STRATEGIES FOR HOST-SEEKING IN ENTOMOPATHOGENIC NEMATODES: MATCHING SPECIES WITH TARGET INSECT PESTS FOR EFFICIENT BIOCONTROL

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ABSTRACT

Entomopathogenic nematodes (EPNs) are endoparasitic organisms capable of actively seeking and infecting a wide range of insect hosts. Furthermore, these organisms stand out as promising future agents in the field of biological control. In this review, three commonly used EPN species, *Steinernema carpocapsae*, *S. feltiae*, and *Heterorhabditis bacteriophora* were comparatively evaluated based on their host-seeking behaviors. Based on current laboratory and field findings, the effects of different foraging strategies (ambushing, intermediate or cruiser) of each species on their effectiveness against specific insect pest groups were reviewed. As an ambush species, *S. carpocapsae* was found to be more effective against insect pests living near the soil surface or in leaf areas. *S. feltiae*, an intermediate forager, offers flexibility in use against pests of different stages and in a wide range of habitats, particularly in temperate conditions. *H. bacteriophora*, a cruiser (active mobile) species, demonstrated superior activity in deeper layers, particularly against insects that are mobile underground. These results suggest that the selection of EPN species should be compatible with the insect pest's behavior and ecological niche to maximize success in biological control.

Keywords: *Heterorhabditis bacteriophora, Host seeking, Steinernema carpocapsae, Steinernema feltiae*

INTRODUCTION

Entomopathogenic nematodes (EPNs) are extensively employed in both conventional and organic agriculture as a viable method for pest control in crops (Smart Jr, 1995; Shapiro-Ilan et al., 2006; Kurtz et al., 2007; Batalla-Carrera et al., 2010; Labaude & Griffin, 2018; Vashisth et al., 2013; Dede et al., 2022). These organisms are known as obligate endoparasites and require insect host tissue to complete their life cycle. The life cycle of EPNs consists of the following stages: egg, first-stage juvenile, second-stage juvenile, third-stage juvenile known as the infective juvenile (IJ), fourth-stage juvenile, and adult (Gaugler et al., 1997; Stuart et al., 2006; Kurtz et al., 2007; Bütüner & Susurluk, 2023a; Bütüner et al., 2024). These obligate endoparasitic organisms can infect their hosts only during the infective juvenile stage of their development (Jansson et al., 1990; Susurluk et al., 2001; Lewis et al., 2006; Kurtz et al., 2007; Susurluk & Ehlers, 2008).

Upon encountering a host, entomopathogenic nematodes enter the host’s body through natural openings such as the mouth or anus, releasing their symbiotic gram-negative bacteria into the host's internal environment (Smart Jr, 1995; Ehlers, 2001; Lewis et al., 2006; Susurluk & Ehlers, 2008). Species belonging to the family Heterorhabditidae introduce these bacteria through regurgitation, whereas species from the Steinernematidae family do so via defecation. The gram-negative bacteria, members of the family Enterobacteriaceae, differ according to the

nematode family: Heterorhabditidae species are symbiotically associated with *Photorhabdus* spp., while Steinernematid species are associated with *Xenorhabdus* spp. Once inside the host, the bacteria multiply rapidly, causing septicemia and ultimately leading to the host's death within 24 to 72 hours (Peters & Ehlers, 1994; Ehlers, 2001; Ciche et al., 2006; Shapiro-Ilan et al., 2006; Lewis et al., 2006; Susurluk & Ehlers, 2008; Susurluk & Bütüner, 2024). Inside the cadaver, the nematodes can complete 3 to 4 generations, and upon depletion of nutrients within the host tissues, infective juveniles (IJs) emerge to seek new hosts (Ciche et al., 2006; Shapiro-Ilan et al., 2006; Susurluk & Bütüner, 2024). It is known that IJs can survive in the soil without feeding and can seek hosts for up to two years (Susurluk & Ehlers, 2008).

The selection of an EPN species for pest management in agricultural fields is of critical importance, as host-seeking behaviour tends to vary considerably between species (Campbell et al., 2003; Lewis et al., 2006; Griffin, 2012). For instance, species like *Heterorhabditis bacteriophora* (Rhabditida: Heterorhabditidae) are generally classified as cruisers (Cohen et al., 2002; Susurluk & Ehlers, 2008; Santhi et al., 2015). *Steinernema feltiae* (Rhabditida: Steinernematidae) is classified as exhibiting an intermediate foraging strategy (Wilson et al., 2012; Santhi et al., 2015), whilst species like *S. carpocapsae* are generally recognized as ambushers (Grewal et al., 1995; Santhi et al., 2015). Therefore, in determining which EPN species to deploy against a particular pest, it is essential to consider whether the insect pest spends any part of its life cycle in the soil, as well as which part of the cultivated plant is affected by its feeding activity (Grewal et al., 1994; Lewis et al., 1995; Campbell et al., 2003). In this review, recent findings on the efficacy of various EPN species against different pests have been reviewed in relation to their host-seeking behaviours.

SELECTING A HOST FOR *Steinernema carpocapsae*

Species of *S. carpocapsae* are generally characterised by limited movement within the soil, typically remaining near the site of application. They are highly effective in the potential control of pests that cause damage on or near the soil surface, particularly around the roots and root collar. In recent years, their use in foliar applications has increased significantly (Lewis et al., 1992; Grewal et al., 1994; Wilson et al., 2012; Baiocchi et al., 2019). Due to their low mobility in soil, they may exhibit greater tolerance to environmental factors compared to other EPN species. However, a notable disadvantage is their limited efficacy in deep soil applications, where their restricted movement reduces their effectiveness against subterranean pests (Lewis et al., 1996; Gang & Hallem, 2016; Baiocchi et al., 2019). Consequently, they may not perform adequately in deep, highly moist soils. In a field study conducted by Nouh & Adly (2021), the efficacy of *H. bacteriophora* and *S. carpocapsae* isolates was evaluated against adults of *Gryllotalpa gryllotalpa* (Orthoptera: Gryllotalpidae). The results showed that at identical application rates, *S. carpocapsae* caused 96% mortality on adult *G. gryllotalpa*, whereas *H. bacteriophora* resulted in 72% mortality. Based on these findings, it can be concluded that *S. carpocapsae*, despite its relatively limited mobility compared to *H. bacteriophora*, may be more successful in controlling *G. gryllotalpa*, particularly given the pest's damaging activity around the root and root collar regions. Similarly, in a study conducted by Morton & Garcia-del-Pino (2017), which simulated field conditions, the efficacy of various commercial and local EPN isolates was assessed against *Agriotes obscurus* (L.) (Coleoptera: Elateridae). The results indicated that *S. carpocapsae* isolates exhibited significantly higher efficacy compared to isolates of other species. In addition, the use of *S. carpocapsae* isolates is commonly preferred for the potential control of certain pests, particularly those belonging to the order Lepidoptera that spend their pupal stage within plant debris or on the upper layers of the soil, where they cause damage. In a study conducted by Gholami Ghavamabad et al. (2024), the efficacy of various isolates was evaluated against *Cydalima perspectalis* (Lepidoptera: Crambidae) and

Hyphantria cunea (Lepidoptera: Arctiidae) under both field and laboratory conditions. The results revealed that *S. carpocapsae* was particularly effective against the larvae of these pests when applied as a foliar treatment.

SELECTING A HOST FOR *Steinernema feltiae*

Species of *S. feltiae* are generally characterized by moderate mobility within the soil and a flexible host-seeking strategy that combines both ambush and cruising behaviors (Grewal et al., 1997; Susurluk, 2008). This intermediate foraging strategy allows *S. feltiae* to effectively target a wide range of insect hosts, particularly those dwelling in the upper soil layers or leaf litter, as well as in cryptic habitats such as crevices and under bark. Because of its sensitivity to chemical signals and capacity to seek out immobile or less active hosts, *S. feltiae* is particularly effective against soft-bodied insect larvae and pupae (Gaugler et al., 1989; Rahoo et al., 2017; Askary et al., 2018). *S. feltiae* is commonly utilized in temperate areas and greenhouse environments due to its tolerance for low temperatures and adaptability to various conditions (Chen & Glazer, 2005; Navaneethan et al., 2010; Rahoo et al., 2016). Nonetheless, its effectiveness sometimes declines in arid soils or at high temperatures, potentially limiting its use in specific field conditions. *S. feltiae* possesses a significant advantage due to its demonstrated efficacy in enclosed environments with increased humidity, making it appropriate for integrated pest management (IPM) initiatives in controlled agriculture (Hirao & Ehlers, 2009; Navaneethan et al., 2010; Rahoo et al., 2016).

In a study conducted by Gouge & Hague (1995), the efficacy of several EPN isolates was evaluated against larvae of *Bradysia paupera* (Diptera: Sciaridae). The experiments were carried out at two different temperatures (22 and 30°C). At both temperatures, isolates of *S. feltiae* were found to be more effective than those of other species, achieving 100% larval mortality at 22°C. Similarly, Morton & García del Pino (2007) assessed the efficacy of several commercial EPN species against larvae of *Scatella stagnalis* (Diptera: Ephydridae). The results indicated that commercial products based on *S. feltiae* produced higher larval mortality rates compared to other species. Similarly, in a study conducted by Susurluk (2011), *Steinernema feltiae* isolates achieved an 80% mortality rate in the potential control of last-instar larvae of *Delia radicum* (Diptera: Anthomyiidae). In a separate study, Kasi et al. (2021) evaluated the potential efficacy of different EPN species against second-instar larvae of *Pieris brassicae* (L.) (Lepidoptera: Pieridae). The highest larval mortality rate, 72%, was observed in treatments involving *S. feltiae* isolates. Furthermore, in a recent study by Polat et al. (2024), the potential of EPNs to control both larvae and adults of *Alphitobius diaperinus* (Coleoptera: Tenebrionidae) was investigated in poultry house environments. The data demonstrated highly effective results for the potential control of *A. diaperinus*, indicating the strong biocontrol potential of the applied EPN species.

SELECTING A HOST FOR *Heterorhabditis bacteriophora*

Heterorhabditis bacteriophora exhibits an active cruising host-seeking strategy, facilitating significant movement throughout the soil matrix in pursuit of appropriate hosts. The IJs of this species can detect and pursue carbon dioxide gradients and other volatiles released by active soil-dwelling insect larvae (Ehlers, 1996; Susurluk & Ehlers, 2008a; Ulu & Susurluk, 2014; Dede et al., 2022). This behaviour makes *H. bacteriophora* particularly effective against mobile insect pests that live in deeper levels of soil and exhibit continuous movement in search of food sources (Susurluk, 2008).

Due to its ability in deep-soil foraging, *H. bacteriophora* is regarded as highly efficient for managing subterranean pests, including larvae of *Diabrotica* spp. (Coleoptera:

Chrysomelidae), *Phyllophaga* spp. (Coleoptera: Scarabaeidae), and *Popillia japonica* (Coleoptera: Scarabaeidae) (Wang et al., 1994; Paoli et al., 2017; Garriga et al., 2024). This species thrives in moist, warm soil conditions, exhibiting optimal activity at temperatures ranging from 20 to 30°C. Nonetheless, its effectiveness may diminish in arid or colder soils, where mobility and host-seeking efficiency are hindered (Susurluk & Ehlers, 2008b; Bütüner & Susurluk, 2023b). In a study conducted by Dede et al. (2022), the *H. bacteriophora* HBH hybrid strain was utilised for the potential control of *Loxostege sticticalis* (Lepidoptera: Pyralidae), which caused an epidemic in Türkiye in 2022. The results revealed that at 30 °C, the application of low doses resulted in up to 97% mortality in last-instar larvae. Similarly, Del Valle et al. (2017) evaluated an isolate of *Steinernema rarum* (Rhabditida: Steinernema) and an isolate of *H. bacteriophora* for their potential to control larvae of *Diloboderus abderus* (Coleoptera: Scarabaeidae). The findings indicated that the *H. bacteriophora* isolate was more effective in the control of *D. abderus* larvae. Likewise, in a study by Goudarzi et al. (2015), the potential efficacy of *S. carpocapsae* and *H. bacteriophora* isolates was assessed against larvae of *Agrotis segetum* (Lepidoptera: Noctuidae). According to the results, *H. bacteriophora* isolates achieved a mortality rate of 98% on *A. segetum* larvae.

CONCLUSIONS

An examination of the potential control of agricultural insect pests using *S. carpocapsae*, *S. feltiae* and *H. bacteriophora* reveals that understanding the host-seeking behaviour of EPNs, along with the life cycle and ecology of the target pest, is essential. When an appropriate EPN species is matched with a suitable target organism, these endoparasitic agents can produce highly effective control outcomes. *S. carpocapsae*, through its ambusher strategy, has proven to be effective against pests that reside close to the soil surface. In contrast, *S. feltiae* demonstrates a more balanced and versatile efficacy across various pest stages and habitats, owing to its intermediate foraging behaviour. *H. bacteriophora*, on the other hand, provides a distinct advantage in the control of mobile pests dwelling in deeper soil layers due to its high mobility and active cruising behaviour. Therefore, the success of EPN-based biological control strategies relies not only on the selection of a virulent isolate but also on the compatibility between the ecological characteristics of the target pest and the behavioural ecology of the nematode. Future applications should prioritise the alignment of EPN behavioural traits with the biology of the pest species, as this approach will be fundamental in enhancing both the efficacy and reliability of biological control efforts.

REFERENCES

Askary, T. H., Jamal Ahmad, M., Wani, A. R., Mohiddin, S., & Sofi, M. A. (2018). Behavioural ecology of entomopathogenic nematodes, *Steinernema* and *Heterorhabditis* for insect biocontrol. Sustainable Agriculture Reviews 31: Biocontrol, 425-441.

Baiocchi, T., Braun, L., & Dillman, A. R. (2019). Touch-stimulation increases host-seeking behavior in *Steinernema carpocapsae*. Journal of Nematology, 51, e2019-67.

Batalla-Carrera, L., Morton, A., & García-del-Pino, F. (2010). Efficacy of entomopathogenic nematodes against the tomato leafminer *Tuta absoluta* in laboratory and greenhouse conditions. BioControl, 55, 523-530.

Bütüner, A. K., & Susurluk, A. (2023a). Türk Entomopatojen Nematodların, *Steinernema feltiae* ve *Steinernema carpocapsae* (Rhabditida: Steinernematidae) Pirinç Biti *Sitophilus oryzae* (Coleoptera: Curculionidae) Üzerinde Patojenisitesi. Türk Tarım ve Doğa Bilimleri Dergisi, 10(3), 541-547.

Bütüner, A. K., & Susurluk, A. (2023b). Efficiency of temperature and storage duration on some morphological measurements and reproductive capacity of the entomopathogenic nematode *Heterorhabditis bacteriophora* Poinar, 1976 (Rhabditida: Heterorhabditidae)'s Turkish HBH hybrid strain. Turkish Journal of Entomology, 47(4), 469-476.

Bütüner, A. K., Ergene, E., İlktan, M., Sepin, S., Susurluk, H., & Susurluk, İ. A. (2024). Impact of some entomopathogenic nematode isolates on the mortality and penetration rate of *Rhyzopertha dominica* and *Tenebrio molitor*. Crop Protection, 179, 106629.

Campbell, J. F., Lewis, E. E., Stock, S. P., Nadler, S., & Kaya, H. (2003). Evolution of host search strategies in entomopathogenic nematodes. Journal of Nematology, 35(2), 142.

Chen, S., & Glazer, I. (2005). A novel method for long-term storage of the entomopathogenic nematode *Steinernema feltiae* at room temperature. Biological Control, 32(1), 104-110.

Ciche, T. A., Darby, C., Ehlers, R. U., Forst, S., & Goodrich-Blair, H. (2006). Dangerous liaisons: the symbiosis of entomopathogenic nematodes and bacteria. Biological Control, 38(1), 22-46.

Dede, E., Bütüner, A. K., & Susurluk, A. (2022). Biocontrol potential of *Heterorhabditis bacteriophora* Poinar, 1976 (Rhabditida: Heterorhabditidae) HBH hybrid strain against the beet webworm, *Loxostege sticticalis* L., 1761 (Lepidoptera: Pyralidae). Turkish Journal of Entomology, *46*(4), 399-405.

Del Valle, E. E., Frizzo, L. S., Lax, P., Bonora, J. S., Palma, L., Desch, N. P. B., ... & Doucet, M. E. (2017). Biological control of *Diloboderus abderus* (Coleoptera: Scarabaeidae) larvae using *Steinernema rarum* CUL (Nematoda: Steinernematidae) and *Heterorhabditis bacteriophora* SMC (Nematoda: Heterorhabditidae). Crop Protection, 98, 184-190.

Ehlers, R. U. (2001). Mass production of entomopathogenic nematodes for plant protection. Applied microbiology and biotechnology, *56*, 623-633.

Gang, S. S., & Hallem, E. A. (2016). Mechanisms of host seeking by parasitic nematodes. Molecular and biochemical parasitology, *208*(1), 23-32.

Garriga, A., Monteiro, H. R., Beltrí, R., Frias, J., Peñalver, Á., Teixeira, M., ... & Simões, N. (2024). Assessment of Azorean native strains of *Heterorhabditis bacteriophora* for the biological control of *Popillia japonica*. Journal of Applied Entomology, 148(8), 977-982.

Gaugler, R., Campbell, J. F., & McGuire, T. R. (1989). Selection for host-finding in Steinernema feltiae. *Journal of Invertebrate Pathology*, *54*(3), 363-372.

Gaugler, R., Lewis, E., & Stuart, R. J. (1997). Ecology in the service of biological control: the case of entomopathogenic nematodes. *Oecologia*, *109*, 483-489.

Gholami Ghavamabad, R., Talebi, A. A., Pedram, M., Farashiani, M. E., & Mehrabadi, M. (2024). Efficacy of entomopathogenic nematodes against *Cydalima perspectalis* and *Hyphantria cunea* (Lepidoptera), two invasive forest pests in Iran. International Journal of Pest Management, 1-15.

Goudarzi, M., Moosavi, M. R., & Asadi, R. (2015). Effects of entomopathogenic nematodes, *Heterorhabditis bacteriophora* (Poinar) and *Steinernema carpocapsae* (Weiser), in biological control of *Agrotis segetum* (Denis & Schiffermüller)(Lepidoptera: Noctuidae). Turkish Journal of Entomology, 39(3), 239-250.

Gouge, D. H., & Hague, N. G. M. (1995). The susceptibility of different species of sciarid flies to entomopathogenic nematodes. Journal of Helminthology, 69(4), 313-318.

Grewal, P. S., Gaugler, R., & Georgis, R. (1995). Predictors of foraging strategy in entomopathogenic nematodes. *Ecology and transmission strategies of entomopathogenic nematodes. Luxembourg, European Commission*, 95-104.

Grewal, P. S., Lewis, E. E., & Gaugler, R. (1997). Response of infective stage parasites (Nematoda: Steinernematidae) to volatile cues from infected hosts. Journal of Chemical Ecology, 23, 503-515.

Grewal, P. S., Lewis, E. E., Gaugler, R., & Campbell, J. F. (1994). Host finding behaviour as a predictor of foraging strategy in entomopathogenic nematodes. Parasitology, 108(2), 207-215.

Griffin, C. T. (2012). Perspectives on the behavior of entomopathogenic nematodes from dispersal to reproduction: traits contributing to nematode fitness and biocontrol efficacy. Journal of Nematology, 44(2), 177.

Hirao, A., & Ehlers, R. U. (2009). Effect of temperature on the development of *Steinernema carpocapsae* and *Steinernema feltiae* (Nematoda: Rhabditida) in liquid culture. Applied Microbiology and Biotechnology, 84, 1061-1067.

Jansson, R. K., Lecrone, S. H., Gaugler, R. R., & Smart Jr, G. C. (1990). Potential of entomopathogenic nematodes as biological control agents of sweetpotato weevil (Coleoptera: Curculionidae). Journal of Economic Entomology, 83(5), 1818-1826.

Kasi, I. K., Singh, M., Waiba, K. M., Monika, S., Waseem, M. A., Archie, D., & Gilhotra, H. (2021). Bio-efficacy of entomopathogenic nematodes, *Steinernema feltiae* and *Heterorhabditis bacteriophora* against the Cabbage butterfly (*Pieris brassicae* [L.]) under laboratory conditions. Egyptian Journal of Biological Pest Control, 31, 1-7.

Kurtz, B., Toepfer, S., Ehlers, R. U., & Kuhlmann, U. (2007). Assessment of establishment and persistence of entomopathogenic nematodes for biological control of western corn rootworm. Journal of Applied Entomology, 131(6), 420-425.

Labaude, S., & Griffin, C. T. (2018). Transmission success of entomopathogenic nematodes used in pest control. Insects, 9(2), 72.

Lewis, E. E., Gaugler, R., & Harrison, R. (1992). Entomopathogenic nematode host finding: response to host contact cues by cruise and ambush foragers. Parasitology, 105(2), 309-315.

Lewis, E. E., Selvan, S., Campbell, J. F., & Gaugler, R. (1995). Changes in foraging behaviour during the infective stage of entomopathogenic nematodes. Parasitology, 110(5), 583-590.

Lewis, E. E., Ricci, M., & Gaugler, R. (1996). Host recognition behaviour predicts host suitability in the entomopathogenic nematode *Steinernema carpocapsae* (Rhabditida: Steinernematidae). Parasitology, 113(6), 573-579.

Lewis, E. E., Campbell, J., Griffin, C., Kaya, H., & Peters, A. (2006). Behavioral ecology of entomopathogenic nematodes. Biological control, 38(1), 66-79.

Morton, A., & García del Pino, F. (2007). Susceptibility of shore fly *Scatella stagnalis* to five entomopathogenic nematode strains in bioassays. Biocontrol, 52(4), 533-545.

Morton, A., & Garcia-del-Pino, F. (2017). Laboratory and field evaluation of entomopathogenic nematodes for control of *Agriotes obscurus* (L.)(Coleoptera: Elateridae). Journal of Applied Entomology, 141(4), 241-246.

Navaneethan, T., Strauch, O., Besse, S., Bonhomme, A., & Ehlers, R. U. (2010). Influence of humidity and a surfactant-polymer-formulation on the control potential of the entomopathogenic nematode *Steinernema feltiae* against diapausing codling moth larvae (*Cydia pomonella* L.)(Lepidoptera: Tortricidae). BioControl, 55, 777-788.

Nouh, G. M., & Adly, D. (2021). Evaluation of the virulence of entomopathogenic nematodes as a biological control agents against *Gryllotalpa gryllotalpa* (Gryllotalpidae). Journal of Applied Entomology, 145(10), 1050-1056.

Paoli, F., Marianelli, L., Torrini, G., Mazza, G., Benvenuti, C., Bosio, G., ... & Roversi, P. F. (2017). Differential susceptibility of *Popillia japonica* 3rd instars to *Heterorhabditis bacteriophora* (Italian strain) at three different seasons. Biocontrol Science and Technology, 27(3), 439-444.

Peters, A., & Ehlers, R. U. (1994). Susceptibility of leatherjackets (*Tipula paludosa* and *Tipula oleracea*; Tipulidae; Nematocera) to the entomopathogenic nematode *Steinernema feltiae*. Journal of Invertebrate Pathology, 63(2), 163-171.

Polat, B., Cengiz, A., Koc, S., Kahraman Kokten, S., Gultekin, Z. N., Caliskan, C., ... & Cetin, H. (2024). Efficacy of *Steinernema feltiae* nematode against lesser mealworm (*Alphitobius diaperinus*) populations from poultry farms in Türkiye. Veterinary Sciences, 11(11), 567.

Rahoo, A. M., Mukhtar, T., Abro, S. I., Gowen, S. R., & Bughio, B. A. (2016). Effect of temperature on emergence of *Steinernema feltiae* from infected *Galleria mellonella* cadavers under moist and dry conditions. Pakistan journal of nematology, 34, 171-176.

Ehlers, R. U. (1996). Current and future use of nematodes in biocontrol: practice and commercial aspects with regard to regulatory policy issues. Biocontrol Science and technology, 6(3), 303-316.

Santhi, V. S., Salame, L., Nakache, Y., Koltai, H., Soroker, V., & Glazer, I. (2015). Attraction of entomopathogenic nematodes *Steinernema carpocapsae* and *Heterorhabditis bacteriophora* to the red palm weevil (*Rhynchophorus ferrugineus*). Biological control, 83, 75-81.

Shapiro-Ilan, D. I., Gouge, D. H., Piggott, S. J., & Fife, J. P. (2006). Application technology and environmental considerations for use of entomopathogenic nematodes in biological control. Biological control, 38(1), 124-133.

Smart Jr, G. C. (1995). Entomopathogenic nematodes for the biological control of insects. Journal of Nematology, 27(4S), 529.

Stuart, R. J., Barbercheck, M. E., Grewal, P. S., Taylor, R. A., & Hoy, C. W. (2006). Population biology of entomopathogenic nematodes: concepts, issues, and models. Biological Control, 38(1), 80-102.

Susurluk, A., & Ehlers, R. U. (2008a). Field persistence of the entomopathogenic nematode *Heterorhabditis bacteriophora* in different crops. BioControl, 53, 627-641.

Susurluk, I. A., & Ehlers, R. U. (2008b). Comparison of some characterizations of recovered from soil and newly fermented entomopathogenic nematode, *Heterorhabditis bacteriophora* (Rhabditida: Heterorhabditidae). Journal of Biological and Environmental Sciences, 2(6).

Susurluk, A., & Bütüner, A. K. (2024). The role of drought in the efficacy of some entomopathogenic nematodes. Turkish Journal of Entomology, 48(1), 103-110.

Susurluk, A., Dix, I., Stackebrandt, E., Strauch, O., Wyss, U., & Ehlers, R. U. (2001). Identification and ecological characterisation of three entomopathogenic nematode-bacterium complexes from Turkey. Nematology, 3(8), 833-841.

Susurluk, I. A. (2008). Influence of temperature on the vertical movement of the entomopathogenic nematodes *Steinernema feltiae* (TUR-S3) and *Heterorhabditis bacteriophora* (TUR-H2), and infectivity of the moving nematodes. Nematology, 10(1), 137-141.

Susurluk, İ. A. (2011). Potential of *Steinernema feltiae* (Rhabditida: Steinernematidae) as a biological control agent against the cabbage maggot *Delia radicum* (Diptera: Anthomyiidae) in oilseed rape. Turkish Journal of Agriculture & Forestry, 35(4), 413-419.

Vashisth, S., Chandel, Y. S., & Sharma, P. K. (2013). Entomopathogenic nematodes-A review. Agricultural Reviews, 34(3), 163-175.

Wang, Y., Gaugler, R., & Cui, L. (1994). Variations in immune response of *Popillia japonica* and *Acheta domesticus* to *Heterorhabditis bacteriophora* and *Steinernema* species. Journal of Nematology, 26(1), 11.

Wilson, M. J., Ehlers, R. U., & Glazer, I. (2012). Entomopathogenic nematode foraging strategies–is *Steinernema carpocapsae* really an ambush forager?. Nematology, 14(4), 389-394.