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Efficacy of Emamectin benzoate, Spinosad and Tolfenpyrad on *Tuta absoluta* Meyrick (Lepidoptera: Gelechiidae) infesting a tomato crop under geothermal greenhouses in Southern Tunisia

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Abstract

The tomato leaf miner, *Tuta absoluta* (Meyrick) (Lepidoptera: Gelechiidae), is considered one of the most devastating pests of tomato crops in geothermal greenhouses. It leads to crop losses reaching 100% among farmers and major tomato exporters. In this research, three insecticides, Emamectin benzoate, Spinosad and Tolfenpyrad were evaluated for their efficacy in the control of *T. absoluta* larvae in heated greenhouses. These three treatments resulted in a significant reduction in the number of *T. absoluta* larvae compared to an untreated control. The Emamectin Benzoate, Spinosad and Tolfenpyrad used were effective in controlling this leafminer with efficacy percentages above 60% against young larvae and above 50% against old larvae.

1. INTRODUCTION

Depuis leur domestication, il y a environ 12.000 In southern Tunisia, tomato cultivation ranks first in the category of geothermal crops with an area of 122.8 hectares representing more than 52.8% of the total area. More than 50% of production for export to European countries (CTCPG, 2021). The tomato leaf miner *Tuta absoluta* Meyrick (Lepidoptera: Gelechiidae), native to South America, is one of the most devastating pests of tomato (Desneux et al., 2010; Tonnang et al., 2015). this leafminer was detected in eastern Spain at the end of 2006 and for the first time in Algeria and Tunisia in 2008 (Chermiti et al., 2009). It has caused significant damage to tomato crops, both in greenhouses and in the field (Biondi et al., 2018; Desneux et al., 2011). And because of the 12-month harvest cycle, tomatoes grown in southern Tunisia under heated greenhouses are constantly threatened (Ettaib et al., 2016). The tomato leaf miner is present throughout the crop cycle. If left uncontrolled, it can cause up to 80 to 100% yield losses (Desneux et al., 2010). Insecticide application is fairly common and remains the most common control method (Roditakis et al., 2018). Chemical control remains the main management option due to the endophytic habits of *T. absoluta* (Biondi et al., 2018; Guedes and Picanço, 2012; Sarr et al., 2021). In the Mediterranean region, chemical control of *T. absoluta* is still based on the use of insecticides belonging to a few distinct chemical classes with different modes of action, namely diamides (chlorantraniliprole and cyantraniliprole), avermectins (abamectin and emamectin benzoate), spinosyns (spinosad) and oxadiazines (indoxacarb) (Roditakis et al., 2018). Tolfenpyrad was first developed and approved in Japan, in 2002 (Hikiji et al., 2013). It belongs to the pyrazole class of insecticides, which has a pyrazole-carboxamide structure. This insecticide is applied to control Hemiptera, Coleoptera, Diptera, Lepidoptera, Thysanoptera and mite pests (Hikiji et al., 2013; Yamaguchi et al., 2012). As a result of the new mode of action, tolfenpyrad is effective against pests resistant to existing insecticides, such as carbamates and organophosphates (Yamaguchi et al., 2012). Emamectin benzoate, as a new macrocyclic lactone insecticide and subgroup of the avermectin family, has been developed to control lepidoptera pests of several vegetable crops (Liguori et al., 2010).

This study was conducted to determine the toxicity of three chemical insecticides Emamectin benzoate, Spinosad and Tolfenpyrad against young larvae (L1, L2) and old larvae (L3, L4) of *T. absoluta* in a heated greenhouse in southern Tunisia.

2. MATERIALS AND METHODS

2.1. Study site

The test was conducted in a geothermal monotunnel greenhouse of tomato *Solanum lycopersicum* variety "Maria" with an area of 500 m^2 in the region of Bechima El Hamma Gabes (33°54'10.7" N, 9°45'01.5"E). The greenhouse contains a water trap (basin containing a mixture of water and oil placed at a height of about 40 cm) with sex pheromone lures (Pherodis®, Koppert Biological Systems) to monitor the flight dynamics of males of T. absoluta.Insecticide treatments were started on 04/02/2019 when the threshold was reached (50 males of *T. absoluta*/ water trap).

2.2. Chemical control of *T. absoluta* under geothermal greenhouse conditions

The two insecticides tested, Emmamectin Benzoate and Spinosad, were considered the most commonly used by Tunisian farmers. Tolfenpyrad is a new substance under registration in Tunisia. The greenhouse was divided into four blocks. There are four middle paired lines. The lines are 1.5 m apart from each other and the intra-line is 40 cm. Each crop row is designated a block. Each block was divided into four elementary plots containing 250 tomato plants. Each elementary plot received one of the treatments: Tolfenpyrad, Emmamectin Benzoate, Spinosad and untreated control. The treatments were carried out using an automatic backpack sprayer of 16 liters. The temperature and the relative humidity were not controlled under greenhouse.

From each elementary plot, twelve leaves (in total 48 leaves) from the apical and medial part of the plant were randomly collected and transferred to the laboratory for examination. The counting of *T. absoluta* larvae was carried out before the treatments and after 7, 14, 21 and 28 days after the treatments. In order to evaluate the efficacy of the insecticide on *T. absoluta* larvae, the following formula was used:

Percentage of efficacy =

(1 – (n in Co before Treatment * n in T after Treatment / (n in Co after Treatment * n in T before Treatment)) * 100

Where n = Insect population, T = treated, Co = Control (Henderson and Tilton, 1955)

2.3. Analysis of the data

The data were analysed using XLSTAT software version 2019. For the determination of the efficacy of insecticides under geothermal

Table 1. Properties of the insecticides tested

Active ingredient	Chemical group	Concentration of active ingredient, Formulation type	Doses	Mode of action
Tolfenpyrad	Pyrazole (21A)	150 g/l, SC	50 cc/hl	Mitochondrial Electron Transport Inhibitors
Emmamectine Benzoate	Avermectin (6)	50 g/l, SC	30 g/hl	Activateurs des canaux chlorure glutamate-dépendants (activateurs GluCl)
Spinosad	Spinosyns (5)	240g/l, SC	60 ml/hl	Activateurs des récepteurs nicotiniques de l'acétylcholine (activateurs nAChR)

SC Suspension Concentrate

greenhouse conditions, the mean numbers of *T. absoluta* larvae and the percent efficacy of the tested insecticides were compared using an ANOVA, while significant differences were detected using Duncan's test at the P <0.05 level.

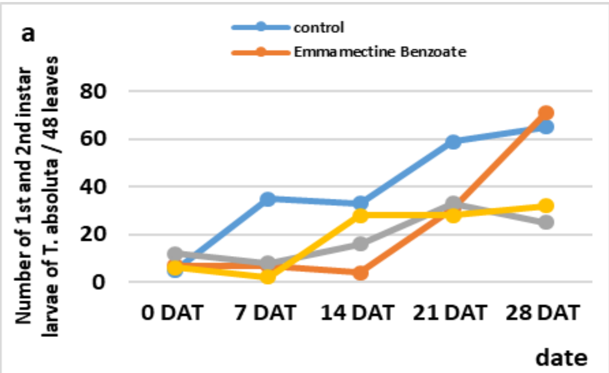
3. RESULTS AND DISCUSSION

The insecticidal action of the tested products was evaluated by counting the different larval stages; young larvae (L1, L2) and old larvae (L3, L4); surviving tomato leaf miner after treatment and determining the rate of efficacy between treated and control plots according to the Henderson and Tilton formula. Insecticide treatments were initiated on 04 February 2019 in a heated greenhouse. According to Fig. 1, the population trend of *T. absoluta* larvae was higher in the untreated control than in the treated elementary plots after 7 days of treatments. During the trial period, the three insecticides Emamectin Benzoate, Tolfenpyrad and Spinosad were effective in reducing *T. absoluta* on tomato plants.

The number of *T. absoluta* larvae per 48 leaves was counted for each treatment on each date and is recorded in Table 2. Statistical analysis shows that there is a significant difference after 7 days of treatment between the number of young larvae (L1, L2) (P<0.0001; F = 8.868) and old larvae (L3, L4) (P = 0.0001; F = 6.927). The difference persisted between the active substances tested and the development stage of the larvae until 14 days after treatment. After 21 days of treatment, there was no significant difference between the numbers of young larvae (P = 0.151; F = 1.786).

The analysis of variance and comparison of means by the Duncan test showed that there was no significant difference between the different insecticides. The percentages of efficacy against young larvae were 67.79%, 63.91% and 64.49% (P = 0.955; F = 0.046) and against old larvae were 58.56%, 56.14% and 53.18% (P = 0.966; F = 0.034) for Spinosad, Emmamectin Benzoate and Tolfenpyrad, respectively.

In this experiment, the three active substances showed a high efficiency against *T. absoluta*



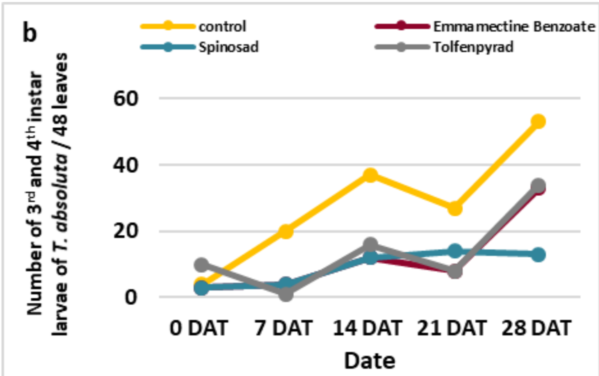


Fig. 1. Percentage of larval Population of *T. absoluta* larvae; a: Young larvae (L1, L2), b: Old larvae (L3, L4). DAT: Date after treatment

Table 2. Effect of insecticides on young larvae (L1, L2) and old larvae (L3, L4) of *T. absoluta*

	Number of 1st and 2nd instar larvae of *T. absoluta*/ 48 leaves				
	0 DAT	7 DAT	14 DAT	21 DAT	28 DAT
control	5 a	35 a	33 a	59 a	65 ab
Emmamectine Benzoate	7 a	7 b	4 b	31 a	71 a
Spinosad	12 a	8 b	16 ab	33 a	25 c
Tolfenpyrad	6 a	2 b	28 a	28 a	32bc
	P= 0.327 F = 1.157	P< 0.0001 F = 8.868	P= 0.007 F = 4.216	P= 0.151 F = 1.786	P = 0.013 F = 3.687
	Number of 3rd and 4th instar larvae of *T. absoluta*/ 48 leaves				
	0 DAT	7 DAT	14 DAT	21 DAT	28 DAT
control	4 a	20 a	37 a	27 a	53 a
Emmamectine Benzoate	3 a	4 b	12 b	8 b	33 ab
Spinosad	3 a	4 b	12 b	14 b	13 b
Tolfenpyrad	10 a	1 b	16 b	8 b	34 ab
	P= 0.237 F =1.422	P=0.0001 F = 6.927	P= 0.004 F = 4.642	P= 0.009 F = 3.975	P=0.004 F = 4.622

larvae, varying between 53.18% and 67.79%. In several studies, spinosad continues to be an extremely potent insecticide for the control of *T. absoluta* (Roditakis et al., 2018). Therefore, this substance is considered as an interesting alternative for the control of *T. absoluta*, which can negatively affect the fertility and fecundity of adults (Benchaâbane et al., 2016). Emamectin benzoate showed efficacy up to 14 days of treatment after which an increase in larvae numbers followed such that there was no significant difference in comparison to the untreated control. The latter disrupts nerve impulses leading to rapid paralysis, cessation of feeding and death within 3 to 4 days (Grafton-Cardwell et al., 2005). According to a study by Gacemi et al., (2008), Emamectin Benzoate showed good activity on *Tuta absoluta* larvae with mortality reaching 87%. In addition, the new substance Tolfenpyrad showed efficacy against *T. absoluta* larvae similar to that of Emamectin Benzoate and Spinosad. This is in accordance with the fact that Tolfenpyrad is used against Lepidoptera (Mallick et al., 2016; Yamaguchi et al., 2012). Tolfenpyrad gave better results against the okra sucking pest complex (Mallick et al., 2016). Nevertheless, Tolfenpyrad has negative effects on auxiliaries. It affects the survival rate, pupation rate, adult emergence and egg hatching of the predator ladybird *Coccinella septempunctata* (Chi et al., 2021). Also, another study shows that Tolfenpyrad has a negative effect on the *Trichogramma pretiosum (Hymenoptera : Trichogrammatidae)* (Khan and Ruberson, 2017).

4. CONCLUSION

In conclusion, the results obtained from the geothermal heated greenhouse trial in southern Tunisia showed that Emamectin benzoate, Spinosad and Tolfenpyrad effectively control *T. absoluta* larvae. Subsequently, these substances minimize the damage of this pest on tomato leaves and. In addition, it is necessary to incorporate chemical control with other methods of biological control such as the use of mirid predators or parasitoids and the use of bio-substances to avoid the phenomenon of resistance to chemicals.

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