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Effect of sprayer, nozzle types and spraying volume on efficacy of chemical compounds against tomato leafminer *Tuta absoluta* (Lepidoptera: Gelechiidae) infesting tomato

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Abstract:

Tomato leafminer, *Tuta absoluta* (Meyrick) (Lepidoptera: Gelechiidae) is a highly destructive insect pest to tomato plants and fruit and is also reported to infest other plants in the Solanacaeae family. In the present study, three equipments were conducted to control *T. absoluta*, at New Salhyia city, Sharqia Governorate. The first equipment, Cawzer sprayer with 3 nozzles type flat fan 02F-110, with spray volume 60L/fed., Matabi sprayer with Full cone Tx-6 with spray volume 35 L/fed., and conventional motor fitted with spray gun at spray volume 300 L/fed., fitted with local spray gun produce hollow cone. The aim of this work is to determine the effects of application method on initial and late biological efficacy of three insecticides , emamectin benzoate (Proclaim) 20% SC., at rate 60 gm/fed.; indoxacarb (Avant) 15% EC at rate 100 ml/fed and alverde (Metaflumizone) – SC. 24% at rate 400ml/fed., against *T. absoluta.* Results in two seasons (2016 and 2017) indicated that, the high efficacy gives by Matabi sprayer with volume mean diameter (VMD) 68.7-94.4µm, and N/cm2 3.94-37.8 and Cawzer sprayer with VMD 51.36-125.35µm. and N/cm2 18-115.5, while less efficient was obtained with conventional Motor, with VMD 480-950µm, and N/cm2 5-21. Otherwise, the highest toxic effect obtained with emamectin benzoate, metaflumizone and indoxacarb with Matabi and Cawzer sprayers.

Introduction

Tomato, *Lycopersicon esculentum* Mill. (Solanales: Solanaceae) is an important vegetable in Egypt and planted throughout the year. Egypt considered the fifth largest tomato producer in the world with about 9.2 million tons produced from about 454,000 Feddans planted with tomato (WPTC, 2011). Tomato infested by more than 200 arthropods (Anonymus, 2001). So, it was of great importance to combat tomato pests since emergence till harvesting to prevent huge damage caused by these pests (Moussa *et al.*,2013). Recently, tomato leafminer borer, *Tuta absoluta* (Meyrick) (Lepidoptera: Gelechiidae), considered the most quick devastating pest of tomato plantations (Shalaby *et al*., 2012). Their larvae were infested leaves, flowers, stems and fruits leads to reduce photosynthesis, impairs fruits and paves the way for pathogens to enter through lesions caused by the pest (Colomo *et al*.,2002) and might lead to complete loss of the yield. In Egypt, the pest was detected for the first time in early 2010 at Marsa Matrouh Governorate. Then other reports confirmed pest presence in other parts of the Delta Valley (EPPO, 2006).

Nowadays pest management had been depended mainly on pesticides applications (Gonza´lez-Cabrera *et al*.,2011). Several insecticides belong to different insecticides classes were recommended for pest control. Emamectin benzoate, indoxacarb and metaflumizonewere the most commonly recommended insecticides used against *T. absoluta* in Egypt according to (Egyptian Agricultural Pesticides Committee).

Pesticide sprays aimed to maximize pesticide efficacy and minimized their adverse effects. So, factors such as optimum droplet size for killing, number of droplets per unit area might be optimized (Sundaram *et al*.,1985). Effective application obtained by increasing coverage percent per unit area (Ferguson *et al*., 2016). Droplet size may be influence the biological efficacy of the applied pesticide as well as environmental hazards and spraying application could be affect toxicant efficacy, through affecting on the spraying parameters, such as optimum volume mean diameter (VMD) which greatly effects on mortality and residual effects (Omar and Matthew, 1991). The insecticidal effect of spraying droplets were dependent not only on droplet diameter but also on droplet number/cm^2 and concentration of active ingredient of used insecticides (Elbert *et al*., 1999). The previous studies suggested that the optimal droplet size varies according to insecticide, target pest and application method.

The aim of this work is to determine the effects of application methods (sprayer, nozzle types and spraying volume) and spray coverage distribution on initial and late efficacy of emamectin benzoate (Proclaim) , indoxacarb (Avant) and alverde (Metaflumizone) against tomato leafminer, *T. absoluta* .

Materials and methods

1. Tested sprayers :

In the current study, three different types of sprayers were evaluated and their technical data illustrates in Table (1).

Table (1): Technical data of tested equipment.

Equipment Parameter	Cawzer (compretion sprayer)	Matabi (hydraulic Hand-Heldsprayer)	Conventional Ground Motor (hydraulic)
Nozzle type	Flat fan 02F-110	Full cone Tx-6	Spray gun
Total Tank capacity (L)	8	20	400
Spray volume (L/fed)	60	35	300
Working Speed (Km/h)	2.4	2.4	2.4
Swath width (m)	2.5 (Hand lance fitted with 3 nozzles)	2	0.75
Flow rate (L/Min)	0.484	0.32	2.16
Spraying height (m)	50 at all treatments		
Spray system	Target spray		

2. **Pesticides used:**

Three insecticides were tested in the current study include: Emamectin benzoate (Proclaim 20% SC., Syngenta, Germany, rate dose 60 gm/feddan), Indoxacarb (Avant 15% EC-Du pont de Nemoursp-USA- rate dose 100 ml /fed) and alverde (Metaflumizone ¬-SC % 24-Basf-Germany- rate dose 400ml/ fed.) as recommended dose for this pest.

3. Field experiments:

Field experiment were conducted during the growing tomato season of March, 2016 and 2017 at New Salhyia city, Sharqia Governorate, Egypt. The experimental area was divided into plots, each is 40m^2 (1/100 fed.) and arranged in randomized complete blocks with four replicates. Four plots were left untreated to serve as control. The normal agricultural practices were done. The tested insecticides were applied at the recommended rate of the aforementioned insecticides. The control plots were sprayed only with water. Also, care was taken to avoid any drift among the treated plots. Samples of 25 leaves were chosen at random from each replicate before treatments and at 1,3,5,7,9,11 and 14 days after pesticides application. The number of *T. absoluta* was counted. Percentage of reduction of the insect population was calculated according to Henderson and Tilton (1955).

4.Collection of spray deposit:

To collect the spray deposit and for a precise evaluation of spray coverage of the tested atomizers in the field, sensitive papers of water were placed on tomato plants canopy before spraying at three trends right, left, middle ones. In addition, the cards were fixed in a wire holders to measure lost spray on the ground. Sensitive papers were given code numbers before being stuck to the plants and the wire holder. About 50 Minutes had elapsed after spraying operation to allow dryness of deposits. So, the sensitive papers were carefully collected. There were transferred to the laboratory for qualitative analysis.

5. Laboratories tools:

5.1. Strubinlense (15x) was used to measure the sprayed spots (Gabir *et al*., 1982).

5.2. Calculator was used to calculate VMD of droplets cards at all trends of tomato plants.

5.3. Computer system was used to analyze data by using statistical analysis system SPSS.

Results and discussion

1. Spray coverage on tomato plants against *Tuta absoluta* by using pesticides during (2016/2017) seasons:

1.1. Cawzer sprayer (compretion sprayer):

Cawzer sprayer used to spray volume of 60L/fed. at the first season, produced volume diameters in the range of 60 - 98µm. The smallest droplet size obtained with proclaim , VMD mean diameter of 60µm followed by avant 75µm and then alverde 98µm. Similarly, at the second season VMD range was 61-97µm with mean diameter volume of 61µm with proclaim, 75µm for avant and 97µm for alverde (Tables, 2 and 3).

1.2. Matabi sprayer (Hand Heldhydraulic sprayer):

Matabi sprayer used spray volume of 35L./fed. and generated in the first season VMD with the range of 80-86µm. The tested pesticides gave mean volume diameter of 83µm with proclaim, 86µm with avant and 80µm with alverde. In the second season VMD recorded 85µm with proclaim, 86µm with avant and 82µm with alverde (Tables, 2 and 3).

1.3. Conventional ground motor:

Conventional motor used spray volume of 300L./fed. and generated in the first season VMD range of 725-825µm. with proclaim mean volume diameter recorded 725µm, 825µm with avant and 745µm with alverde. Similarly, in the second season VMD recorded 718,789µm and 735µm for proclaim, avant and alverde, respectively (Tables, 2 and 3).

Table (2): Spray coverage means as obtained from three sprayers by using insecticides on tomato plants for controlling *Tuta absoluta* during season 2016.

Equipment		Cawzer sprayer			Matabi sprayer			Conventional motor		
Spraying volume		60 L.			35 L.			300 L.		
Spectrum Insecticide		VMD (µm)	N/cm²	N%	VMD (µm)	N/cm²	N%	VMD (µm)	N/cm²	N%
2016										
Proclaim	Right plant	62	111	44	91	33	29.7	850	12	24.5
	Middle plant	65	54	21.3	85	37	33.3	650	8	16.3
	Left plant	61	43	17.1	87	35	31.5	900	10	20.4
	Wire holder	52	44	17.6	70	6	5.4	500	19	38.8
Avant	Right plant	95	29	18	94	32	35.6	900	7	15.6
	Middle plant	84	32	20	94	24	26.7	800	9	20
	Left plant	65	47	29.3	81	28	31.1	950	11	24.4
	Wire holder	56	53	32.7	73	61	6.7	650	18	40
Alverde	Right plant	126	18	14.5	85	38	33.6	870	11	22
	Middle plant	85	39	31.3	81	36	31.9	780	5	10
	Left plant	86	31	25.3	87	35	31	850	13	26
	Wire holder	95	36	28.9	69	4	3.6	480	21	42

Table (3): Spray coverage means as obtained from three sprayers by using insecticides on tomato plants for controlling *Tuta absoluta* during season 2017.

Equipment		Cawzer			Matabi Sprayer			Conventional Motor		
Spraying volume L/fed.		60			35			300		
Spectrum Insecticide		VMD (µm)	N/cm²	N%	VMD (µm)	N/cm²	N%	VMD (µm)	N/cm²	N%
2017										
Proclaim	Right plant	64	108	43.21	93	32	29.79	820	12	25.5
	Middle plant	66	53	21.44	86	36	33.89	644	8	16.6
	Left plant	60	44	17.8	89	34	31.78	876	10	21.1
	Wire holder	53	44	17.56	72	5	4.54	530	18	36.8
Avant	Right plant	97	28	17.6	93	32	35.76	880	7	15.3
	Middle plant	83	32	20	93	24	26.9	756	9	20.4
	Left plant	67	45	28.18	81	28	30.84	870	12	25.7
	Wire holder	54	55	34.25	75	6	6.51	650	18	38.6
Alverde	Right plant	121	19	14.92	87	37	33.51	850	11	22.3
	Middle plant	87	38	30.36	83	35	31.85	770	5	10
	Left plant	87	31	24.75	89	34	31.06	840	13	26
	Wire holder	91	37	29.96	70	4	3.58	480	21	41.6

2. Biological efficacy of the tested treatments:

Biological efficacy was carried out for three insecticides (Proclaim, alverde and avant) belong to different insecticides classes. The treatment was accomplished with three different equipment for successive two seasons. Percent reduction was recorded after 5 and 10 days and the findings were as follow:

2.1. The first season:

2.1.1. Percent reduction after 5 days:

Matabi sprayer showed that the highest biological efficacy and proved the highest percent reduction with the tested insecticides. Proclaim recorded the highest percent reduction followed by alverde and finally avant with values of 98.85, 96.27 and 92.12%, respectively. Cawzer sprayer followed matabi in biological efficacy with percent reduction values of 89.85, 85.09 and 82.94 %for proclaim, alverde and avant, respectively. While, conventional motor recorded the least efficacy with percent reduction values of 85.69, 79.49 and 75.81% for proclain, alverde and avant, respectively (Table, 4).

2.1.2. Percent reduction after 10 days:

Unlike to 5 days results, cawzer sprayer showed that the greatest biological efficacy with the three tested insecticides. Percent reduction values were 93.60, 94.36 and 97.63 % for proclaim, alverde and avant, respectively. The follower was matabi sprayer with Percent reduction of 91.31, 90.91 and 77.41 %for proclaim, alverde and avant, respectively. The least efficacy obtained with conventional motor and recorded 87.20, 77.02 and 74.35 % for proclaim, alverde and avant, respectively (Table, 4).

2.2. The second season:

2.2.1.Percent reduction after 5 days:

Results showed that the same trend obtained in the first season. Matabi sprayer showed that the greatest percent reduction and recorded 95.30, 83.40 and 93.10 %for proclaim, alverde and avant, respectively. Also, Cawzer sprayer showed the same trend with percent reductionof 85.89, 70.86 and 78.76% for proclain, alverde and avant, respectively. Finally, the least efficacy obtained with conventional motor with percent reductionof 89.40, 57.26 and 59.35% for proclain, alverde and avant, respectively (Table,4).

2.2.2. Percent reduction after 10 days:

Percent reduction obtained with Matabi sprayer was recorded 96.10, 85.73 and 82.27 for proclaim, alverde and avant, respectively. While, Cawzer sprayer proved percent reduction of 93.97, 84.28 and 91.62 % for proclaim, alverde and avant, respectively. In contrast, conventional motor showed the least efficacy with percent reduction values of 87.38, 69.81 and 67.58 % for proclaim, alverde and avant, respectively (Table,4).

3. Pairwise correlation analysis:

Correlation analysis between volume mean diameter (VMD) and percent reduction was carried out. The analysis performed for the tested insecticides with the used equipment and in the range of the used VMD.

3.1.Correlation analysis between volume mean diameter (VMD) and percent reduction after 5 days:

Correlation analysis showed significant negative correlations (at 0.01 level) for the following: Proclaim and avant with Cawzer sprayer ; proclaim, avant and alverde with Matabi sprayer ; proclaim with conventional motor. In contrast, there was positive correlations for the following: Alverde with Cawzer sprayer and alverde and avant with conventional motor (Table,5).

3.2. Correlation analysis between volume mean diameter (VMD) and percent reduction after 10 days:

Correlation analysis for the aforementioned factors showed significant negative correlations (at 0.01 level) for the following: Avant with cawzer sprayer , avant and alverde with Matabi sprayer and proclaim with conventional motor. In contrast, analysis showed positive correlations for the following: Proclaim and alverde with Cawzer sprayer; proclaim with Matabi sprayer and avant and alverde with conventional motor (Table,5).

Table(4): Percent reduction of leafminer numbers (*Tuta absoluta*) after treated with pesticides used by three equipments during 2016 and 2017seasons .

Equipment		Matabi Sprayer			Cawzer Sprayer			Conventional Motor			LSD
Spraying volume (L/f)		35			60			300			
Pesticides & dosages		Proclaim	Alverde	Avant	Proclaim	Alverde	Avant	Proclaim	Alverde	Avant	
		60 gm/fed.	400ml/fed.	100ml/fed.	60 gm/fed.	400ml/fed.	100ml/fed.	60 gm/fed.	400ml/fed.	100ml/fed.	
Season 2016											
Reduction %	5 days	98.85 ±1.15	96.27 ±1.32	92.12 ±3.39	89.85 ±2.80	85.09 ±4.54	82.94 ±3.26	85.69 ±3.90	79.49 ±6.77	75.81 ±7.15	6.07
	10 days	91.31 ±3.72	90.91 ±4.14	77.41 ±8.11	93.6 ±1.28	94.36 ±2.30	97.63 ±1.36	87.2 ±1.98	77.02 ±2.62	74.35 ±1.76	5.15
Season 2017											
Reduction %	5 days	95.3 ± 2.99	83.4 ±5.63	93.1 ± 4.45	85.89 ± 7.61	70.86 ± 3.71	78.76 ± 5.58	89.40±2.89	57.26 ± 8.54	59.35±12.01	9.3
	10 days	96.10± 0.79	85.73± 2.05	82.27± 2.53	93.97 ± 1.16	84.28± 0.66	91.62 ± 1.78	87.38 ±1.87	69.81 ±1.86	67.58 ± 1.86	4.45

Table (5): Pairwise correlation analysis between volume mean diameter (VMD) and percent reduction .

Equipment		Reduction								
		Cawzer Sprayer			Matabi Sprayer			Conventional Motor		
Insecticides		Avant	Proclaim	Alverde	Avant	Proclaim	Alverde	Avant	Proclaim	Alverde
VMD	5 days	-1.000**	-1.000**	1.000**	-1.000**	-1.000**	-1.000**	1.000**	-1.000**	1.000**
	10days	-1.000**	1.000**	1.000**	-1.000**	1.000**	-1.000**	1.000**	-1.000**	1.000**

****. Correlation is significant at the 0.01 level (2-tailed).**

In the current study, *T. absoluta* showed variable responses to different insecticides treatments. Results indicated that the highest toxic effect obtained with emamectin benzoate, metaflumizone and indoxacarb with Matabi and Cawzer sprayers. On the other hand, conventional motor produced the least effect. Our results in line with Moussa *et al*. (2013), who stated that, emamectin benzoate gave satisfactory *T. absoluta* control five days after treatment. Similarly, other studies proved the efficiency of emamectin, metaflumizone and indoxacarb in *T. absoluta* control (Gacemi and Guenaoui, 2012; Hanafy and El-Sayed, 2013 and Santos *et al*., 2011).

In this study, spraying tool affected seriously pesticides efficacy. The highest percent reduction were obtained with either Matabi sprayer or Cawzer sprayer. While less efficient was obtained with conventional motor. Droplet size plays important role in pesticides efficacy. Small droplets (≤ 20 µm in diameter) do not impact efficiently on targets (Mason, 1971). In dry climates, the evaporation of the diluent will cause the droplets to shrink, slightly larger droplets are thus desirable. Also, too large droplets, i.e. ≥300 µm, they not only give poor coverage of the spray plot but also do not penetrate into the sites of the micro-habitat of the target insect (Joyce *et al.*, 1977 and Barry *et al.*, 1978). Obtained results indicates that equipment with small droplets have a greater effect. This interpreted as a result to small droplets might produce a more uniform dose and, greater number of contact points (Symmons *et al.*, 1991). In addition, the volume of water used to carry the pesticide to the target is one key parameter of sprayer operation that can be varied by the grower to improve the level of coverage of the target crop (Landers, 2004).

Matthews (1977) stated that ,one of the most important factors controlling deposition pattern within the canopy is the droplet size spectrum. Drops with diameters of approximately 100 µm maximize deposition on the pest or foliage, improve the level of control, reduce pesticide costs and minimize ground contamination but are prone to drift. Much lower droplet size may pose a greater environmental threat through spray drift, contamination of soil water and toxicity to nontarget species outside the crop environment (Cooke and Hislop, 1987). Although spray drift is most likely to occur by the smaller drops of ~80µm (Miller, 1993), producing small drops (c. 100µm) within a narrow drop size spectrum utilizes their greater target accuracy and may thereby lower off-target effects. Droplet size affected seriously droplets movement; whereas, droplet falls down increases proportionally with the force of gravity. So, terminal velocity is normally reached in less than 25 mm by droplets smaller than 100µm diameter and in 70 cm for a 500µm droplet (Matthews *et al.*, 2014). Ideally there is an optimum droplet size (Himel, 1969) or spectrum which gives the most effective coverage of the target with minimum contamination of the environment.

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