoluta*. Also to determine the dissipation of coragen and aljambo compounds in tomato fruits to establish the Pre Harvest Interval (PHI) that should be followed before marketing the produce in order to minimize health hazards.

MATERIALS AND METHODS

Insecticides used:

- Coragen 20% SC (Chlorantroniliprole)
- Aljumbo 80% SC (20% emamectin benzoate+60% bifinithrin)
- Avaunt 15% SC (Indixocarb)
- Superlambda 5% EC (lambdacyhalothrin). The rate of application of these chemicals was 250, 250, 50 and 500 mL/200 L water/feddan, respectively

These compounds were obtained from the market, the most popular source of insecticides for the farmers.

Field experiment: The field experiment was carried out in El-Mahmodia village, Dekernis district, Dakahlyia Governorate, Egypt. Experimental area (approximately 900 m^2) was planted with tomato *Lycopersicon esculentum* (Mill.) variety 'Super Strain B' after seeded in a greenhouse and then transferred to the field during summer cultivation season of 2013, under normal field and agricultural practices. The experiment block design was randomized with each treatment replicated three times. Each plot had five rows with 25 plants row^{-1}. The 15 plants of medium row were used for data collection. The plant space was 0.5×1.0 m. The insecticides, avaunt, coragen, aljambo and superlambda were applied as foliar spray on June 15, 2013 at the recommended rates using a knapsack sprayer. The 5th treatment was left untreated to serve as control. The evaluations against leaf miner were conducted on 40 leaflets (Gonzalez-Cabrera *et al*., 2011) were randomly collected from each replicate before spraying as well as 1, 2, 3, days; 1, 2 and 3 weeks after spraying. The outer plants were never sampled in order to avoid border effects. Alive and death larvae were counted using a binocular microscope. Eggs and tunnels per 40 leaflets were counted from each replicate. Percent reduction in infestation was calculated using Henderson and Tilton (1955).

Determination of tested insecticide residues in tomato fruits: Representative samples of tomato fruits were collected from the treated plots by coragen and aljambo insecticides after 1 h

(initial deposits) and 1, 3, 5, 7, 10, 15 and 21 days after spraying. Clean polyethylene bags were used for preserving the collected samples. The samples were stored at -20°C in deep freezer until analysis.

Washing with tap water: Tomato fruits were rinsed for 2 min with running tap water and then drained on a clean paper for one hr until dry. Samples were kept in polyethylene bags in the deep freezer until analysis (Shady *et al*., 2000).

Extraction from plant samples by using QuEChERS method: This method is known as the quick, easy, cheap, effective, rugged and safe (QuEChERS) method for pesticide residues in vegetables and herbs. The procedure involved the extraction of a 15 g sample with 15 mL acetonitrile, followed by a liquid-liquid partitioning step performed by adding 6 g anhydrous $MgSO_4$ plus 1.5 g NaCl. After centrifugation, the extract was decanted into a tube containing 300 mg Primary Secondary Amine (PSA) sorbent plus 1.8 g anhydrous $MgSO_4$, which constituted a cleanup procedure called dispersive solid-phase extraction (dispersive SPE). After a second shaking and centrifugation step, the acetonitrile extract was transferred to autosampler vials for concurrent analysis by gas chromatography/mass spectrometry with an ion trap instrument and liquid chromatography/tandem mass spectrometry with a triple quadruple instrument using electrospray ionization (Lehotay *et al*., 2005).

The Residual half Lives (RL_{50}) periods for the tested insecticides were calculated according to Moye *et al*. (1987) equation.

Statistical significance of data was assessed by Duncan and Tukey test at $p_{0.05}$ (Snedecor and Cochran, 1980).

RESULTS AND DISCUSSION

Effect of tested insecticides on the infestation rates by *T. absoluta* at different time intervals: Data shown in Table 1 indicated that the percent reduction in infestation of tomato leaf miner ranged from 74.7-95.1% after one day of treated plants by avaunt, coragen, aljambo and superlambda. This values decreased with time elapsed to reached 52.6, 79.3, 57.5 and 59.9% after 3 weeks of treatment, respectively. General mean of a live larvae infested tomato plants were 23.1, 9.4, 7.3, 5.8 and 8.3 larvae/40 leaflets in control, avaunt, coragen, aljambo and superlambda treatments, respectively while the average of percent reduction infestation were, 61.2, 88.6, 82.1 and 77.5% in avaunt, coragen, aljambo and superlambda treatments. Statitically, there are highly significant differences between the most effective compounds (coragen and aljambo) and the other two compounds. These results are in agreement with the information included in the report released by DuPont™ (2008) where the coragen insecticide provides unprecedented larval control against a wide range of economically important lepidopterious species. It is particularly potent against neonate larvae as they hatch from the eggs. Results of Valchev *et al*. (2013) are closed with our results where they determined a very good biological activity of both coragen and avant insecticides towards the larvae of *Tuta absoluta* that their effectiveness were 79.38 and 79.18%, respectively, 14 days after treatment. Hanafy and El-Sayed (2013) reported that pyridalyl was the most effective in reducing infestation of *T. absoluta* followed by coragen, then avaunt and least by chlorfenapyr. On the other hand, our results disagree with those obtained by Santos *et al*. (2011), who reported that indoxacarb (avaunt) caused 96.1 and 93.6% reduction of *T. absoluta* infestation at 3 and 7 days after application.

Table 1: Effect of tested insecticides on the infestation rates by *T. absoluta* at different time intervals

		Allive larvae					
		Days					
		1		2		3	
Treatments	Pretreatment	No.	*R (%)	No.	*R (%)	No.	*R (%)
Control	23.0^{bc}	24.67^{a}	….	19.67^{a}	….	22.33^{a}	….
Avaunt	19.67^{c}	5.33^{b}	74.7	4.67^{b}	72.24	6.0^{b}	68.6
Coragen	30.0^{a}	2.0^{c}	93.8	2.33^{c}	90.90	2.67^{cd}	90.8
Aljambo	19.0^{c}	1.0^{c}	95.1	1.33^{c}	91.80	2.0^{d}	89.2
Superlambda	24.0^{b}	3.33^{bc}	87.1	3.0^{bc}	85.40	4.0^{bc}	82.8
LSD 5%	3.9	2.83		2.08		2.16	

		Allive larvae							
		Weeks							
		1		2		3		General mean	
Treatments	Pretreatment	No.	*R (%)	No.	*R (%)	No.	*R (%)	No.	*R (%)
Control	23.0^{bc}	18.5^{a}	….	28.67^{a}	….	24.67^{a}	….	23.1^{a}	……
Avaunt	19.67^{c}	8.0^{b}	49.4	12.33^{b}	49.7	10.0^{b}	52.6	9.4^{b}	61.2
Coragen	30.0^{a}	2.0^{d}	91.7	5.67^{c}	84.8	6.67^{b}	79.3	7.3^{bc}	88.6
Aljambo	19.0^{c}	2.0^{d}	86.9	6.67^{c}	71.8	8.67^{b}	57.5	5.8^{c}	82.1
Superlambda	24.0^{b}	4.0^{c}	89.6	11.67^{b}	61.0	10.33^{b}	59.0	8.3^{b}	77.5
LSD 5%	3.9	1.71		2.08		3.9		2.4	

Means followed by the same letters are not significantly different according to the Tukey test (p = 0.05), *R(%): Percent reduction in the number of alive larvae

Effect of tested insecticides on the number of eggs laid by *T. absoluta* females: Data shown in Table 2 indicate that coragen and aljambo insecticides affected strongly the number of eggs laid by *T. absoluta* females while the other two compounds have lower effect. The percent reduction of the deposited eggs were 23.3, 57.7, 72.0 and 16.2% one day after treatment in treated plants by avaunt, coragen, aljambo and superlambda, respectively. The highest percent reduction in the deposited eggs was noticed after one day in aljambo treated plants (72.0%) and after 2 days in case of avaunt and superlambda (36.4 and 40.6%) while, it recorded 95% in coragen 1 week after treatment. Three weeks later, these values dropped to 12.3, 67.4, 55.2 and 18.2% in treated plants by avaunt, coragen, aljambo and superlambda, respectively. Also, the data show that there are highly significant differences in the number of deposited eggs between coragen and aljambo from one side and the other two compounds (avant and superlambada) from other side. In relation to control, there is highly significant reduction in the number of eggs laid due to using coragen and aljambo insecticides in all tested periods.

Generally, using either coragen or aljambo insecticides against *T. absoluta* caused the females oviposit significantly fewer eggs than the control. These results are in agreement with data included in the report of DuPont™ (2008) about coragen, where, a significant ovicidal activity of coragen is observed and this effect is enhanced when eggs are laid on treated leaves. When coragen applied at the time of eggs laying, the long lasting activity on the eggs prevents the establishment and growth of pest population at low use rates.

Table 2: Effect of tested insecticides on the number of eggs laid by *T. absoluta* females on tomato plants at different time intervals

		Eggs laid					
		Days					
		1		2		3	
Treatments	Pretreatment	No.	*R (%)	No.	*R (%)	No.	*R (%)
Control	12.33^{b}	16.67^{a}	....	18.0^{a}	....	18.67^{a}	....
Avaunt	9.33^{d}	9.67^{b}	23.3	8.67^{b}	36.4	10.33^{b}	26.9
Coragen	21.00^{a}	12.0^{b}	57.7	6.33^{b}	79.3	5.0^{b}	84.3
Aljambo	15.00^{b}	5.67^{d}	72.0	6.67^{b}	69.6	8.67^{b}	61.8
Superlambda	10.00^{cd}	11.33^{b}	16.2	8.67^{b}	40.6	9.33^{b}	38.4
LSD 5%	2.64	1.52		0.82		3.03	

		Eggs laid							
		Weeks							
		1		2		3		General mean	
Treatments	Pretreatment	No.	*R (%)	No.	*R (%)	No.	*R (%)	No.	*R (%)
Control	12.33^{b}	26.67^{a}	....	30.0^{a}	....	36.67^{a}	....	22.7^{a}	....
Avaunt	9.33^{d}	15.67^{b}	25.6	20.33^{b}	10.4	24.33^{b}	12.3	14.0^{b}	22.5
Coragen	21.00^{a}	2.0^{e}	95.6	13.33^{b}	73.9	20.33^{b}	67.4	11.4^{b}	76.4
Aljambo	15.00^{b}	12.0^{d}	63.0	18.33^{b}	49.8	20.00^{b}	55.2	12.3^{b}	61.9
Superlambda	10.00^{cd}	13.67^{b}	36.7	18.33^{b}	24.7	24.33^{b}	18.2	13.7^{b}	29.1
LSD 5%	2.64	1.23		4.68		2		0.95	

Means followed by the same letters are not significantly different according to the Tukey test (p = 0.05), *R(%): Percent reduction in the number of eggs laid

Effect of tested insecticides on the number of tunnels in the tomato plants infested by *T. absoluta* at different time intervals: Data presented in Table 3 show the effect of tested insecticides on the numbers of tunnels in the infested plants by *T. absoluta*. They were 23.0, 22.0, 25.67, 21.67 and 22.33 tunnels in control, avaunt, coragen, aljambo and superlambda treatments, respectively. These values were increased in check plants (24.67) and decreased in pesticides treated plants (20.33, 20.0, 20.33 and 21.67 tunnels/40 leaflets) after one day of application with percent reduction reached to 13.8, 27.2, 12.5 and 9.5%, respectively. Three weeks later, percent reductions in the number of tunnels were 24.1, 55.55, 39.9 and 42.6% for the previous compounds. The averages of percent reduction were 21.1, 49.7, 30.9 and 30.1% of treated plants by pervious insecticides, respectively. Generally, these results revealed that coragen was the most toxic compound against this pest followed by aljambo and superlambda while avaunt was the lowest. At all tested periods, there were highly significant reductions in the number of tunnels due to treatment with coragen and aljambo insecticides rather than the other two compounds and control.

These results are in agreement with those obtained by many investigators (Colomo *et al*., 2002; Molla *et al*., 2011) who reported that *T. absoluta* larvae can damage tomato plants during all growth stages, producing large galleries in their leaves, burrowing stalks, apical buds, green and ripe fruits. Also, it can cause important yield loss in different production regions and under diverse production systems.

Table 3: Effect of tested insecticides on the number of tunnels/40 leaflets of tomato plants infested by *T. absoluta* at different time intervals

		Tunnels					
		Days					
		1		2		3	
Treatments	Pretreatment	No.	*R (%)	No.	*R (%)	No.	*R (%)
Control	23.00^{b}	24.67^{a}	....	26.0^{a}	....	26.33^{a}	....
Avaunt	22.00^{b}	20.33^{b}	13.8	20.67^{bc}	16.9	24.0^{b}	4.70
Coragen	25.67^{a}	20.0^{b}	27.2	19.0^{cd}	34.5	14.33^{e}	51.2
Aljambo	21.67^{b}	20.33^{b}	12.5	17.67^{d}	27.9	22.0^{c}	11.3
Superlambda	22.33^{b}	21.67^{ab}	9.50	21.33^{b}	15.5	19.33^{d}	24.4
LSD 5%	2.52	3.3		2.24		2.84	

		Tunnels							
		Weeks							
		1		2		3		General mean	
Treatments	Pretreatment	No.	*R (%)	No.	*R (%)	No.	*R (%)	No.	*R (%)
Control	23.00^{b}	36.0^{a}	....	38.0^{a}	....	37.67^{a}	....	30.2^{a}	....
Avaunt	22.00^{b}	23.0^{b}	33.2	24.0^{b}	34.0	27.33^{b}	24.1	23.0^{b}	21.1
Coragen	25.67^{a}	14.67^{d}	63.5	14.0^{c}	67.0	18.7^{d}	55.5	18.0^{c}	49.7
Aljambo	21.67^{b}	18.0^{cd}	46.9	19.0^{b}	46.9	21.33^{c}	39.9	20.0^{bc}	30.9
Superlambda	22.33^{b}	20.0^{bc}	45.8	20.0^{b}	45.8	21.0^{c}	42.6	20.8^{bc}	30.1
LSD 5%	2.52	3.99		4.86		1.84		3.17	

Means followed by the same letters are not significantly different according to the Tukey test (p = 0.05), *R(%): Percent reduction in the number of alive larvae

Dissipation behavior of coragen and aljambo insecticides in tomato fruits: Under defined conditions the retention time for coragen was 6.38 min while this value for aljambo mixture was 8.76 for bifinithrin and 11.12 min for emamectin benzoate. In addition, the results were corrected according to the rates of recovery which were determined in fortified untreated samples. The average rates of recovery for coragen, bifinithrin and emamectin benzoate in tomato fruits were 96.7, 93.8 and 94.9%, respectively.

Data in Table 4 indicate the amount of coragen and aljambo residues on tomato fruits at different intervals after application. The initial deposits (1 h after application) were 11.4 and 9.6 ppm, respectively. These residues decreased to 8.76 and 7.7 ppm after 24 h. The residue of coragen dropped to 6.41, 5.0, 2.6, 0.98 and 0.67 ppm after 2, 3 days; 1, 2 and 3 weeks, respectively from treatment. The corresponding values of aljambo residues were 5.46, 4.7, 2.1, 0.87 and 0.16 ppm at the same intervals. Also, the results revealed that the residue loss continued on over time, where the percent loss rate amounted to 23.2, 43.8, 56.1, 77.2, 91.4 and 94.1% after 1, 2, 3 days; 1, 2 and 3 weeks, respectively for coragen residues. The corresponding percent loss on aljambo residues were 19.8. 43.1, 51.0, 78.1, 90.9 and 98.3%. The amount of residues recorded during the experimental period varied for each insecticide to another. These levels depend on the rate of use, the initial deposits, the rate of exposure of the fruits to the environmental factors and the reaction between the treated surface and the chemicals applied (Soliman *et al*., 2005;

Table 4: Dissipation of Coragen and Aljambo insecticides in tomato fruits and effect of washing process on their residues

	Coragen				Aljambo			
	Residue dissipation		After washing		Residue dissipation		After washing	
Time periods	ppm	Loss (%)	ppm	Removal (%)	ppm	Loss (%)	ppm	Removal (%)
Initial deposit*	11.4	....	5.8	49.1	9.6	.....	4.6	52.1
Days								
1	8.76	23.2	4.6	47.5	7.7	19.8	3.4	55.8
2	6.41	43.8	3.45	46.2	5.46	43.1	2.1	61.5
3	5.0	56.1	2.9	42.0	4.7	51.0	1.7	63.8
Weeks								
1	2.6	77.2	1.7	34.6	2.1	78.1	1.0	52.4
2	0.98	91.4	0.64	34.7	0.87	90.9	0.34	60.9
3	o.67	94.1	0.3	55.2	0.16	98.3	0.08	50.0
RL_{50} (h)	89.5	59.6						

*One hour after application, RL_{50}: Residual half live periods

Shalaby *et al.*, 2012). Also, Stevens *et al.* (1988) demonstrated that uptake of pesticides on plant surface is affected by the chemical structure, formulation as well as the rate of used insecticide, the nature of the recipient surface, the used spraying equipment and the climatic conditions, especially the ambient temperature during pesticide application. Concerning health hazards, the Maximum Residue Limits (MRL) for coragen was 0.6 mg kg^{-1} while it was 0.3 and 0.02 mg kg^{-1} for aljambo mixture (binifithirin and emmactin benzoate) on tomato fruits established by Codex Alimentarius committee for pesticide residues (Anonymous, 2012). In the same trend, tomato fruits previously treated with coragen and aljambo insecticides should be at least 3 weeks to ensure that the fruits contain residue level below its MRL. The corresponding recommended preharvest intervals (PHI) were 3 weeks after application for both compounds. The present findings revealed also, the half lives ($RL_{0.5}$) values in tomato fruits were 89.5 and 59.6 h for coragen and aljambo insecticides, respectively. These amounts indicated that coragen had high stability (or had lower degradation rate) in tomato fruits when compared with the another compound under field conditions.

Effect of washing process on removal of coragen and aljambo residues: Increasing the use of chemical insecticides to control the economic pests which attack field crops has increased the pollution of the environment with their toxic residues. Therefore, the need for efficient treatments to reduce or remove such residues has become urgent. There was an effect of washing tomato fruits under tap water on reducing the contamination by coragen and aljambo residues (Table 4). The initial deposits of both insecticides were 11.4 and 9.6 ppm, the washing process reduced these amounts to 5.8 and 4.6 ppm representing removal of 49.1 and 52.1% of their residues on tomato fruits. Also, the present data revealed that the removal percent of coragen residues by washing process ranged from 34.6-55.2% while it ranged from 50.0-63.8% in case of aljambo residues. In the same respect, Bonnechere *et al.* (2012) reported that the washing step allowed decreasing the concentration of residues for all pesticides upto ~90%. It was the most effective step to remove pesticide residues from carrots.

CONCLUSION

The present findings revealed that coragen was the most effective insecticide against *Tuta absoluta* followed by aljambo and superlambda while, avaunt was the least effective compound. Also, the data indicated that coragen had high stability in tomato fruits when compared with other compounds under field conditions. Finally, tomato fruits previously treated with coragen and aljambo insecticides should be left at least 3 weeks to ensure that the fruits contain residue level below its MRL.

ACKNOWLEDGMENTS

We thank Prof. Dr. H. S. Salama former president of NRC, Egypt and Professor of Entomology at Department of Pests and Plant Protection for supervision and critical comments on this manuscript. This study was supported by the National Research Center Research Grant No. 9050806.

REFERENCES

Anonymous, 2001. Professional recommendation in agriculture pest control. Ministry of Agriculture and Land Reclamation, Cairo, Egypt, pp: 1-76.

Anonymous, 2012. Codex pesticides residues in food online database. http://www.codexalimentarius.net/

Bonnechere, A., V. Hanot, R. Jolie, M. Hendrickx, C. Bragard, T. Bedoret and J. Van Loco, 2012. Processing factors of several pesticides and degradation products in carrots by household and industrial processing. J. Food Res., 1: 68-83.

Colomo, M.V., D.C. Berta and M.J. Chocobar, 2002. [The complex hymenoptera parasitoids that attack tomato moth *Tuta absoluta* (Lepidoptera: Gelechiidae) in Argentina]. Acta Zoologica lilloana, 46: 81-92 (In Spanish).

De Medeiros, M.A., G.L.V. Boas, O.A. Carrrijo, N. Makishima and N.J. Vilela, 2005. [Integrated tomato leafminer in greenhouse management]. Circular Tecnica No. 36, August 2005, pp: 1-10. http://bbeletronica.cnph.embrapa.br/2005/ct/ct_36.pdf (In Portuguese)

DuPont™, 2008. DuPont™ Coragen® insect control technical bulletin. http://www2.dupont.com/Production_Agriculture/en_US/assets/downloads/pdfs/K-14833.pdf

Gonzalez-Cabrera, J., O. Molla, H. Monton and A. Urbaneja, 2011. Efficacy of *Bacillus thuringiensis* (Berliner) in controlling the tomato borer, *Tuta absoluta* (Meyrick) (Lepidoptera: Gelechiidae). BioControl, 56: 71-80.

Hanafy, H.E. and W. El-Sayed, 2013. Efficacy of bio-and chemical insecticides in the control of *Tuta absoluta* (Meyrick) and *Helicoverpa armigera* (Hubner) infesting tomato plants. Aust. J. Basic Applied Sci., 7: 943-948.

Henderson, C.F. and E.W. Tilton, 1955. Acaricides tested against the brown wheat mite. J. Econ. Entomol., 48: 157-161.

Knapp, J.L., J. Pena, P. Stansly, J. Heppner and Y. Yang, 1994. The citrus leafminer, *Phyllocnistis citrella*, a new pest of citrus in Florida. Florida Cooperative Extension, Florida, USA.

Lehotay, S.J., A.D. Kok, M. Hiemstra and P.V. Bodegraven, 2005. Validation of a fast and easy method for the determination of residues from 229 pesticides in fruits and vegetables using gas and liquid chromatography and mass spectrometric detection. J. AOAC Int., 88: 595-614.

Molla, O., J. Gonzalez-Cabrera and A. Urbaneja, 2011. The combined use of *Bacillus thuringiensis* and *Nesidiocoris tenuis* against the tomato borer *Tuta absoluta*. BioControl, 56: 883-891.

Moye, H.A., M. H. Malagodi, J.J. Yoh, G.L. Leibee, C.C. Ku and P.G. Wislocki, 1987. Residues of avermectin B1a rotational crops and soils following soil treatment with (C14) avermectin B1a. Agric. Food Chem., 35: 859-864.

Santos, A.C.D., R.C.O.D.F. Bueno, S.S. Vieira and A.D.F. Bueno, 2011. Efficacy of insecticides on *Tuta absoluta* (Meyrick) and other pests in pole tomato. BioAssay, 6: 1-6.

Shady, M.F.A., M.E.A. Hegazy, F.A. Adam, M.A.A. El-Baki and S.A. Shokr, 2000. Persistence of malathion and prothiofos organophosphorus insecticides on and in some vegetable crops. Egypt. J. Agric. Res., 78: 605-621.

Shalaby, S.E.M., M.M.M. Soliman and A.E.M.A. Ei-Mageed, 2012. Evaluation of some insecticides against tomato leaf minor (*Tuta absoluta*) and determination of their residues in tomato fruits. Applied Biol. Res., 14: 113-119.

Snedecor, G.W. and W.G. Cochran, 1980. Statistical Methods. 7th Edn., Iowa State University Press, Ames, Iowa, USA., Pages: 507.

Soliman, M.M.M., A.A.A. Sallam and S.E.M. Shalaby, 2005. Persistence of chlorpyrifos-methyl and profenofos residues in fresh and processed tomato fruits. Bull. Entomol. Soc. Egypt Econ., 31: 95-106.

Stevens, P.J., E.A. Baker and N.H. Anderson, 1988. Factors affecting the foliar absorption and redistribution of pesticides. 2. Physicochemical properties of the active ingredient and the role of surfactant. Pesticide Sci., 24: 31-53.

Valchev, N., V. Yankova and D. Markova, 2013. Biological activity of plant protection products against *Tuta absoluta* (Meyrick) in tomato grown in greenhouses. Agric. Sci. Technol., 5: 318-321.