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Research Article

# Short and long term effects of some bio-insecticides on *Tuta absoluta* Meyrick (Lepidoptera: Gelechiidae) and its coexisting generalist predators in tomato fields

**Leila Nazarpour[1], Fatemeh Yarahmadi[1*], Moosa Saber[2] and Ali Rajabpour[1]**

1. Department of Plant Protection, Faculty of Agriculture, Ramin Agriculture and Natural Resources University of Khuzestan, Mollasani, Ahwaz, Iran.
2. Department of Plant Protection, Faculty of Agriculture, University of Tabriz, Tabriz, Iran.

**Abstract:** Tomato leaf miner, *Tuta absoluta* Meyrick (Lepidoptera: Gelechiidae), is one of the most destructive pests of tomato in many parts of the world including Iran. Field studies were conducted to determine the short and long term effects of *Bacillus thuringiensis* var Kurstaki (Bt), azadirachtin (AZ), a mix of AZ + Bt, and indoxacarb, as a current chemical insecticide, on *T. absoluta* larvae. Also, effects of the insecticides were studied on the coexisting generalist predators, *Coccinella septempunctata* L., *Chrysoperla carnea* Stephens and *Syritta* sp. Sampling of *T. absoluta* and its coexisting generalist predators were performed 1 day before treatment (DBT) and one, 5, 8, 14 and 19 days after treatment (DAT). The results indicated significant short term effect of indoxacarb on the pest larvae. Indoxacarb reduced *T. absoluta* density and damages. Bt, AZ and mixture of them significantly suppressed the larval density at 19 DAT and caused significant reduction in leaf, stem and fruit damage. The highest long term effect on the pest abundance and damage were observed in Az + Bt caused 100% reduction in fruit and foliage damage compared to the control. The highest and lowest adverse effects on *C. carnea*, *C. septempunctat* and *Serrita* sp. were observed in indoxacarb and Bt treatments, respectively. Findings of this study imply that the mixture of Az + Bt has the highest selective toxicity on the pest and the lowest effect on its coexisting generalist predators.

**Key words:** Tomato, leafminer, Bt, Azadirachtin, indoxacarb, toxicity

## Introduction

Tomato *Lycopersicon esculentum* Mill. is an economically important and remunerative vegetable crop belonging to the Solanaceae and grown around the world for fresh market and processing (Salunkhe *et al.*, 1987). The tomato leafminer, *Tuta absoluta*, is considered as a key pest of tomato both in the field and under protected conditions (Yankova, 2012). This pest has spread from Americas to other regions & into Asia into Asia (Desneux *et al.*, 2011). Larvae preferentially feed on all above-ground parts of tomato, create mines on the leaves and penetrate into young stems and fruits. Both yield and fruit quality can be significantly reduced by the direct feeding of the pest and the secondary pathogens which may then enter through the wounds made by the pest (Cristina *et al.*, 2008). Severely attacked tomato fruits lose their commercial value. Sixty to 100% losses have been reported in tomato crops, and even where chemical control is implemented, losses can still

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* **Corresponding author**, e-mail: yarahmadi@ramin.ac.ir
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exceed 5% (Korycinska and Moran, 2009). Its presence inside the mines, the high reproductive potential, polyvoltine nature and poor spraying technology make the leaf miner difficult to control chemically (Lietti *et al.*, 2005, Valchev *et al*. 2013). So farmers apply insecticide 8 to 25 times in a season (Temerak, 2011). The indiscriminate use of synthetic chemical pesticides to control this pest resulted in the rapid development of resistance (Dittrich *et al.,* 1990) and harmful pesticide residues in fruits (Amos *et al.,* 1992, 1994), destruction of natural enemy populations (Campbell *et al.*, 1991).

Applying new types of insecticides, originated from natural agents or products that disrupt the physiological processes of the target pest, could be useful alternatives in the integrated management approach (Parsaeyan *et al.*, 2013). Biopesticides based on azadirachtin and *Bacillus thuringiensis* Berliner (or Bt) represent important pest control options for integrated pest management (IPM) because of their low eco-toxicological effects and short persistence in the environment (Lacey and Siegel, 2000; Anonymous, 2011; Braham and Hajji, 2012). Indoxacarb, the active ingredient in DuPont™ Steward® EC insecticide, is a broad-spectrum Lepidoptera insecticide that also has activity on other pests such as bollworms, budworms, armyworms, cutworms, loopers and clover worms (Anonymous, 2006). The insecticide was broadly recommended for control of *T. absoluta* in tomato fields of Iran. Effect of some chemical and biorational insecticides on *T. absoluta* were previously investigated in field and laboratory conditions (Gonzales-Cabera *et al.*, 2011; Mollá *et al.*, 2011; Hanafy and El-Sayed, 2013; Larrain *et al.*, 2014).

The existence of naturally occurring biocontrol agents, including ladybirds, lacewings, carabid beetles, spiders etc, as generalist predators, is one of main reasons why many plant feeding insects do not ordinarily become economic pests. The importance of such agents often becomes quite apparent when application of an insecticide to control one pest results in other pest outbreaks due to the chemical destruction of important natural enemies (El-Wakeil *et al.*, 2013). The compatibility of biological control agents with pesticides is a central concern in integrated pest management programs (Stark *et al.*, 2007). A few studies were done on the effects of applied insecticides on natural enemies of *T. absoluta* (Consoli *et al.*, 1998; Arno and Gabarra, 2011; Mollá *et al.*, 2011).

This study was carried out to evaluate the effect of biorational and chemical insecticides such as azadirachtin, indoxacarb, and *Bacillus thuringiensis* (Bt.) against *T. absoluta* and to investigate their effects on population of its coexisting general predators in tomato fields.

## Materials and Methods

The present study was conducted in tomato field in Masjed Soleiman (31° 56' 11" North, 49° 18' 14" East), Khuzestan province, Iran during the 2013/2014 growing season. The King Stone tomato cultivar was used in the trials. Growing, fertilizing, weeding and irrigation (every 7 days) of tomato were done according to the routine practice of Khuzestan Agricultural Organization (KAO). The field was divided into 5 plots (500 $m^2$) and wide ridges (1 meter).

The information about insecticide treatments is presented in Table 1. Control was sprayed with water.

Treatments were applied using a backpack sprayer in a broadcast application using the hollow cone, solid spray tip type of nozzle (TXVK-10). The equipment was set to deliver 1000 L/ha, following growers' usual practice. Sprayings were done after the first flight activity of *T. absoluta* moths .The male flight activity was monitored using sex pheromone lures (Russel IPM, U. K.) placed inside Delta sticky traps. The number of males caught in traps was recorded weekly.

Sampling for estimation of *T. absoluta* densities was performed 1 day before treatment (DBT) and 1, 5, 8, 14 and 19 days after treatment (DAT). At each sampling time, 6 plants were randomly selected. From each chosen plant, 10 leaves and 10 fruits were randomly selected from the upper part of the plant and numbers of live larvae of *T. absoluta*, larval mines and percentage of damaged fruits were separately recorded for each experimental treatment. Also, the numbers of the coexisting generalist predators such as *Coccinella septempunctata* L. (Coleoptera: Coccinellidae), *Chrysopa carnea* Stephens (Neuroptera: Chrysopidae), *Syrrita* sp. (Diptera: Syrphidae) on the plant foliage were recorded at the same time. All of the predators coexisting with *T. absoluta* in tomato fields of Khuzestan province also fed on other important pests such as aphids, whiteflies and some other caterpillars.

**Data analysis**

Experiment was performed in a Completely Randomized Design (CRD) in four replications. Data were analyzed by one-way analysis of variance (ANOVA) to detect significant difference between treatments. Statistical analysis was performed using SPSS computer software (version 16).

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## Results

### *T. absoluta* larvae density

Larval densities of *Tuta absoluta* before and after treatments are presented in Table 2. No significant difference was observed between treatments one day before insecticide application. At this time, the mean number of total live larvae per plant varied from 2.7-3.5.

The larval density of *T. absoluta* was significantly reduced by indoxacarb at 1 DAT. Azadirachtin and azadirachtin + Bt proved to be nearly as effective as indoxacarb. However, no significant difference was observed between Bt and control regarding the mean number of live larvae. At 5 DAT, all experimental treatments significantly suppressed population of the pest larvae. The effects of azadirachtin, azadirachtin + Bt and Bt on *T. absoluta* larvae were significantly more than indoxacarb at 8 DAT. Nevertheless, indoxacarb significantly decreased larval density of the pest compared to control. The same trend of efficacy was observed for all treatments at 14 and 19 DAT.

The highest and lowest long term effects on the pest population were observed in azadirachtin + Bt and indoxacarb treatments, respectively. At 19 DAT, 100 and 38% reduction in larval density were observed in azadirachtin + Bt and indoxacarb, respectively. The pest density in the plants that were treated with azadirachtin, azadirachtin + Bt and Bt was always significantly lower than indoxacarb and control in all sampling dates. Generally, the tested bio-insecticides were more effective.

### Leaf and stem

The mean number of leaf and stem damages are shown in Table 3. There was no significant difference in the observed recorded damage between insecticide treatments and control in 8 DAT. After two weeks, the number of leaf and stem mines were significantly reduced compared to control. At the end of sampling, minimum mines were recorded in azadirachtin and azadirachtin + Bt treatments (1.6 mines per plant) and maximum in control (38.3 mines per plant). Therefore, azadirachtin alone and combined with Bt caused 96% reduction in leaf or stem mines.

### Fruit

Percentage of damaged fruits is presented in Table 4. No significant difference was observed between treatments at 1 DBT and 1 DAT. But all the insecticide treatments significantly reduced the damaged fruits compared to control 5 DAT. At 19 DAT, the effect of azadirachtin + Bt and azadirachtin were equal while Bt alone was less effective. However, indoxacarb was not effective compared to control. Damaged fruit in azadirachtin + Bt treatment was less than all other treatments. As the percent damaged fruits was nil in this treatment (Table 4).





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**Generalist predator densities**

*Chrysoperla carnea*, *C. septempunctat* and *Seritta* sp. densities before and after treatments are presented in Tables 5-7. Population of the predators was significantly suppressed by indoxacarb until the end of sampling compared to control. The least detrimental effects on population density of the natural enemies were recorded in Bt treatment. In all dates after Bt treatment, the predator densities were not significantly different to control. Azadirachtin alone and combined with Bt had moderate destructive effects on the generalist predators.

**Table 1** Insecticide information in the treatments.

| Treatment | Trade name | Formulation | Mode of action | Applied rate per hectare |
|---|---|---|---|---|
| Indoxacarb[1] | Avaunt ® | SC 15% | Sodium channel modulator | 250 ml |
| *Bacillus thuringiensis ssp.* Kurstaki[2] (Bt) | Belthirul® | 32000 spore/g WP | Delta- endotoxin as digestive toxin | 0.5 kg |
| Azadirachtin[3] (Az) | Neemarin 1500 ppm® | EC 1% | Insect growth regulator | 1 L |
| Mix of Bt and Az | - | - | - | 0.5 kg (Bt) + 1 L (AZ) |

1 Sumitomo chemical company, Japan.
2 Probelte SA, Spain.
3 Biotech International Ltd.

**Table 2** Mean number of *Tuta absoluta* total live larvae per plant before and after treatment.

| Treatments | Days before treatment[1] | Days after teatment[1] | | | | |
|---|---|---|---|---|---|---|
| | 1 | 1 | 5 | 8 | 14 | 19 |
| Indoxacarb | 2.8 ± 1.3 | 0.2 ± 0.17[b] | 0.7 ± 0.33[b] | 3.3 ± 0.49[b] | 7.2 ± 1.01[b] | 4.3 ± 1.11[b] |
| Bt | 2.0 ± 0.6 | 4.0 ± 1.30[a] | 2.0 ± 0.89[b] | 1.3 ± 0.61[c] | 3.2 ± 1.30[c] | 3.0 ± 0.52[ab] |
| Azadirachtin + Bt | 1.4 ± 0.6 | 2.8 ± 1.20[ab] | 1.7 ± 0.95[b] | 0.3 ± 0.21[c] | 0.2 ± 0.17[c] | 0[c] |
| Azadirachtin | 2.2 ± 0.9 | 2.3 ± 1.05[ab] | 1.3 ± 0.49[b] | 1.7 ± 0.56[ab] | 1.3 ± 0.49[c] | 0.7 ± 0.33[c] |
| Control | 3.1 ± 1.2 | 4.2 ± 1.40[a] | 8.8 ± 1.97[a] | 8.8 ± 1.97[a] | 11.0 ± 1.40[a] | 7.0 ± 0.97[a] |
| F – value (df = 4, 19) | 1.70 | 2.60 | 3.20 | 13.39 | 22.07 | 15.63 |
| P - value | 0.467 | 0.032 | 0.026 | < 0.0001 | < 0.0001 | < 0.0001 |

1 Means followed by different letters in each column indicate significant differences (Duncan's test, $P \leq 0.05$).

**Table 3** Mean ± numbers of leaf and stem mines caused by *Tuta absoluta* before and after treatment.

| Treatments | Days before treatment[1] | Days after teatment[1] | | | | |
|---|---|---|---|---|---|---|
| | 1 | 1 | 5 | 8 | 14 | 19 |
| Indoxacarb | 8.3 ± 5.3 | 5.0 ± 2.2 | 3.3 ± 2.1 | 5.0 ± 2.2[b] | 10.0 ± 6.3[b] | 5.0 ± 2.2[b] |
| Bt | 6.6 ± 3.3 | 11.6 ± 5.4 | 10.0 ± 6.3 | 5.0 ± 2.2[b] | 5.0 ± 2.2[b] | 5.0 ± 2.2[b] |
| Azadirachtin + Bt | 6.6 ± 4.2 | 8.3 ± 6.5 | 6.6 ± 4.9 | 1.6 ± 1.6[b] | 0[b] | 1.6 ± 1.6[b] |
| Azadirachtin | 8.3 ± 6.5 | 10.0 ± 6.3 | 10.0 ± 4.4 | 1.6 ± 1.6[b] | 1.6 ± 1.6[b] | 1.6 ± 1.6[b] |
| Control | 8.3 ± 4.7 | 13.3 ± 7.1 | 23.0 ± 10.5 | 40.0 ± 15.1[a] | 41.6 ± 9.1[a] | 38.3 ± 12.4[a] |
| F value (df = 4, 19) | 0.24 | 0.3 | 1.4 | 7.1 | 11.3 | 7.21 |
| P - value | 0.9 | 0.87 | 0.24 | < 0.001 | < 0.001 | < 0.001 |

1 Means followed by different letters in each column indicate significant differences (Duncan's test, $P \leq 0.05$).

**Table 4** Mean percentages of damaged fruits caused by *Tuta absoluta* before and after treatment.

| Treatments | Days before treatment[1] | Days after teatment[1] | | | | |
|---|---|---|---|---|---|---|
| | 1 | 1 | 5 | 8 | 14 | 19 |
| Indoxacarb | 0.8 ± 0.30 | 1.0 ± 0.36 | 1.0 ± 0.36 | 0.7 ± 0.30[b] | 0.8 ± 0.30[b] | 2.6 ± 0.80[ab] |
| Bt | 0.6 ± 0.30 | 0.8 ± 0.10 | 0.8 ± 0.16 | 0.3 ± 0.30[b] | 0.2 ± 0.16[b] | 1.0 ± 0.50[bc] |
| Azadirachtin + Bt | 0.8 ± 0.30 | 1.0 ± 0.40 | 1.0 ± 0.44 | 0.2 ± 0.16[b] | 0.2 ± 0.16[b] | 0[c] |
| Azadirachtin | 1.0 ± 0.25 | 1.0 ± 0.70 | 1.0 ± 0.70 | 0.3 ± 0.20[b] | 0.2 ± 0.16[b] | 0.5 ± 0.22[c] |
| Control | 0.6 ± 0.30 | 1.1 ± 0.50 | 1.16 ± 0.50 | 3.5 ± 1.20[a] | 4.0 ± 0.70[a] | 3.6 ± 0.91[a] |
| F- value (df = 4, 19) | 0.2 | 0.06 | 2.2 | 5.5 | 23.1 | 6.1 |
| P - value | 0.93 | 0.99 | 0.99 | 0.003 | < 0.0001 | < 0.001 |

1 Means followed by different letters in each column indicate significant differences (Duncan's test, $P \leq 0.05$).

**Table 5** Mean number of *Chrysoperla carnea* per plant before and after treatment.

| Treatments | Days before treatment[1] | Days after teatment[1] | | | | |
|---|---|---|---|---|---|---|
| | 1 | 1 | 5 | 8 | 14 | 19 |
| Indoxacarb | 0.37 ± 0.12 | 0[c] | 0[b] | 0[a] | 0.33 ± 0.21 | 0.50 ± 0.22 |
| Bt | 0.37 ± 0.07 | 0.37 ± 0.14[ab] | 0.25 ± 0.10[ab] | 0.29 ± 0.10[ab] | 0.33 ± 0.21 | 0.66 ± 0.33 |
| Azadirachtin + Bt | 0.41 ± 0. 10 | 0.08 ± 0.04[c] | 0.08 ± 0.08[ab] | 0[a] | 0.66 ± 0.21 | 0.50 ± 0.22 |
| Azadirachtin | 0.29 ± 0.07 | 0.12 ± 0.07[bc] | 0.08 ± 0.08[ab] | 0[a] | 0.50 ± 0.22 | 0.33 ± 0.21 |
| Control | 0.29 ± 0.14 | 0.41 ± 0.10[a] | 0.29 ± 0.07[a] | 0.58 ± 0.27[b] | 0.33 ± 0.21 | 0.66 ± 0.33 |
| df | 4, 19 | 4, 19 | 4, 19 | 4, 19 | 4, 29 | 4, 29 |
| F - value | 0.26 | 4.22 | 2.4 | 3.07 | 0.48 | 0.26 |
| P - value | 0.89 | 0.017 | 0.05 | 0.04 | 0.74 | 0.89 |

1 Means followed by different letters in each column indicate significant differences (Duncan's test, $P \leq 0.05$).

**Table 6** Mean number of *Coccinella septempunctata* per plant before and after treatment.

| Treatments | Days before treatment[1] | Days after teatment[1] | | | | |
|---|---|---|---|---|---|---|
| | 1 | 1 | 5 | 8 | 14 | 19 |
| Indoxacarb | 0.21 ± 0.10 | 0[b] | 0 | 0[b] | 0[b] | 0.041 ± 0.04 |
| Bt | 0.16 ± 0.06 | 0.08 ± 0.40[b] | 0.08 ± 0.05 | 0.25 ± 0.10[a] | 0.21 ± 0.08[a] | 0.041 ± 0.04 |
| Azadirachtin + Bt | 0.12 ± 0.08 | 0.04 ± 0.04[b] | 0 | 0[b] | 0 [b] | 0 |
| Azadirachtin | 0.21 ± 0.80 | 0.04 ± 0.04[b] | 0 | 0[b] | 0[b] | 0 |
| Control | 0.12 ± 0.80 | 0.21 ± 0.04[a] | 0.13 ± 0.08 | 0.335 ± 0.12[a] | 0.25 ± 0.08[a] | 0.08 ± 0.05 |
| F - value (df = 4, 19) | 0.25 | 4.26 | 3 | 5.18 | 6 | 1.05 |
| p - value | 0.9 | 0.017 | 0.5 | 0.008 | 0.004 | 0.415 |

1 Means followed by different letters in each column indicate significant differences (Duncan's test, $P \leq 0.05$).

**Table 7** Mean number of *Syritta* sp. per plant before and after treatment.

| Treatments | Days before treatment[1] | Days after teatment[1] | | | | |
|---|---|---|---|---|---|---|
| | 1 | 1 | 5 | 8 | 14 | 19 |
| Indoxacarb | 0.08 ± 0.40 | 0 | 0 | 0 | 0[b] | 0 |
| Bt | 0.12 ± 0.07 | 0 | 0 | 0.04 ± 0.04 | 0.25 ± 0.11[ab] | 0 |
| Azadirachtin + Bt | 0.04 ± 0.04 | 0.04 ± 0.004 | 0.04 ± 0.04 | 0.04 ± 0.04 | 0.08 ± 0.05[ab] | 0 |
| Azadirachtin | 0.04 ± 0.04 | 0 | 0 | 0.08 ± 0.05 | 0.08 ± 0.05[ab] | 0 |
| Control | 0.04 ± 0.04 | 0.08 ± 0.040 | 0.08 ± 0.05 | 0.08 ± 0.05 | 0.29 ± 0.12[a] | 0 |
| F – value (df = 4, 19) | 0.59 | 3.34 | 1.71 | 0.75 | 2.41 | |
| P - value | 0.48 | 0.084 | 0.199 | 0.57 | 0.05 | |

1 Means followed by different letters in each column indicate significant differences (Duncan's test, $P \leq 0.05$).





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**Discussion**

The main purpose of this study was to evaluate short and long term effects of indoxacarb (as a chemical insecticide) and Bt, azadirachtin and mixture of AZ + Bt (as biorational insecticides) against *T. absoluta* larvae and its coexisting generalist predators in the field. In Iran, on June 2011, the pest was detected in 24 different locations. Thus, based on experiences of other countries an IPM program was developed according to available facilities (Baniameri and Cheraghian, 2012). Despite the high cost of Avant (indoxacarb), it is now the widely used bioinsecticide for management of this insect. Findings of this field study suggest the good performance of indoxacarb, Bt, Bt + AZ and azadirachtin. Our field data suggest good short term performance of indoxacarb. The short term efficacy of indoxacarb against *T. absoluta* is due to its rapid activity as a powerful voltage-dependent sodium channel blocker in nerve axons which inhibits propagation of nerve potential, which occurs rapidly in Lepidoptera (Derbalah *et al.*, 2012). Our study showed that indoxacarb loses its efficacy after nearly one week. Also, Liu *et al.* (2003) showed that toxicity of field-aged leaf residues of indoxacarb against *Plutella xylostella* L. (Lepidoptera: Gelechiidae) gradually decline 21 days after treatment in cabbage field. Takkar *et al.* (2011) stated that indoxacarb residues on cauliflower leaf dissipate after 7 days.

Moderate levels of resistance (up to 27.5-folds) were also reported for indoxacarb (Silva *et al.*, 2011). Indoxacarb is a powerful insecticide in controlling many Lepidopteran pests. Wakil *et al.* (2009) showed that integrating weed control, larvae hand picking and indoxacarb sprays to control *Helicoverpa armigera* Hubner (Lepidoptera: Noctuidae) reduce the larval population, pod infestation and maximize grain yield. Braham and Hajji (2012) conducted field and laboratory trials on tomato to control *T. absoluta* using spinosad, indoxacarb and pyrethroid compounds. They demonstrated that the product indoxacarb tends to be a powerful control tool of *T. absoluta* larvae.

Biopesticides based on Bt are used as an alternative strategy to control pests. Bt is a rod-shaped, gram positive, endospore-forming bacterium, characterized by its ability to synthesize delta endotoxins as protein inclusion crystals (or Cry proteins) during sporulation. Bt, an entomopathogenic bacterium, has also been used in the control of tomato plant pests (Hofte and Whiteley, 1989).

In the UK, three insecticides have been registered for the control of *T. absoluta* in tomato, pepper and aubergine, viz; *B. thuringiensis var.* kurstaki, indoxacarb and spinosad (FERA, 2009).

Bt exhibited satisfactory efficacy against *T. absoluta* in this study and this is in agreement with the results of Derbalah *et al*. (2012) who reported that the metabolites in Bt have potential insecticidal activity against pests. They showed that insecticidal activity of Bt filtrate against *T. absoluta* may be due to the presence of known bioactive compounds Gonzales-Cabera *et al.* (2011) explained that the impact of *T. absoluta* can be greatly reduced by spraying only Bt-based formulations, with no need for further chemical insecticides. Same results were reported by other authors (Giustolin and Vendramim, 2001; Yousef and Hassan, 2013).

Suitable long term insecticidal activity of azadirachtin is proven in our research. Products with active ingredient azadirachtin, tetranortriterpenoid extracted from seeds and vegetative mass of the neem tree *(Azadirachta indica* a. Juss), and the fruit of chinaberry, *Melia azaderach* L. (Meliaceae) are limonoids and possess specific antifeedant and deterrent activity, suppress and stop insect feeding, reduce moulting and cause deformations in pupae and in the imago, and decrease fecundity of the females (Isman, 2006). The application of plant extracts is an important element of the strategy for integrated management of *T.*





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*absoluta* (Braham and Hajji, 2012). Findings of this study support the results of Yankova *et al.* (2014) for effectiveness of phytopesticide Neem Azal T/S 0.3% against larvae of *T. absoluta*. According to Mudathir and Basedow (2003) neem formulations significantly reduced pest attack on tomato and increased yield. Farrokhi *et al*. (2011) suggested that selective pesticides (azadirachtin, spinosad and indoxacarb) at recommended doses are effective against *T. absoluta* without adverse effects on natural enemies.

This study also showed the possibility of mixing Bt with botanical extracts which could help to delay the resistance development by the insect. It seems that azadirachtin and Bt have additive effect. Similarly, it is demonstrated that the combination of Bt and spinosad (a biorational insecticide) have good additive effect when compared to each treatment singly. In contrast to our finding, laboratory study of Amizadeh *et al.* (2015) on compatibility and interaction of Bt and some chemical and biorational insecticides (eg. abamectin, azadirachtin, indoxacarb, chlorantraniliprole, dichlorovos, and metaflumizone) showed an antagonistic effect for mix of Bt and azadirachtin. The authors stated that simultaneous use of the chemical insecticides tested and Bt was not recommended for *T. absoluta* control; and that a proper time lapse was needed. The different results may be related to different conditions between laboratory and field trials.

The greatest effect on *C. carnea*, *C. septempunctat* and *Serrita* sp. was observed in the indoxacarb treatment. Indoxacarb is a selective insecticide belonging to oxadiazine group and is active against lepidopteran pests (Wing *et al.*, 1998). Indoxacarb was considered safe to natural enemies and other beneficial organism (Horowitz and Ishaaya, 2004). Several assays have been performed to evaluate the toxicity of indoxacarb to some generalist predators such as *Chrysopa rufilabris* Burneister, *C. septempunctat* (Olszak and Sekrecka, 2008), *Coleomegilla maculata* DeGeer, *Harmonia axyridis* Pallas and *Orius insidiosus* Say (Musser and Shelton, 2003). In contrast to our findings, indoxacarb exhibited good selectivity to all of the natural enemies tested in these experiments. The different predator species and experimental conditions may have caused these differences. Our results were similar to those of Arno and Gabbara (2011) who showed that indoxacarb is highly toxic for nymphs and adults of *Macrolophus pygmaeus* Rambur and *Nesidiocoris tenuis* Reuter, two generalist predators of *T. absoluta*. They showed that seven days after application at the maximum recommended field rates, the mortality produced by indoxacarb on the predators was significantly higher than that produced by azadirachtin (Arno and Gabarra, 2011). Similar results were stated by Galvan *et al.* (2005) and Awasthi *et al.* (2013) for *Harmonia axyridis* Pallas and *Cheilomenes* sp., respectively.

Bt has the least effect on the generalist predator densities. Endotoxins from Bt are generally not toxic to predatory and parasitic arthropods. However, elimination of Bt-susceptible prey and hosts in Bt treated crops could reduce predator and parasitoid population and thereby disrupt the bio control by other herbivorous pests (Schoenly *et al.*, 2003). Selectivity of *B. thuringiensis* var kurstaki on lepidopteran pests and its reduced effect on the predators that coexist with *T. absoluta* indicates that it is a good candidate for integration with other suitable strategies in IPM. Furlong *et al.* (2008) described that he *Bt*-natural enemy strategy significantly increased crop yields and the impact of both parasitoid and predator natural enemies on pest populations. Molla *et al.* (2011) demonstrated that Bt and *N. tenuis* are compatible in IPM program of *T. absoluta*. In this study, it was shown that application of Bt immediately after the initial detection of the pest on the host plant, doesn't interfere with *N. tenuis* establishment.

Azadirachtin alone and combined with Bt caused reduction in population of the coexisting predators in comparison with the control but the effect was almost less than indoxacarb. Side effect of azadirachtin enhanced gradually on the





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predators by time. Deterrent effects of azadirachtin on the predators may be a reason for reduction in their population. Azadirachtin is repellent to *Venturia canescens* Gravenhorts (Tunca *et al*., 2012) and *Coleomegilla maculata lengi* Timb. (Roger *et al.*, 2009). Our results are in agreement with Travares *et al.* (2010) who reported that toxicity of Azadiracchtin to *Eriopis connnexa* Germar (Coleoptera: Coccinellidae) is lower than lufenuron. Toxic effects of azadirachtin on two chrysopids, *Chrysoperla externa* Hagen and *Ceraeochrysa cubana* Hagen, were demonstrated by Cordeiro *et al.* (2010). A similar conclusion about toxicity of azadirachtin was also reached by Spollen and Isman (1996) for *Aphidoletes aphidimyza* Rondani (Diptera: Cecidomyiidae).

## Conclusion

Short and long term effects of Bt and azadirachtin alone or in combination contribute positively to control of *T. absoluta* in tomato fields. The relatively high mortality induced by azadirachtin on the generalist coexisting predators however, is suggestive that Bt is the better option for control of the pest. Use of selective insecticides may improve the conservation of natural enemies and therefore contribute to the success of integrated pest management (IPM) programs in tomato fields.

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# اثرات کوتاه و درازمدت برخی سموم زیستی روی مینوز برگ گوجه‌فرنگی *Tuta absoluta* Meyrick (Lepidoptera: Gelechiidae) و شکارگران هم‌جا با آن در مزارع گوجه‌فرنگی

**لیلا نظرپور[1]، فاطمه یاراحمدی[1*]، موسی صابر[2] و علی رجب‌پور[1]**

۱-گروه گیاه‌پزشکی، دانشکده کشاورزی، دانشگاه کشاورزی و منابع طبیعی رامین خوزستان، ملاثانی، اهواز، ایران.
۲- گروه گیاه‌پزشکی، دانشکده کشاورزی، دانشگاه تبریز، تبریز، ایران.
* پست الکترونیکی نویسنده مسئول مکاتبه: yarahmadi@ramin.ac.ir
دریافت: ۲۸ مرداد ۱۳۹۴؛ پذیرش: ۳۱ اردیبهشت ۱۳۹۵

**چکیده:** مینوز برگ گوجه‌فرنگی *Tuta absoluta* (Lepidoptera: Gelechiidae) یکی از خطرناک‌ترین آفات گوجه‌فرنگی در بسیاری از نقاط دنیا از جمله ایران می‌باشد. مطالعات مزرعه‌ای به‌منظور تعیین اثرات کوتاه و درازمدت باسیلوس تورینجنسیس زیرگونه کروستاکی (Bt)، آزادیراختین (Az)، مخلوط آزادیراختین و Bt و ایندوکساکارب (به‌عنوان یک حشره‌کش رایج) روی لاروهای *T. absoluta*، انجام شد. هم‌چنین تأثیرات این حشره‌کش‌ها روی شکارگران عمومی‌خوار هم‌جای این آفت (*Coccinella septempunctata* L.، *Chrysopa carnea* Stephens و *Syritta* sp.) نیز مورد مطالعه قرار گرفت. نمونه-برداری‌ها از *T. absoluta* و شکارگران عمومی‌خوار هم‌جای آن در یک روز قبل (DBT) و بعد از تیمار نمودن، ۵، ۸ و ۱۴ و ۱۹ روز پس تیمار (DAT) انجام شد. نتایج نشان‌دهنده اثرات کوتاه‌مدت معنی‌دار ایندوکساکارب روی لاروهای این آفت بود. ایندوکساکارب تراکم *T. absoluta* و خسارت آن را کاهش داد. Bt، آزادیراختین و ترکیب آنها به‌صورت معنی‌داری تراکم لاروی را در ۱۹ روز پس از تیمار سرکوب نموده و موجب کاهش معنی‌دار در خسارت روی برگ، ساقه و میوه شد. بیش‌ترین اثر بلندمدت روی جمعیت این آفت در تیمار آزادیراختین +Bt و مشاهده شد. آزادیراختین +Bt موجب کاهش صد در صدی در خسارت اندام‌های هوایی در مقایسه با تیمار شاهد شد. بیش‌ترین و کم‌ترین اثرات روی *C. carnea*، *C. septempunctata* و *Syrrita* Sp. به‌ترتیب در تیمارهای ایندوکساکارب و Bt مشاهده شد. نتایج این مطالعه بیانگر این بود که ترکیب آزادیراختین و Bt دارای بیش‌ترین اثر اختصاصی روی این آفت و کم‌ترین اثرات سوء روی شکارگران عمومی هم‌جای آن است.

**واژگان کلیدی:** مینوز برگی گوجه‌فرنگی، بی‌تی، آزادیراختین، ایندوکساکارب، سمیت





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