J. Pest. Control & Environ. Sci., 1 : 54 - 64(2016)

Leafminer, *Tuta absoluta* and the influence of the sprayer type

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ABSTRACT

The tomato leafminer, Tuta absoluta (Meyrick) (Lepidoptera: Gelichiidae), is the major limiting factor for tomato production. The use of insecticides based on different chemical groups and with varying modes of action is an important component of an integrated pest management strategy. The efficiency of some insecticides and bioinsecticides regimens and in combination against the tomato leafminer, Tuta absoluta was investigated. The influence of the sprayer type on the insecticides efficiency and the chlorophyll content of tomato leaves were tested. The results indicated that no significant differences were recorded among all tested regimens. However, regimen 2; spray of imidacloprid, indoxacarb and Bacillus thuringiensis (Bt) + mineral oil and regimen 3; spray of chlorpyrifos methyl, lufenuron and spray abamectin were higher in the reduction percentages than that of regimen 1; drench of imidacloprid, spray of pyridalyl and Bt and regimen 4; spray of diazinon, mineral oil and emamectin benzoate. Moreover, the inhibitory effect of different treatments on the chlorophyll content was lower than that of the untreated check. Regarding to the general mean, it was observed that, using of Engine-Powered Knapsack sprayer decreased the side-effects of tested insecticides on the chlorophyll formation. However, the efficiency of tested treatments against T. absoluta was lower when used Engine-Powered Knapsack sprayer than that of used Hydraulic handgun sprayer.

Keywords: tomato; leafminer; insecticide regimens; Hydraulic handgun sprayer; Powered Knapsack sprayer.

INTRODUCTION

The tomato leafminer, Tuta absoluta (Meyrick), is an eotropical oligophagous insect, which attacks solanaceous crops. Since the 1960s it has become one of the key pests of tomato crops in many South American countries (Souza et al., 1983; Larrain, 1986). This pest invaded Egypt in 2009 and at 2010 it had reached Giza, coming well established in all Governorates of Fevm (Tamerak, 2011 and Gaffar, 2012). Under Mediterranean conditions, adults of T. absolutacan be detected over the year (Vercher et al., 2010). It can complete 9 to l0 generations per year in field tomatoes and 12 generations per year in greenhouse tomatoes (Junco and Cardeoso-Herrero, 2008). The most important identifying characters are the filiform antenna, grey coloured scales and black spots present on the anterior wings (USAID-Inma, 2001). Its life cycle comprises four development stages; egg, larva, pupa and adult, and is completed within 24 days at 27°C. The larval stage is the most damaging to plants and is completed within 12-15 days under optimal conditions (Muruvanda et al., 2013).

Integrated Pest Management (IPM) programs are principally based on environmentally sound strategies (Desneux et al., 2010). Increasing problems in the control of T. absoluta necessitate development of an integrated control program through a combination of preventive methods, biological control and chemical control if needed in order to keep the population density as low as possible (Gacemi and Guenaoui, 2012). Up to 100% losses have been reported in tomato crops, and even where chemicals control is implemented, losses can still exceed 5% (Korycinska and Moran, 2009). Control of T. absoluta is difficult because of the latent way of life the larva in the mines high reproductive potential, polyvoltine development and manifestation of resistance to great part of the applied insecticides (Siqueira et al., 2000; Lietti et al., 2005). Integrated plant protection systems including a complex of practices (crop rotation, use of pheromone tapes, of insect nets, application of bioagents and bioproducts, treatment with insecticides) are developed for successful control of the pest (EPPO, 2005; Benvenga et al., 2007; Faria et al., 2008). Organophosphates were initially used for T. absoluta control, which were gradually replaced by pyrethroids (Lietti et al., 2005). Some insecticides were recommended for the control of larval infestations in different countries such as indoxacarb, spinosad, imidacloprid, deltamethrin and Bacillus thuringiensis (Bt) var. kurstaki in Spain (Fera, 2009; Russell, 2009); chlorpyrifos and pyrethrins in Italy (Garzia et al., 2009); abamectin, indoxacarb, spinosad, imidacloprid, thiacloprid, lufenuron, and Bt in Malta (Mallia, 2009); indoxacarb and Bt in France (FREDON-Corse, 2009). IPM compatible petroleum spray oils are able to provide an effective control of leafminer (Rae et al., 1997). The use of insecticides based on different chemicals with varying modes of action is an important component of the IPM strategy. The bioinsecticide, emamectin benzoate is a non-systemic insecticide which penetrates leaf tissues by translaminar movement, following its treatment; larvae stop feeding within hours and die after 2-4 days (Hanafy and El-Sayed, 2013). Gaccmi and Guenaoui (2012) illustrated the high efficacy of emamectin benzoate on the larvae of the tomato leafminer under greenhouse conditions. The biopesticides, Bt var. *kurstaki* was the best compound used to control T. absoluta (Reda and Hatem, 2012). Azadiractin and Bt provide satisfactory results (Moussa et al., 2013).

Chemical control using synthetic insecticides is the primary method to manage the pest. But it has serious drawbacks, including reduced profits from high insecticide costs, destruction of natural enemy populations (Campbell et al., 1991), build-up of insecticide residues on tomato fruits (Walgenbach et al., 1991) resistance development for several insecticides (Siqueira et al., 2000; 2001). Since there are multiple insecticides with different modes of action that can provide good-to-excellent control, tomato growers have the advantage of rotating these insecticides to reduce the probability of resistance developing in the pest (Moussa et al., 2013). An approach to insect pest control is the use of substances that adversely affect insect growth and development such as insect growth regulators (IGRs) owing to their effects on certain physiological regulatory processes essential to the normal development of insects or their progeny (Siddall, 1976; Mulla, 1995).

On the other hand, the photosynthetic pigment chlorophyll is present in most plants and may be present in several forms in varying ratios. Chlorophyll ais the most abundant form of chlorophyll within photosynthetic organisms and, for the most part, gives plants their green color. However, there are other forms of chlorophyll, coded *b, c* and *d*, which augment the overall fluorescent signal. The types of chlorophyll can be present in all photosynthetic organisms but vary in concentrations (Milenkovic et al., 2012). Photosynthesis is the ultimate physiological limitation to crop production. The photosynthetic capacity of individual leaves is one factor, which determines crop dry matter yield (Ayari et al., 2000). The content of chlorophyll might reasonably be impacted by sub-lethal doses of the chemicals. For these reasons, chlorophyll was examined as a parameter that may be a useful indicator of environmental exposure to the test pesticide (Mishra et al., 2008). Chlorophyll *a, b* and total increased by chlorpyrifos (Parween et al., 2011) whereas, decreased by dimethoate (Mishra et al., 2008).

The objectives of this study are the following; efficiency evaluation of different regiments involved some insecticides and bioinsecticides, diazinone (Durasen, EC 60%), chlorpyrifos-methyl (Trifedant, EC 50%); indoxacarb (Avaunt, EC 15%); imidacloprid (Best, WP 25%); abamectin (Gold, EC 1.8%); emamectin benzoate (Pasha, EC 1.9%); lufenuron (Match, EC 5%); *Bacillus thuringiensis* (Dipel 2x, WP 6.4%); pyridalyl (Pleo, EC 50%) and mineral oil (Diver, EC 97%) against *T. absoluta* under greenhouse and open field conditions. Also, the influence of the sprayer type on the insecticides efficiency and the chlorophyll content of tomato leaves were tested.

MATERIAS AND METHODS

Field trial

Efficiency of some insecticides regimens against *T. absoluta*

The experiment was carried out in Abo Alamtamer city, El-Behira Governorate, Egypt to study the efficiency of some insecticides rotation against tomatoleafminer *T. absoluta* during the tomato growing season June 2013. The cultivation tomato variety was Elisa. Plots of 10 m2 each, arranged in a complete randomized block design and three replicates (20 plants for each) were used for each treatment. The average infestation level in all experimental plots was monitored until that reached one larva for replicate at zero time of treatment (USDA, 2011). Four untreated and treated leaves were sampled from each tomato plant (80 leaves/replicate) and the percent reduction of the infestation was calculated according to the equation as reported by Henderson and Tilton (1955). The different treatments were sprayed using Knapsack sprayer with 400 liter water/feddan. The treatments were regimens as follow; No. (1) drench of imidacloprid (Best WP 25% at 750 g/F), spray of pyridalyl (Pleo EC 50% at 100 mL/F) and Bt (Dipel 2x WP 6.4% at 200 g/F). No. (2) spray of imidacloprid (Best WP 25% at 500 g/F), indoxacarb (Avant EC 15% at 160 ml/F) and Bt (Dipel 2x WP 6.4% at 200 g/F) + mineral oil (Diver EC 97% at 1 L/F). No. (3) spray of chlorpyrifos methyl (Trifedan EC 50% at 1.5 L/F), lufenuron (Match EC 5% at 160 mL/F) and abamectin (Gold EC

1.8% at 250 mL/F). No. (4) spray of diazinon (Durasen EC 60% at 1.5 L/F), mineral oil (Diver EC 97% at 2 L/F) and emamectin benzoate (Pasha EC 1.9% at 250 mL/F).

Greenhouse trial

Efficiency of some insecticides mixture against T. absoluta using two types of sprayers

The experiment was conducted to evaluate the rate of each sprayer type; Hydraulic handgun sprayer at rate of 800 L/F and Engine-powered knapsack sprayer at rate of 400 L/F on the efficacy of some insecticides against tomato leafminer and such side-effect on tomato plant recorded by chlorophyll content. The experiment was carried out during the tomato growing season Feb. 2013 at Abo Ghalb city, Kaliobia Governorate, Egypt. All cultural methods were made according to good agricultural practice. Plots of 60 m2 each containing 60 plants arranged in a complete randomized block design. For each treatment including the check, three replications were tested. Samples of four leaves were collected at random from each plant (20 leaves/replicate). Percentage of *T. absoluta* infestation was determined by investigation of level samples to detect the externally and internally larvae as well as the infestation symptoms.

The treatments were as follow; diazinon (Durasen EC 60% at 1.5 L/F) + mineral oil (Diver EC 97% at 1 L/F); abamectin (Gold EC 1.8% at 250 mL/F) + mineral oil; lufenuron (Match EC 5% at 80 mL/F) + mineral oil; pyridaly (Pleo EC 50% at 100 mL/F) + mineral oil; imidacloprid (Best WP 25% at 500 g/F); indoxacarb (Avaunt EC 15% at 160 ml/F) + mineral oil; Bt (Dipel 2x WP 6.4% at 200 g/F) + mineral oil and emamectin benzoate (Pasha EC 1.9% at 250 mL/F) + mineral oil.

Determination of chlorophyll content

The chlorophyll content of tomato leaves was determined according to the procedure of Grodzinsky and Grodzinsky (1973). The absorption was measured spectrophotometerically at 645 nm and 663 nm using Thermos electron corporation evaluation 100 Spectrophotometer.

RESULTS AND DISCUSSION

Efficiency of some insecticide regimens against *T. absoluta*

Four suggested insecticidal sequences were evaluated and represented by three different insecticides for each sequence. Table (1) shows the reduction percentages of tomato leafminer, T. absoluta during the application of different sequences of certain insecticides. The first spray by diazinon (Durasen EC 60%) and chlorpyrifos methyl (Trifedan EC 50%) caused infestation reduction percentage of 67.14 after one week. The insecticide imidacloprid (Best WP 25%) caused infestation reduction percentage of 57.14 and 32.86% with its treatment as spray and soil injection, respectively. No significant difference was observed among the spray treatments of diazinon, chlorpyrifos methyl and imidacloprid whereas, the significant difference was recorded between the three insecticides and imidacloprid with soil injection treatment. The infestation reduction percentages of tested insecticides were more in the second treatment than that in the first treatment except in the case of mineral oil (Diver). The statistical analysis revealed that the lowest efficacy was obtained from mineral oil treatment, caused 57.64% infestation reduction. No significant differences among infestation reduction percentages of pyridalyl (Pleo), indoxacarb (Avant) and lefunuron (Match) treatments, caused 83.49, 86.97 and 83.01%, respectively. The 3rd treatment of B.t (Dipel 2x), B.t + mineral oil as a tank mixing, abamectin (Gold) and emamectin benzoate (Basha) caused 100% infestation reduction percentage. The average of infestation reduction percentages of T. absoluta was also estimated. No significant differences were recorded among all tested regimens. However, the tested different insecticide sequences could be classified in tow groups as follows; first group included the regimens 2 and 3 which caused 81.37 and 83.3 and second group included the regimens 1 and 4 which caused 72.12and 74.93 infestation reduction percentages, respectively.

T. absoluta have a short generation time and high biotic potential, is at increased risk of developing resistance to insecticide use (Lietti et al., 2005). Insecticide resistance has been recorded for several products (Lietti et al., 2005; Salazar and Araya, 1997, 2001; Siqueira et al., 2000, 2001). The difference in infestation reduction percentages can be attributed to different modes of action of the insecticides (Hanafy and El-Sayed, 2013). Therefore, use of the insecticides in sequences including alternative compounds could be prevent or delay the resistance phenomenon. Good efficacy of different insecticides on T. absoluta larvae such as emamectin benzoate (Gacemi and Guenaoui, 2012), abamectin (Braham and Hajji, 2012), B.t (Reda and Hatem, 2012; Moussa et al., 2013) was documented.

Efficiency of some insecticides on *T. absoluta* and their side-effect on tomato leaves using the two types of sprayers

The two tested types of sprayers were compared by examining the efficacy of different treatments against the tomato leafminer, T. absoluta. The data in Table (2) showed that the significant differences were detected between the two application tools, Hydraulic handgun sprayer and Engine-Powered Knapsack sprayer for many tested treatments such as (abamectin + mineral oil), (pyridalyl + mineral oil), imidacloprid, (indoxacarb + mineral oil), (emamectin benzoate + mineral oil) and (lufenuron + mineral oil). Furthermore, concerning to general mean, the Hydraulic handgun sprayer was significantly more effective than of Engine-Powered Knapsack sprayer.

Moreover, the side-effect of the tested insecticides on total chlorophyll - formation in tomato leaves varied due to the sprayer type used in for insecticide application (Table 3). The statistical analysis indicated that the treatments of (abamectin + mineral oil), imidacloprid, (indoxaocarb + mineral oil), (emamectin benzoate + mineral oil) and (Bt + mineral oil) using Hydraulic handgun sprayer were more inhibitory effect than that using Engine-Powered Knapsack sprayer. However, no significant differences were detected between the two types of sprayer in the case of (diazinon + mineral oil), (lufenuron + mineral oil) and depend upon the general mean.

In general, using of Hydraulic handgun sprayer improved the treatments efficiency against T. absoluta.

This result is agreement with the result obtained by Roy et al. (1988). However, using of Engine-Powered Knapsack sprayer decreased the side-effect of treatments on the chlorophyll content. Accordingly, it was suggested that the amount of the tested insecticide solution reached to tomato foliage was more with Hydraulic handgun sprayer (32 L of water was used containing the recommended rate of tested compounds) than Engine-Powered Knapsack sprayer (16 L of water contained the same insecticide quantities was used). It was expected that because the Hydraulic handgun sprayer has a high pressure and greater insecticide solution, the tomato plants were good covered by insecticide solution compared to that in the case of Engine-Powered Knapsack sprayer with low pressure and low amount of insecticide solution. Therefore, our result might be due to various factors; the covering uniform of the insecticide solution for the plant foliage (Gan-Mor et al., 1996; Fabio and Carlos, 2006; Safari et al., 2013), the size particle of droplets (Richard et al., 1977; Campbell and 2003) and the high pressure (Himelrick and Ogburn, 1999).

In conclusion, the evaluation of different insecticide regimens point out to prevent repletion of insecticide application in the same season. Furthermore, using alternatives in sequence with synthetic ones and looking forward to an integrated pest management to overcome pest problems. It is also suggested that the Hydraulic handgun is a suitable sprayer for insecticides application against *T. absoluta* in greenhouse and open field tomato plantation.

Table 1: Reduction percentage of Tuta abosluta infestation after different regimens applied.

Regimens	Infestation reduction (%)			
	1st treatment	2nd treatment	3rd treatment	Average
Regimen 1	Best (injection) 32.86 b	Pleo 83.49a	Dipel-2X 100a	72.12 a
Regimen 2	Best (spray) 57.14a	Avaunt 86.97a	Dipel-2X + Diver 100a	81.37 a
Regimen 3	Trifedan 67.14a	Match 83.01a	Gold 100 a	83.38 a
Regimen 4	Durasen 67.14a	Diver 57.64b	Bacha 100 a	79.93 a

Values within the same column having the same letter are not statistically different from each other, $p<0.05$.

Table 2: Effect of the sprayer type on the efficacy of different treatments in reducing the infestation of*Tuta absoluta* larval population at 7th day after treatment.

Treatments		Recommended rate / Feddan	% Infestation reduction	
Common name	Trade name		Hydraulic Handgun sprayer	Engine-Powered Knapsak sprayer
Diazinon + mineral oil	Durasen EC 60% + Diver EC 97%	1.5 L + 1 L	41.00 b	46.46 a
Abamectin + mineral oil	Gold EC 1.8% + Diver EC 97%	250 mL + 1 L	88.11 a	33.09 b
Pyridalyl + mineral oil	Pleo EC 50% + Diver EC 97%	100 mL + 1 L	77.85 a	36.20 b
Imidacloprid	Best WP 25%	500 g	91.81 a	47.17 b
Indoxacarb + mineral oil	Avaunt EC 15% + Diver EC 97%	160 mL + 1 L	84.87 a	33.90 b
Emamectin benzoate + mineral oil	Pasha EC 1.9% + Diver EC 97%	250 mL + 1 L	89.63 a	40.72 b
B.t + mineral oil	Dipel-2X WP 6.4% + Diver EC 97%	200 g + 1 L	53.35 b	60.80 a
Lufenuron + mineral oil	Match EC 5% + Diver EC 97%	160 mL + 1 L	43.81 a	38.13 a
General mean			71.30 a	42.05 b

Values within the same row having the same letters and number are not statistically different from each other, $P<0.05$.

Table 3: Effect of different treatments applied using two sprayer types on total chlorophyll content of tomato leaves.

Treatments		Recommended rate / Feddan	Total chlorophyll (mg/100g leaves)	
Common name	Trade name		Hydraulic Handgun sprayer	Engine-Powered Knapsak sprayer
Diazinon + mineral oil	Durasen EC 60% + Diver EC 97%	1.5 L + 1 L	11.46 a	9.14 a
Abamectin + mineral oil	Gold EC 1.8% + Diver EC 97%	250 mL + 1 L	9.26 b	12.20 a
Pyridalyl + mineral oil	Pleo EC 50% + Diver EC 97%	100 mL + 1 L	9.55 a	4.48 b
Imidacloprid	Best WP 25%	500 g	10.08 b	12.65 a
Indoxacarb + mineral oil	Avaunt EC 15% + Diver EC 97%	160 mL + 1 L	9.80 b	13.51 a
Emamectin benzoate + mineral oil	Pasha EC 1.9% + Diver EC 97%	250 mL + 1 L	9.22 b	11.96 a
B.t + mineral oil	Dipel-2X WP 6.4% + Diver EC 97%	200 g + 1 L	9.83 b	15.39 a
Lufenuron + mineral oil	Match EC 5% + Diver EC 97%	160 mL + 1 L	8.46 a	10.72 a
General mean			9.71 a	11.26 a

Values within the same row having the same letters and number are not statistically different from each other, $P<0.05$.

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كفاءة بعض نظم تتابع المبيدات و خلائطها على صانعات أنفاق الطماطم (توتا أبسليوتا) وتأثير نوع آلة الرش

حشرة صانعات الأنفاق بالطماطم (توتا أبسليوتا) من الحشرات الهامة والمحددة لزراعة الطماطم. إستخدام المبيدات كأحد عناصر المكافحة الكيماوية يعتمد على الأختلاف فى التركيب الكيماوى وتنوع ميكانيكية التأثير السام. فى هذه الدراسة تم تقييم كفاءة بعضالمبيدات الكيماوية و الحيوية و هى : ديازنون(ديوراسين%60 EC) ، كلوروبيرفوس ميثيل (ترايفيدان%50 EC) ، اندوكسوكارب (أفانت %15 EC) ، اميداكلوبريد (بست %25 WP) ، أبامكتين (جولد %EC1.8) ، امامكتين بنزوات (باشا %1.9 EC) ، ليفينرون (ماتش %5 EC) ، ناساس ثيرجنسيس (دابيل WP) ، بيردليل (بليو %EC50) ، زيت معدنى (دايفر %97 EC). وقد تم تقييم كفاءة المركبات ومخاليطها ضد حشرة توتا أبسليوتا بالصوبة الزراعية ومقارنة كفاءة نوعين من آلات الرش (الرشاشة الهيدروليكية بموتور ذات الرشاش اليدوى , الرشاشة الظهرية بالموتور). وأيضا دراسة التأثيرات الجانبية على محتوى الكلوروفيل لأوراق نبات الطماطم. وأظهرت النتائج أنه لا توجد فروق معنوية بين جميع أنظمة تتابع المبيدات المختبرة إلا أن نظام تتابع (رش اميداكلوبريد – اندكوكارب - باسلس + زيت معدنى) يليه التتابع (كلوربيرفوس ميثيل - ليفنيرون- ابامكتين) أظهرا أعلى فعالية عن نظام تتابع (حقن اميداكلوبريد - بيريدليل - باسلس) وتتابع (ديازينون - زيت معدنى - امامكتين بنزوات). ومن الملفت للنظر أنه بتقدير محتوى الكلوروفيل فى أوراق النبات سليم (كنترول سليم) وأوراق النبات مصاب بحشرة توتا أبسليوتا (كنترول مصاب) فقد ظهر جلياً أنه بالرغم من أن المركبات المختبرة خفضت محتوى الكلوروفيل إلا أن هذا الخفض أقل من الانحفاض الناتج عن إصابة الأوراق بحشرة توتا أبسليوتا. و اتضح أيضا أن استخدام الرشاشة الهيدروليكية بموتور ذات الرشاش اليدوى أدت الى حماية أعلى للنبات بخفض نسبة الاصابة إلا أنها أدت الى تأثيرات سلبية على محتوى الكلورفيل أعلى بالمقارنة بالرشاشة الظهرية بالموتور.