

Entomopathogenic nematodes (Steinernematidae, Heterorhabditidae: Rhabditida) of Turkey

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Abstract

A total of 82 species of entomopathogenic nematodes (EPNs) has been identified worldwide belonging to *Steinernema* (65), *Neosteinernema* (1) and *Heterorhabditis* (16). This number is going up in parallel to new investigations. Five species of *Steinernema* and three *Heterorhabditis* species were identified in Turkey. There are only a few literature supports about detrimental effects of Turkey origin EPNs on maleficent groups having economical importance.

Entomopathogenic nematodes (EPNs), the beneficial nematodes of genera *Steinernema*, *Heterorhabditis* and *Neosteinernema* are frequently found as parasites of soil dwelling insect pests. They are highly regarded as biological control agents because they have an extraordinarily broad host range of insects but are safe to vertebrates and plants. The use of EPNs against pests in the biological control of the agricultural areas increased by greater in recent years. EPNs have an important place in the control against pests as they have a wide host range; kill the host within 48 hrs by the bacteria they carry, remain alive for a long time in the environment in the absence of host, not to harm the environment and can be used as bio-pesticides.

Currently, over 60 species of *Steinernema* and 16 species of *Heterorhabditis* (Nguyen & Hunt, 2007) have been described, and the number of nominal species is increasing rapidly. Hominick (2002) reported that the number of EPN species described until 2002 was 34 of which 23 were described from 1989-2002. Researchers continue to search for new and better strains of EPNs, in part for commercial reasons. Particular attention has focused on indigenous EPNs as they are considered to be better adapted to local habitats. Furthermore, the use of native EPNs allays the

fears of those concerned about release of exotic EPNs into the environment particularly with regard to their impact on non-target insects and possible displacement of native species (Ehlers, 2005).

A total of 82 species of EPN has been identified worldwide (Nguyen, 2014) belonging to *Steinernema* (65), *Neosteinernema* (1) and *Heterorhabditis* (16). This number is going up in parallel to new investigations. First EPN belonging to *Steinernema* in Turkey was detected by Özer *et al.*, (1995) as *S. feltiae* from soil samples collected from Rize. First nematode species belonging to *Heterorhabditis* in Turkey was detected by Kepenekci *et al.*, (1999) as *H. bacteriophora* in *Aelia* population (*Aelia rostrata* Boh.) collected from Ekecik (Aksaray) winter quarters. Eight species belonging to *Steinernema* and *Heterorhabditis* have so far been detected in Turkey are listed below including soil or host sample and isolation area with their reference (Table 1). Surveys have been conducted regarding the utilization of EPNs in biological fighting, principally types and hosts conducted in Turkey (Özer *et al.*, 1995; Kepenekci & Susurluk, 2000; Kepenekci, 2002; Hazır *et al.*, 2003a; Gözel *et al.*, 2007; Erbaş *et al.*, 2011; Güneş & Gözel, 2011a). Moreover, efficacy studies on indigenous EPNs on maleficent pest groups having economical importance have also been conducted (Table 2).

Table 1. Entomopathogenic nematodes identified in Turkey.

Nematode species	Host/soil	Isolation area	Reference
<i>Steinernema affine</i> (Bovien, 1937) Wouts <i>et al.</i> , 1982	Soil	Icel, Adana (South of Turkey), Mardin (Southeast Anatolia), Tokat (North of Turkey), Tekirdag, Kirlareli (Northwestern Turkey)	Hazır <i>et al.</i> , 2003a
<i>S. anatoliense</i> Hazır <i>et al.</i> , 2003	Soil	Kars (East Anatolia)	Hazır <i>et al.</i> , 2003b
<i>S. carpocapsae</i> (Weiser, 1955) Wouts <i>et al.</i> , 1982	Soil	Antalya and Icel (South of Turkey)	Kepenekci, 2002
<i>S. feltiae</i> (Filipjev, 1934) Wouts <i>et al.</i> , 1982	Soil	Rize (North of Turkey)	Özer <i>et al.</i> , 1995
<i>S. weiseri</i> Mráček <i>et al.</i> , 2003	Soil	Ankara (Central Anatolia)	Ünlü <i>et al.</i> , 2007
<i>Heterorhabditis bacteriophora</i> Poinar, 1976	Host	Aksaray (Central Anatolia)	Kepenekci <i>et al.</i> , 1999
<i>H. marelatus</i> Liu & Berry, 1996	Soil	Ankara (Central Anatolia)	Kepenekci & Susurluk, 2000
<i>H. megidis</i> Poinar <i>et al.</i> , 1987	Soil	Black Sea region	Yılmaz <i>et al.</i> , 2007

Table 2. Efficacy studies of indigenous entomopathogenic nematodes against important pests in Turkey.

Pests	Nematode species	Reference
<i>Ceratitis capitata</i> (Wied) (Diptera: Tephritidae)	<i>Steinernema carpocapsae</i> <i>Heterorhabditis marelatus</i> <i>H. bacteriophora</i>	Kepenekci <i>et al.</i> , 2002
<i>Rhagoletis cerasi</i> L. (Diptera: Tephritidae)	<i>S. carpocapsae</i> <i>H. bacteriophora</i> <i>H. bacteriophora</i> (Tur-H1)	Gökçe <i>et al.</i> , 2003
<i>C. capitata</i> and <i>R. cerasi</i>	<i>S. feltiae</i> (All) <i>S. feltiae</i> (S3)	Kepenekci & Susurluk, 2006
<i>Bactrocera oleae</i> Gmelin (Diptera: Tephritidae)	<i>S. carpocapsae</i> <i>S. feltiae</i> <i>H. bacteriophora</i> (Y 70) <i>H. bacteriophora</i> (Y 91)	Güneş & Gözel, 2011b

<i>Cydia pomonella</i> L. (Lepidoptera: Tortricidae)	<i>H. bacteriophora</i> (Tur-H1) <i>H. bacteriophora</i> (Tur-H2) <i>S. feltiae</i> <i>H. bacteriophora</i>	Evlice <i>et al.</i> , 2007 Bulun & Gözel, 2011
<i>Cydia splendana</i> (Hübner) and <i>C. elephas</i> Vilvens	<i>S. feltiae</i> <i>S. weiseri</i>	Karagöz <i>et al.</i> , 2007
<i>Yponomeuta mallinellus</i> Zell. and <i>Y. padella</i> L. (Lepidoptera: Yponomeutidae)	<i>H. bacteriophora</i> <i>S. feltiae</i> (Tur-S3) <i>S. feltiae</i> (All) <i>H. bacteriophora</i> (Tur-H1) <i>H. bacteriophora</i> (Tur-H2)	Kepenekci <i>et al.</i> , 2007
<i>Sesamia nonagrioides</i> Lef. (Lepidoptera: Noctuidae)	<i>S. carpocapsae</i> <i>S. feltiae</i> <i>H. bacteriophora</i>	Gözel & Güneş, 2009
<i>Spodoptera littoralis</i> (Boisduval) (Lepidoptera: Noctuidae)	<i>S. affine</i> <i>S. carpocapsae</i> <i>H. bacteriophora</i> (Y 91) <i>H. bacteriophora</i> (Y 200)	Gözel <i>et al.</i> , 2011
<i>Spodoptera</i> sp.	<i>S. feltiae</i> <i>S. carpocapsae</i> <i>S. weiseri</i> <i>H. bacteriophora</i> <i>Heterorhabditis</i> sp.	Gulcu <i>et al.</i> , 2012
<i>Helicoverpa armigera</i> (Lepidoptera: Noctuidae) <i>Ostrinia nubilalis</i> (Lepidoptera: Crambidae)	<i>S. feltiae</i> (All) <i>S. feltiae</i> (S3)	Kepenekci & Evlice, 2009
<i>Thaumetopoea pityocampa</i> Den. & Schiff. (Lepidoptera: Thaumetopoeidae)	<i>S. carpocapsae</i> <i>S. feltiae</i> <i>H. bacteriophora</i> (Y 91) <i>H. bacteriophora</i> (Y 200)	Muslu <i>et al.</i> , 2011
<i>Tuta absoluta</i> Meyrick (Lepidoptera: Gelechiidae)	<i>H. bacteriophora</i>	Çakmak <i>et al.</i> , 2011
<i>Agrotis segetum</i> Denis & Schiffermüller (Lepidoptera: Noctuidae)	<i>S. feltiae</i> (Tur-S3) <i>S. carpocapsae</i> (Anamur)	Unlu <i>et al.</i> , 2007
<i>Eurygaster maura</i> (L.) (Hemiptera: Scutelleridae)	<i>S. carpocapsae</i> (Anamur) <i>H. bacteriophora</i> (Tur-H1) <i>H. bacteriophora</i> (Tur-H2)	Kepenekci, 2004

<i>E. maura</i>	<i>S. feltiae</i> (All) <i>S. feltiae</i> (S3)	Koçak <i>et al.</i> , 2007
<i>Curculio elephas</i> (Gyllenhal) (Coleoptera: Curculionidae)	<i>S. carpocapsae</i> (Anamur) <i>S. feltiae</i> (Tur-S3) <i>H. bacteriophora</i> (Tur-H1) <i>H. bacteriophora</i> (Tur-H2)	Kepenekci <i>et al.</i> , 2004a
<i>Otiorhynchus sulcatus</i> (Fabricius) (Coleoptera: Curculionidae)	<i>H. bacteriophora</i>	Susurluk & Ehlers, 2008
<i>Bothynoderes punctiventris</i> Germ. (Coleoptera: Curculionidae)	<i>S. feltiae</i> (Tur-S3) <i>S. weiseri</i> (BEY) <i>H. bacteriophora</i> (TUR-H2)	Susurluk, 2008
<i>Tenebrio molitor</i> L. (Coleoptera: Tenebrionidae)	<i>S. feltiae</i> (Tur-S3) <i>H. bacteriophora</i> (Tur-H2)	Susurluk, 2006
<i>Dorcadion pseudopreissi</i> Breuning (Coleoptera: Cerambycidae)	<i>S. carpocapsae</i> (Tur-S4) <i>S. feltiae</i> (Tur-S3)	Susurluk <i>et al.</i> , 2009
<i>Hyalopterus pruni</i> (Geoffroy) (Homoptera: Aphididae)	<i>S. feltiae</i> (Tur-S3) <i>H. bacteriophora</i> (Tur-H1) <i>H. bacteriophora</i> (Tur-H2)	Kepenekci <i>et al.</i> , 2004b
<i>Meloidogyne incognita</i> Chitwood (Tylenchida: Meloidogynidae)	<i>S. feltiae</i> <i>H. bacteriophora</i>	Bulun <i>et al.</i> , 2009

Discussion

There is no any proper literature support regarding entomopathogenic nematodes encountered so far in Turkey. Kepenekci & Susurluk (2000, 2003) recovered one isolate of *Steinernema feltiae* and two of the genus *Heterorhabditis* from 26 soil samples collected from 13 different areas of the campus of the Faculty of Agriculture, University of Ankara, Turkey. Susurluk *et al.*, (2001) used molecular and cross-breeding techniques to identify these heterorhabditid nematodes and their symbiotic bacteria. Heat tolerance and control potential of all three isolates at variable soil humidity was investigated at Institute for Phytopathology, Department for Biotechnology and Biological Control, Christian Albrechts University-Kiel (Susurluk, 2007). This study

intends to compile all entomopathogenic nematode species detected so far during nematological investigations from Turkey.

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