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Effects of some bioinsecticides on the tomato leaf miner, *Tuta absoluta* (Meyrick, 1917) (Lepidoptera: Gelechiidae)

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Abstract

Background: In this study, commercial bioinsecticides including entomopathogenic fungi, *Beauveria bassiana*, *Metarhizium anisopliae*, and *Verticillium lecanii*, and Spinetoram active ingredient insecticide were evaluated against the tomato leaf miner, *Tuta absoluta* (Meyrick, 1917) (Lepidoptera: Gelechiidae) larvae.

Main body: The active ingredients were prepared at the recommended concentrations under laboratory conditions and applied to the 2nd instar larvae of *T. absoluta* by spraying with a hand sprayer. On the 1st, 3rd, 5th, and 7th days of the application, evaluations were made by counting survived individuals. The findings showed that the highest mortality rates were detected in the case of Spinetoram with 56, 60, 88, and 100% on all counting days of the experiments, respectively. The highest mortality rate among bioinsecticides was recorded for *M. anisopliae*, with 87% mortality on the 7th day of application.

Short conclusion: As a result, Spinetoram was found the most effective insecticide when applied to *T. absoluta*, followed by *M. anisopliae*.

Keywords: Bioinsecticide, Entomopathogenic fungi, Spinetoram, *Tuta absoluta*, Efficiency

Background

Tomato (*Solanum lycopersicum* L.) is an annual vegetable that belongs to the Solanaceae family, native to South and Central America. It has gained an important place with its high nutritional values and the usage in food industry (Keskin and Gül 2004; Canpolat 2016; Gölükçü et al. 2016). Tomatoes are the most produced vegetables worldwide as well as in Turkey. Due to its economic importance, it is essential to protect its plants from diseases and pests. The red spider mites, thrips, whiteflies, aphids, and leaf gallery flies cause damages to vegetables in regions where climate conditions are suitable for pests (Tunç and Göçmen 1995; Ulubilir and Yabaş 1996; Bulut and Göçmen 2000; Güncan et al. 2006). Tomato leaf miner *Tuta absoluta* (Meyrick, 1917)

(Lepidoptera: Gelechiidae), which was first recorded in Turkey in 2009, has become a main pest in intensive tomato-producing areas (Kılıç 2010). *T. absoluta* larvae attack the leaves, stems, and fruits of the tomato plants. The irregular galleries formed by the larvae feeding result in necrosis on the leaf, and its color turns brown and causes completely drying of the plant. Due to its feeding on the fruits, disease factors occur and the market value of the fruit decreases (Mahmoud et al. 2014; Polat et al. 2016). The pest control, mainly applied by chemical control, enables the destruction of natural enemy populations, and the development of resistant races and residue problems arise (Braz 2000; Siqueira et al. 2000; Öztemiz 2012). For these reasons, it is important to search for alternative methods to chemical control with low risks in terms of environment and human health.

In this study, the commercial bioinsecticides including the entomopathogenic fungi, *Beauveria bassiana*, *Metarhizium*

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anisopliae, and *Verticillium lecanii*, and the insecticide Spinetoram were evaluated against the 2nd instar larvae of *T. absoluta* under laboratory conditions.

Main text

Materials and methods

Growing of tomato plants

In the study, the Mercury F1 tomato (*Solanum lycopersicum* L.) variety seedlings were planted in 1.5-l pots, containing a mixture of soil and peat. The production of tomato plants was carried out in climate rooms at 25 ± 1 °C, $60 \pm 5\%$ RH, and 16:8 h photoperiod.

Producing of tomato leaf miner

Tomato leaf miner adults were obtained collected from emission bottle over tomato plants in the greenhouse of Pamukkale University, School of Applied Sciences, Department of Organic Agriculture Business Management in Turkey, and brought to the climate room. These adult individuals were allowed to lay eggs on 15–20-cm height tomato seedlings. In order to increase the pest population and to ensure the continuity of insect stock culture, tomato plants in the climate rooms were renewed periodically. The 2nd instar larvae of *T. absoluta* were selected from this stock culture to be used in the experiments. The production of tomato leaf miner was carried out under the above climatic room conditions in which the tomato plants were grown.

Commercial bioinsecticides tested

The commercial bioinsecticides tested are given in Table 1. Spinetoram was used as a negative control to be compared to insecticides. The recommended concentrations were placed in sterile distilled water, mixed with the help of a mixer, and used in experiments.

Experimentation

Fresh tomato leaves were placed on moistened blotting papers in Petri dishes. Five individuals of 2nd instar *T. absoluta* larvae were placed on each leaf, with 5 replications, according to the randomized parcel design. The bioinsecticides, prepared at the recommended concentrations, were sprayed 3 times (average 1–2 mg solution/cm²) on the larvae using a hand sprayer. Distilled water was used in the control. To prevent larval escapes, Petri

dishes were wrapped up with parafilm after spraying. Live larvae were recorded on the 1st, 3rd, 5th, and 7th days of the experiment, using a binocular stereo microscope.

Data evaluation

Obtained data were analyzed by one-way analysis of variance (ANOVA), and IBM SPSS® Statistics (version 20.0, August 2011, SPSS Inc., Chicago, IL, USA) package program was used to evaluate the results. To calculate the differences among the group average, the Tukey (1949) multiple comparison test ($P < 0.05$) was used. However, the percentage of real mortality rates was determined by using the corrected Abbott formula (Abbott 1925). In addition, the estimated time to kill 50% of the insects (LT₅₀) was determined by the Probit analysis program (Finney 1971; Throne et al. 1995).

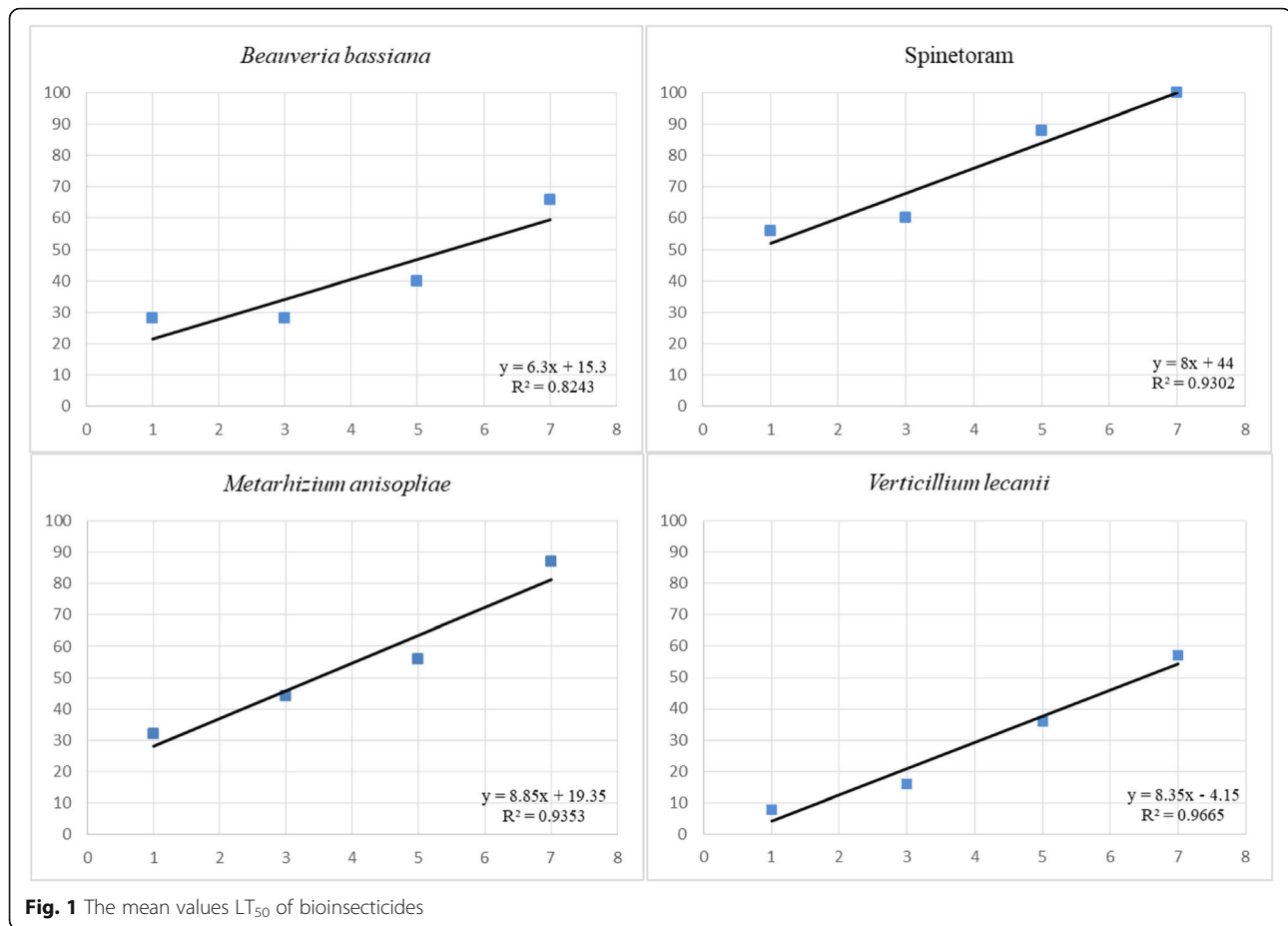
Results and discussion

The percentage of mortality rates resulting from the application of the bioinsecticides and the insecticide to the 2nd instar larvae of the tomato leaf miner are given in Fig. 1. The highest mortality rates were recorded in the case of the Spinetoram insecticide, which were statistically different than the other experiment bioinsecticides, as 56, 60, 88, and 100% on the 1st, 3rd, 5th, and 7th days, respectively, were recorded. On the 3rd day counts, Spinetoram (60%) was first, followed by *M. anisopliae* (44%), *B. bassiana* (28%), and then *V. lecanii* (16%). On the 5th day counts, the percentage mortality of *T. absoluta* by *M. anisopliae* was 56%, *B. bassiana* 40%, and *V. lecanii* 36%. On the 7th day counts, the highest mortality rate was recorded in the case of Spinetoram (100%), followed by *M. anisopliae* (87%) (Table 2).

After the application of *B. bassiana* and *M. anisopliae* isolates to first instar larvae of *T. absoluta*, mortality rates on the 7th day were found as 4.17 and 91.67%, respectively (Inanlı et al. 2012). The soil isolates of *B. bassiana* and *M. anisopliae* at a concentration of 10^{10} spore ml⁻¹ caused 100 and 93.3% mortality for the 4th instar larvae, while these rates were recorded 30 and 23.3% for *T. absoluta* pupae, respectively. When the same isolates were applied from leaves, the mortality rates were recorded by 90 and 80% in larvae, respectively (Youssef 2015). In another study, the application of *B. bassiana* isolate at a concentration of 2.5×10^7 spore

Table 1 Contents and recommended concentrations of the commercial bioinsecticides used in the experiment

Bioinsecticides	Active ingredient	Active ingredient ratio	Recommended concentrations
Nostalgist BL*	<i>Beauveria bassiana</i> strain Bb-1	1×10^8 cfu ml ⁻¹	250 ml 100 l ⁻¹
Met 52*	<i>Metarhizium anisopliae</i> var. <i>anisopliae</i> strain F52	9×10^{11} cfu kg ⁻¹	50 g 100 l ⁻¹
Nibortem*	<i>Verticillium lecanii</i> strain V1-1	1×10^8 cfu ml ⁻¹	250 ml 100 l ⁻¹
Radiant*120 SC	Spinetoram	120 g l ⁻¹	50 ml 100 l ⁻¹



ml^{-1} recorded as 95% mortality in larvae (El-Kichaoui et al. 2016). Abdel-Raheem et al. (2015) reported that the LC_{50} values of *B. bassiana*, *M. anisopliae*, and *V. lecanii* isolates treated at a concentration of 10^7 spore ml^{-1} on the 1st, 2nd, and 3rd larval instars of *T. absoluta* were 0.28×10^5 – 0.11×10^5 – 3.25×10^5 , 0.45×10^5 – 0.46×10^5 – 5.47×10^5 , and 0.32×10^5 – 0.27×10^5 – 3.28×10^5 conidia ml^{-1} . In Ayele et al. (2020), when AAUM78, AAUM39, and AAUM76 isolates of *M. anisopliae* were applied on the 2nd and 3rd larval instars of *T. absoluta*, mortality rates were 88, 90, and 95 and 90, 93.3, and 95.7%, respectively. However, it was reported that URPE-6 and URPE-19 isolates of *M. anisopliae* showed very high effects on eggs and larvae of *T. absoluta* (Pires et al. 2010).

The mortality rates of tomato leaf miner larvae, examined based on the time, LT_{50} values, recorded 0.75, 3.46, 5.51, and 6.48 days for Spinetoram, *M. anisopliae*, *B. bassiana*, and *V. lecanii*, respectively (Fig. 1).

As a result of treated *M. anisopliae* and *B. bassiana* isolates at 10^8 spore ml^{-1} concentration against *T. absoluta* larvae, LT_{50} values were determined as 3.9 and 5.2 days and 82.8 and 60.8% mortality rates (Ndereyimana et al. 2019). The application of the same isolates at a concentration of 2.5×10^9 conidia ml^{-1} recorded a mortality rate of 87.50% for *M. anisopliae* and 95.83% for *B. bassiana*. In addition, LT_{50} values were determined as 4.82 and 5.01 days, respectively (Tadele and Emanu 2017). The LC_{50} value of *M. anisopliae* isolate against *T. absoluta* larvae was reported as 0.34×10^9 conidia l^{-1}

Table 2 Mortality rates (%) resulting from the application of different bioinsecticides against the *Tuta absoluta* larvae

Formulations	1 DAA	3 DAA	5 DAA	7 DAA
<i>Beauveria bassiana</i>	28.00 ± 12.00ab	28.00 ± 10.20ab	40.00 ± 10.95b	66.00 ± 6.00bc
<i>Metarhizium anisopliae</i>	32.00 ± 8.00ab	44.00 ± 13.27ab	56.00 ± 7.48ab	87.00 ± 5.39ab
<i>Verticillium lecanii</i>	8.00 ± 4.90b	16.00 ± 7.48b	36.00 ± 7.48b	57.00 ± 10.91c
Spinetoram	56.00 ± 9.80a	60.00 ± 8.94a	88.00 ± 4.90a	100.00 ± 0.00a

The means followed by the same letters within columns are not significantly different from each other according to Tukey's HSD ($P < 0.05$)

and the LC_{90} value as 2×10^9 conidia l^{-1} (Contreras et al. 2014). Also, the LC_{50} values of *B. bassiana* and *M. anisopliae* isolates against *T. absoluta* larvae under laboratory conditions were 129.4×10^4 and 98.7×10^4 spore ml^{-1} , respectively (Sabbour 2014). In another study, A-Tz1 and A-Tz2 isolates of *Aspergillus oryzae* at 10^8 conidia ml^{-1} concentration, it was reported that *T. absoluta* mortality rate 70% for larvae and 84.5% for pupae and adult emergence was prevented by 74.4% in 3 days post-application period (Zekeya et al. 2019).

Conclusion

As a result of the study, Spinetoram insecticide had the highest mortality rate, followed by *M. anisopliae* bioinsecticide. Further studies under field conditions are needed.

Abbreviations

CFU: Colony forming units; DAA: Days after application; ANOVA: Analysis of variance

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Authors' contributions

ABE, OE, and IK collaborated in the creation of the manuscript. ABE carried out the experiments, recorded the data, interpreted the results, and wrote the manuscript. The authors read and approved the final manuscript during the present study.

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Ethics approval and consent to participate

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Competing interests

The authors declare that they have no competing interests.

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