# PROCEEDING BOOK

## 6TH WORLD CONFERENCE ON SUSTAINABLE LIFE SCIENCES

## WOCOLS 2025

## 10-16 NOVEMBER 2025

## MARDİN, TÜRKİYE

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WOCOLS SCIENCE FOR LIFE

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# Preface

Dear Colleagues,

We pleased and honored that "World Conference on Sustainable Life Science (WOCOLS 2025 MARDİN)" was been held in Mardin, Türkiye on 10-16 November 2025.

WOCOLS 2025 MARDİN promoted and disseminated the knowledge concerning several topics and technologies related to life sciences.

The main goal of WOCOLS 2025 MARDİN was to bring together researchers, scientists and experts in universities, companies, institutions, communities, agencies, associations and societies to provide them a unique platform for sharing worldwide ideas well as the recent developments on life sciences.

Thank you all for your great contributions to the conference.

Sincerely yours,

On Behalf of the Conference Organizing Committee

Asst. Prof. Dr. Aziz Şatana, Chair

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# ORAL PRESENTATIONS

## FULL-TEXT

# Toxicity of Bacterial Symbionts of Native Entomopathogenic Nematodes on the Larvae of Mediterranean Flour Moth, *Ephestia kuehniella* Zeller (Lepidoptera: Pyralidae)

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## ABSTRACT

Mediterranean Flour Moth, *Ephestia kuehniella* Zeller (Lepidoptera: Pyralidae) is a critical stored product pest with a high damage potential, especially in stored and processed wheat. With the emergence of the adverse effects of chemicals used in the control of *E. kuehniella* on human and environmental health, the search for more environmentally friendly and effective alternative control methods for this pest has accelerated. However, entomopathogenic nematodes (*Steinernema* and *Heterorhabditis* spp.) and thier bacterial symbionts (*Xenorhabdus* and *Photorhabdus* spp.) have become one of the most studied topics in the last 10 years in the search for sustainable control methods. In this study, the contact toxicity of bacterial symbionts (*Photorhabdus luminescens* subsp. *kayaii* AVB_15 and *Xenorhabdus bovienii* MCB_8) of *Steinernema feltiae* MCB-8 and *Heterorhabditis bacteriophora* AVB-15 isolates on the late-stage larvae of *E. kuehniella* was tested under laboratory conditions (25 °C, 60% RH). Cell-free supernatants of both bacterial strains caused significant mortality on *E. kuehniella* larvae compared to control groups ($P \leq 0.05$). The highest mortality (85%) was obtained by *X. bovienii* MCB_8 at the 3rd day after application. These results indicate that the tested bacterial symbionts have great potential in the biological control of *E. kuehniella*.

**Keywords:** Wheat, Stored product pests, Biological Control

**Acknowledgment:** This study was supported by Scientific Research Projects Coordination Unit of Erciyes University (FHD-2024-13902).

## INTRODUCTION

As a stable food, wheat is one of the most important cereals in the world. After being harvested, wheat is stored in silos for a certain period and then made available for consumption as needed. However, due to diseases and pests encountered during storage process, a significant portion of the stored wheat is lost every year. Stored product pests (SPPs) cause yield losses of 9% in developed countries and 20% in developing countries each year (Emekci and Ferizli, 2000; Phillips and Thron, 2010). In addition to direct damage, SPPs can cause secondary infections by creating a pathway for microbial agents especially in areas with inadequate storage conditions. Among these pests, *Ephestia kuehniella* Zeller (Lepidoptera: Pyralidae), also known as the Mediterranean flour moth, is one of the most damaging pests during wheat processing (Emekci and Ferizli, 2000). *Ephestia kuehniella* larvae feed directly on flour obtained from wheat, causing both quality and quantity losses in contaminated areas (Athanassiou, 2012). In addition, the webs produced by the larvae in contaminated factories cause machinery breakdowns and pipe blockages (Emekci and Ferizli, 2000). To combat this pest, some fumigants such as phosphine, carbonyl sulfide, ethyl formate, hydrogen cyanide, methyl iodide, propylene oxide, and sulfuryl fluoride are generally used in storage facilities (Athanassiou, 2012). However, the success of this application depends on the storage areas being well isolated. The success of this control is limited when the maintenance of storage areas and buildings are neglected. In addition, the active ingredients of the fumigants used trigger the development of resistance in agricultural pests, cause residues in wheat grains and processed products, and have many adverse effects on the living and non-living environment (Boopathy et al., 2022). Therefore, there is a need for more environmentally friendly practices with a high chance of success in the control of SPPs. In this century, there is a growing interest in sustainable and environmentally friendly pest control methods. Entomopathogenic nematodes (EPNs) have been one of the trend topics worldwide in recent years due to their success in combating agricultural pests (Koppenhöfer et al., 2020). EPNs are soil-dwelling microscopic organisms that require a host insect to survive in the soil. The third-stage larvae of EPNs, called infective juveniles (IJs), are found free in the soil and search for a suitable host (Singh et al., 2022). After finding a suitable host insect, IJs penetrate the insect's body through natural openings such as the mouth or anus. They initiate infection by releasing their bacterial associates, *Xenorhabdus* and *Photorhabdus* spp. bacteria, into the host's body (Tarasco et al., 2023). *Xenorhabdus* and *Photorhabdus* spp. bacteria begin to multiply rapidly, using the hemolymph of the host insect as a nutrient medium (Ozakman and Eleftherianos, 2020). During the infection process, they produce a series of enzymes, proteins, and toxins that suppress the insect's defense mechanisms and cause toxemia (ffrench-Constant and Bowen, 2000; Abd-Elgawad et al.,

2017; Ogier et al., 2023). As a result of infection, host insects die within 24-48 hours, and numerous IJs emerge from the insect cadaver and begin searching for new hosts (Singh et al., 2022). In recent years, these bacteria have attracted the attention of many researchers, and studies have begun to investigate their pathogenicity on insects by isolating them from nematodes without nematode vectors (da Silva et al., 2020; Cimen et al., 2022). Studies conducted to date have shown that cell-free supernatants of these bacteria, produced in artificial culture media in the laboratory, have contact and oral activity on insects belonging to different insect orders (Gerritsen et al., 2005; Brown et al., 2006; Hinchliffe et al., 2010; da Silva et al., 2013; Ulug et al., 2024). Although *Ephestia kuehniella* is one of the major storage pests worldwide, no study was evaluated the biocontrol potential of these bacteria on this pest. Therefore, this study was conducted to determine the effectiveness of Turkish bacterial strains on the *Ephestia kuehniella* larvae.

## MATERIAL AND METHODS

The isolation of endosymbiotic bacteria was carried out from entomopathogenic nematode isolates previously isolated from Nevşehir province. The bacterial symbionts associated with these nematodes were identified in previous years in project studies supported by TÜBİTAK (Project No: 120O041). Nematodes (*Steinernema feltiae* MÇB-8 and *Heterorhabditis bacteriophora* AVB-15) in the stock cultures at Erciyes University Entomology Laboratory were propagated using *Galleria mellonella* L. (Lepidoptera: Pyralidae) larvae (Yüksel and Canhilal, 2019; Yüksel et al., 2022). Third-stage infective juveniles (IJs) were surface-disinfected using 10% sodium hypochlorite and then washed several times with sterile Ringer's solution. Subsequently, the IJs were crushed using a pestle in 1 ml of Phosphate Buffered Saline Solution (PBS) to release the endosymbionts present in their intestines. Next, 10 µl portions of this solution were inoculated onto Nutrient Bromthymol Blue Tetrazolium Agar (NBTA) in Petri dishes (9 cm) and incubated at 28 °C for 2 days (Boemare and Akhurst, 1988).

At the end of the incubation period, the bacterial colonies (blue-green) in phase I were inoculated again onto NBTA to obtain pure cultures, and bacterial colonies taken from the pure cultures were transferred into 300 ml Erlenmeyer flasks containing 100 ml of Nutrient Broth using a pipette. Following this procedure, the cultures were incubated for 6 days in shaking incubators (150 rpm and 28 °C) in the dark. At the end of this period, the bacterial cultures were transferred to 50 ml centrifuge tubes and centrifuged at 20,000 rpm for 15 minutes at 4 °C to separate the bacterial cells from the supernatants. To completely separate the bacterial cells from the supernatant solutions, they were passed through syringes equipped with 0.22 µm Millipore filters. To check whether bacterial cells were present in the solution,

2 ml of supernatant solution was added to NBTA medium and incubated at 28 °C for 2 days (Hazir et al., 2016). The final solution were stored at +9 °C for 2 weeks for use in the experiments.

*E. kuehniella* larvae were obtained from the Plant Protection Department of the Faculty of Agriculture, Ankara University, and reared in a laboratory environment (25 °C, 60% RH) using flour. After obtaining the number of larvae required, the larvae were collected and placed in Petri dishes for use in the experiments. Ten fourth-instar larvae were placed in each Petri dish and 1 ml of cell-free supernatants (CFSs) was sprayed. The Petri dishes were then covered with parafilm and stored in a laboratory environment (25 °C, 60% RH) for 1 week. The survival of the larvae were monitored daily for three days and recorded. The experiments were set up with 4 replicates and 2 replications. NBTA medium without CFSs and pure water were used as control groups.

## DATA ANALYSIS

Data were analyzed using two-way (Repeated Measures) ANOVA with the IBM SPSS (20.0) program. Multiple comparisons were made using the Tukey Test ($P \leq 0.05$).

## RESULTS AND DISCUSSION

The ANOVA analysis showed that CFSs, Time, and their inretactions (CFS x Time) significantly afffected the larval survival (Table 1). On the first day after application, no mortality occurred in the control groups, while mortality exceeded 15% in larvae treated with *Xenorhabdus bovienii* MCB_8 and *Photorhabdus luminescens subsp. kayaii* AVB_15. Mortality rates increased with the exposure time to CFSs, reaching 58% at 2nd day and over 70% at 3rd day. The highest mortality rate (85%) was obtained from the *Xenorhabdus bovienii* MCB_8 strain at 3rd day after application (Table 2) (Figures 1 and 2).

Table 1. ANOVA statistical analysis results (Along with control groups)

| | Degree of Freedom (df) | F value | P value |
|---|---|---|---|
| CFS* | 3 | 896.796 | <0.001 |
| Time | 2 | 466.156 | <0.001 |
| CFS x Time | 6 | 145.615 | <0.001 |
| Error 1 | 28 | | |
| Error 2 | 56 | | |

Table 2. Mortality rates (% ± standard error) observed in *Ephestia kuehniella* larvae 1st, 2nd, and 3rd day after contact treatment of cell-free bacterial supernatants (Tukey; $P \leq 0.05$).

| Exposure times | Cell-free supernatants (CFSs) | Mean Mortality (%±Sdt. Error) |
|---|---|---|
| DAY 1 | *Xenorhabdus bovienii* MCB_8 | 18,75±2,26B |
| | *Photorhabdus luminescens* subsp. *kayaii* AVB_15 | 15,00±1,88B |
| | CONTROL_NTBT | 0,00±0,00A |
| | CONTROL_SAFSU | 0,00±0,00A |
| DAY 2 | *Xenorhabdus bovienii* MCB_8 | 75,00±2,67C |
| | *Photorhabdus luminescens* subsp. *kayaii* AVB_15 | 58,75±2,26B |
| | CONTROL_NTBT | 2,50±1,63A |
| | CONTROL_SAFSU | 0,00±0,00A |
| DAY 3 | *Xenorhabdus bovienii* MCB_8 | 85,00±1,88C |
| | *Photorhabdus luminescens* subsp. *kayaii* AVB_15 | 71,25±1,25B |
| | CONTROL_NTBT | 2,50±1,25A |
| | CONTROL_SAFSU | 2,50±1,25A |

Among the biological control agents used to combat agricultural pests, *Bacillus thuringiensis* (Bt) preparations have been the most widely used biopesticide and the most preferred by producers. Proteins from this bacterium cause oral toxicity in insects, leading to death within a short period of time. However, recent studies have shown that some agricultural pests can develop resistance to this bacterium, which has been used for a long time (Griffitts and Aroian, 2005; Moar et al., 2008; Tabashnik et al., 2008). Therefore, the development of new biopesticides that could be alternatives to Bt preparations is of great importance. In vitro-produced secondary metabolites from *Xenorhabdus* and *Photorhabdus* spp. bacteria have been studied to date against Western flower thrips *Frankliniella occidentalis* (Thysanoptera: Thripidae) and Tobacco thrips *Thrips tabaci* (Thysanoptera: Thripidae) (Gerritsen et al., 2005), grapevine moth *Lobesia botrana* (Lepidoptera: Tortricidae) (Vicente-Díez et al., 2023), aphids (Hemiptera: Aphididae) (Wu et al., 2022), wax moth *Galleria mellonella* (Lepidoptera: Pyralidae) (Santhoshkumar et al., 2021), Colorado potato beetle *Leptinotarsa decemlineata* (Coleoptera: Chrysomelidae) (Erdem et al., 2024). Although numerous local EPN species have been isolated in our country, to date, studies on bacterial isolation from these nematodes and their effectiveness against agricultural pests have been quite limited. Although the number of researchers working in this field in our country is quite low, previous studies have shown that symbiotic bacteria obtained from local EPN species are effective

against the two-spotted spider mite *Tetranychus urticae* (Acari: Tetranychidae) (Incedayi et al., 2021), mosquito species *Aedes aegypti*, *Aedes albopictus* (Diptera: Culicidae) (Ulug et al., 2024) and *Culex pipiens* (Diptera: Culicidae) (Yüksel et al., 2023), the seedling root weevil *Capnodis tenebrionis* L. (Coleoptera: Buprestidae) (Yiğit et al., 2015), citrus mealybug *Planococcus citri* (Hemiptera: Pseudococcidae) (Özdemir and Yüksel, 2024), *Tuta absoluta* (Meyrick) (Lepidoptera: Gelechiidae) (Yüksel, 2022), *Cydia pomonella* (L.) (Lepidoptera: Tortricidae) (Gümüşsoy et al., 2022), the cutworm *Agrotis ipsilon* (Lepidoptera: Noctuidae) (Ünal et al., 2022) and *Agrotis segetum* (Lepidoptera: Noctuidae) (Yüksel et al., 2022), and *Ephestia cautella* (Pyralidae: Lepidoptera) show great potential in biological control. To date, the only study testing the effectiveness of bacterial symbionts belonging to EPNs on *Ephestia kuehniella* was conducted by Jallouli et al. (2013), and in this study, only bacterial cells belonging to *Photorhabdus temperata* were used. However, the study by Jallouli et al. (2013) did not test the in vitro cultured secondary metabolites produced by *Xenorhabdus* and *Photorhabdus* spp. bacteria on E. *Kuehniella* larvae, and the activity of these secondary metabolites on the target pest was not evaluated.

## CONCLUSION

*Ephestia kuehniella* is one of the most important storage pests worldwide. Preventing the losses caused by this pest through sustainable control methods has the potential to minimize residue problems in stored and processed wheat products and eliminate environmental problems caused by pesticides. This study has yielded important findings regarding the sustainable control of this pest. The secondary metabolites of the bacterial strains used can have a high potential to control the flour moth pest when used in appropriate formulations.

## References

Abd-Elgawad, M. M., Abd-Elgawad, M. M. M., Askary, T. H., & Coupland, J. (2017). Toxic secretions of Photorhabdus and their efficacy against crop insect pests. Biocontrol Agents: Entomopathogenic and Slug Parasitic Nematodes; Abd-Elgawad, MMM, Askary, TH, Coupland, J., Eds, 231-260.

Athanassiou, C. G. (2012). Introduction to “Recent advances in stored product protection”. Journal of Pest Science, 85(3), 283-284.

Azar, Z. S., Kary, N. E., & Mohammadi, D. (2024). Characterization of Two Novel Isolates of Photorhabdus and Xenorhabdus: Molecular Identification, Growth Rate, Virulence, and Antibacterial Susceptibility.

Boemare, N. E., & Akhurst, R. J. (1988). Biochemical and physiological characterization of colony form variants in Xenorhabdus spp.(Enterobacteriaceae). Microbiology, 134(3), 751-761.

Boopathy, B., Rajan, A., & Radhakrishnan, M. (2022). Ozone: an alternative fumigant in controlling the stored product insects and pests: a status report. Ozone: Science & Engineering, 44(1), 79-95.

Brown, S. E., Cao, A. T., Dobson, P., Hines, E. R., Akhurst, R. J., & East, P. D. (2006). Txp40, a ubiquitous insecticidal toxin protein from Xenorhabdus and Photorhabdus bacteria. Applied and Environmental Microbiology, 72(2), 1653-1662.

Cimen, H., Touray, M., Gulsen, S. H., & Hazir, S. (2022). Natural products from Photorhabdus and Xenorhabdus: mechanisms and impacts. Applied Microbiology and Biotechnology, 106(12), 4387- 4399.

da Silva, O. S., Prado, G. R., da Silva, J. L. R., Silva, C. E., da Costa, M., & Heermann, R. (2013). Oral toxicity of Photorhabdus luminescens and Xenorhabdus nematophila (Enterobacteriaceae) against Aedes aegypti (Diptera: Culicidae). Parasitology research, 112, 2891-2896.

da Silva, W. J., Pilz-Júnior, H. L., Heermann, R., & da Silva, O. S. (2020). The great potential of entomopathogenic bacteria Xenorhabdus and Photorhabdus for mosquito control: a review. Parasites & vectors, 13, 1-14.

Emekci, M., Ferizli A. G. (2000). Current status of stored products protection in Turkey. Bulletin OILB/SROP, 23(10) 39-46.

Erdem, E., Yüksel, E., & Canhilal, R. (2024). Evaluation of cell-free supernatants from the symbiotic bacteria of entomopathogenic nematodes for controlling the colorado potato beetle [Leptinotarsa decemlineata (Say)(Coleoptera: Chrysomelidae)]. Journal of Plant Diseases and Protection, 1-12.

ffrench-Constant*, R. H., & Bowen, D. J. (2000). Novel insecticidal toxins from nematode-symbiotic bacteria. Cellular and Molecular Life Sciences CMLS, 57, 828-833.

Gerritsen, L. J., Georgieva, J., & Wiegers, G. L. (2005). Oral toxicity of Photorhabdus toxins against thrips species. Journal of invertebrate pathology, 88(3), 207-211.

Griffitts, J. S., & Aroian, R. V. (2005). Many roads to resistance: how invertebrates adapt to Bt toxins. Bioessays, 27(6), 614-624.

Gümüşsoy, A., Yüksel, E., Özer, G., İmren, M., Canhilal, R., Amer, M., & Dababat, A. A. (2022). Identification and biocontrol potential of entomopathogenic nematodes and their endosymbiotic bacteria in apple orchards against the codling moth, Cydia pomonella (L.)(Lepidoptera: Tortricidae). Insects, 13(12), 1085.

Hasan, M. A., Ahmed, S., Mollah, M. M. I., Lee, D., & Kim, Y. (2019). Variation in pathogenicity of different strains of Xenorhabdus nematophila; Differential immunosuppressive activities and secondary metabolite production. Journal of invertebrate pathology, 166, 107221.

Hazir, S., Shapiro-Ilan, D. I., Bock, C. H., Hazir, C., Leite, L. G., & Hotchkiss, M. W. (2016). Relative potency of culture supernatants of Xenorhabdus and Photorhabdus spp. on growth of some fungal phytopathogens. European Journal of Plant Pathology, 146, 369-381.

Hinchliffe, S. J., Hares, M. C., & Dowling, A. J. (2010). Insecticidal toxins from the Photorhabdus and Xenorhabdus bacteria. The Open Toxinology Journal, 3(1).

Incedayi, G., Cimen, H., Ulug, D., Touray, M., Bode, E., Bode, H. B., & Cakmak, I. (2021). Relative potency of a novel acaricidal compound from Xenorhabdus, a bacterial genus

mutualistically associated with entomopathogenic nematodes. Scientific Reports, 11(1), 11253.

Jacob, T. A., & Cox, P. D. (1977). The influence of temperature and humidity on the life-cycle of Ephestia kuehniella Zeller (Lepidoptera: Pyralidae). Journal of Stored Products Research, 13(3), 107-118.

Jallouli, W., Abdelkefi-Mesrati, L., Tounsi, S., Jaoua, S., & Zouari, N. (2013). Potential of Photorhabdus temperata K122 bioinsecticide in protecting wheat flour against Ephestia kuehniella. Journal of stored products research, 53, 61-66.

Koppenhöfer, A. M., Shapiro-Ilan, D. I., & Hiltpold, I. (2020). Entomopathogenic nematodes in sustainable food production. Frontiers in Sustainable Food Systems, 4, 125.

Kushwah, J., & Somvanshi, V. S. (2015). Photorhabdus: a microbial factory of insect-killing toxins. In Microbial Factories: Biodiversity, Biopolymers, Bioactive Molecules: Volume 2 (pp. 235-240). New Delhi: Springer India.

Moar, W., Roush, R., Shelton, A., Ferré, J., MacIntosh, S., Leonard, B. R., & Abel, C. (2008). Fieldevolved resistance to Bt toxins. Nature biotechnology, 26(10), 1072-1074.,

Ogier, J. C., Akhurst, R., Boemare, N., & Gaudriault, S. (2023). The endosymbiont and the second bacterial circle of entomopathogenic nematodes. Trends in Microbiology, 31(6), 629-643.

Ozakman, Y., & Eleftherianos, I. (2020). Immune interactions between Drosophila and the pathogen Xenorhabdus. Microbiological Research, 240, 126568.

Phillips, T. W., & Throne, J. E. (2010). Biorational approaches to managing stored-product insects. Annual review of entomology, 55, 375-397.

Půža, V., Nermuť, J., Konopická, J., & Habuštová, O. S. (2024). The effect of Xenorhabdus bacteria metabolites on Colorado potato beetle (Leptinotarsa decemlineata) adult feeding and larval survival. Journal of Invertebrate Pathology, 108075.

Santhoshkumar, K., Mathur, C., Mandal, A., & Dutta, T. K. (2021). A toxin complex protein from Photorhabdus akhurstii conferred oral insecticidal activity against Galleria mellonella by targeting the midgut epithelium. Microbiological Research, 242, 126642.

Sheets, J., & Aktories, K. (2017). Insecticidal toxin complexes from Photorhabdus luminescens. The molecular biology of Photorhabdus bacteria, 3-23.

Singh, A. K., Kumar, M., Ahuja, A., Vinay, B. K., Kommu, K. K., Thakur, S., & Parihar, M. (2022). Entomopathogenic nematodes: A sustainable option for insect pest management. In Biopesticides (pp. 73-92). Woodhead Publishing.

Tabashnik, B. E., Gassmann, A. J., Crowder, D. W., & Carrière, Y. (2008). Insect resistance to Bt crops: evidence versus theory. Nature biotechnology, 26(2), 199-202.

Tarasco, E., Fanelli, E., Salvemini, C., El-Khoury, Y., Troccoli, A., Vovlas, A., & De Luca, F. (2023). Entomopathogenic nematodes and their symbiotic bacteria: from genes to field uses. Frontiers in Insect Science, 3, 1195254.

Ulug, D., Touray, M., Gulsen, S. H., Cimen, H., Hazir, C., Bode, H. B., & Hazir, S. (2024). A taste of a toxin paradise: Xenorhabdus and Photorhabdus bacterial secondary metabolites against Aedes aegypti larvae and eggs. Journal of Invertebrate Pathology, 108126.

Ünal, M., Yüksel, E., & Canhilal, R. (2022). Biocontrol potential of cell suspensions and cell-free superntants of different Xenorhabdus and Photorhabdus bacteria against the different

larval instars of Agrotis ipsilon (Hufnagel)(Lepidoptera: Noctuidae). Experimental Parasitology, 242,

Vicente-Díez, I., Pou, A., & Campos-Herrera, R. (2023). The deterrent ability of Xenorhabdus nematophila and Photorhabdus laumondii compounds as a potential novel tool for Lobesia botrana (Lepidoptera: Tortricidae) management. Journal of invertebrate pathology, 198, 107911.

Wu, S., Toews, M. D., Cottrell, T. E., Schmidt, J. M., & Shapiro-Ilan, D. I. (2022). Toxicity of Photorhabdus luminescens and Xenorhabdus bovienii bacterial metabolites to pecan aphids (Hemiptera: Aphididae) and the lady beetle Harmonia axyridis (Coleoptera: Coccinellidae). Journal of Invertebrate Pathology, 194, 107806.

Yiğit, T., Er, M. K., Hazır, S., Özcan, S., Çevik, T., & Öylek, H. Ş. (2015, June). Evaluation of entomopathogenic fungi and nematodes against Capnodis tenebrionis L.(Coleoptera: Buprestidae) larvae in apricot orchards. In XVI International Symposium on Apricot Breeding and Culture 1214 (pp. 243-248).

Yuksel, E., & Canhilal, R. (2019). Isolation, identification, and pathogenicity of entomopathogenic nematodes occurring in Cappadocia Region, Central Turkey. Egyptian Journal of Biological Pest Control, 29, 1-7.

Yüksel, E., Imren, M., Özdemir, E., Bozbuğa, R., & Canhilal, R. (2022). Insecticidal effect of entomopathogenic nematodes and the cell-free supernatants from their symbiotic bacteria against different larval instars of Agrotis segetum (Denis & Schiffermüller)(Lepidoptera: Noctuidae). Egyptian Journal of Biological Pest Control, 32(1), 54.

Yüksel, E. (2022). Biocontrol potential of endosymbiotic bacteria of entomopathogenic nematodes against the tomato leaf miner, Tuta absoluta (Meyrick)(Lepidoptera: Gelechiidae). Egyptian Journal of Biological Pest Control, 32(1), 135.

Yüksel, E., Özdemir, E., Delialioğlu, R. A., & Canhilal, R. (2022). Insecticidal activities of the local entomopathogenic nematodes and cell-free supernatants from their

symbiotic bacteria against the larvae of fall webworm, Hyphantria cunea. Experimental Parasitology, 242, 108380.

Yüksel, E., Yıldırım, A., İmren, M., Canhilal, R., & Dababat, A. A. (2023). Xenorhabdus and photorhabdus bacteria as potential candidates for the control of Culex pipiens L.(Diptera: Culicidae), the principal vector of west nile virus and lymphatic filariasis. Pathogens, 12(9), 1095.

Yüksel, E., Ormanoğlu, N., Imren, M., & Canhilal, R. (2023). Assessment of biocontrol potential of different Steinernema species and their bacterial symbionts, Xenorhabdus species against larvae of almond moth, Ephestia cautella (Walker). Journal of Stored Products Research, 101, 102082.

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