

HELMINTHOLOGIA, 50, 1: 3 – 14, 2013

Review Article

Organic amendments of soil as useful tools of plant parasitic nematodes control

M. RENČO

Institute of Parasitology, Department of Environmental and Plant Parasitology, Slovak Academy of Sciences,
Hlinkova 3, 040 01 Košice, Slovak Republic, E-mail: renco@saske.sk

Summary

Use of organic soil amendments is a traditional agricultural practice for improving physical and chemical soil properties, soil structure, temperature and humidity conditions as well as nutrients content which are needful for plants growth. Application of organic materials to soil can cause a change in soil microflora and microfauna including soil nematodes. Nematodes, are the most ample and varied group of soil fauna. They are ever-present habitants of all soil types with high population densities. The changes in soil nematodofauna can results in an increase in the number of beneficial nematodes such as bacterial or fungal feeders and decrease and/or suppression in the occurrence of economically important plant parasitic nematodes. A variety of organic amendments, such as animal and green manure, undecomposed (raw) or decomposed materials (compost) are used for this purpose. Generally, plant parasitic nematodes have been controlled mainly by chemical soil fumigants and nematicides, agricultural practices or resistant cultivars. However, organic amendments can provide an environmentally friendly alternative to the use of chemical nematicides, which are often expensive, of limited availability in many developing countries and above all environmentally hazardous.

Introduction

The enhancement consideration to the environment protection and to human and animal health, according to the recent European Legislations (Reg. CE 396/2005; 1095/2007; 33 and 299/2008 and 1107/2009) which have deeply delimited and revised the use of pesticides on agricultural crops, is stimulating investigation to find new alternative control strategies that are environmentally sound and economically convenient at the same time. Therefore, research on small environmental impact alternatives to chemicals has received a strong impulse and considered a wide range of options including agronomical

and physical methods (green manures, crop rotations, soil amendments, the use of resistant cultivars and arbuscular mycorrhizal fungi, soil solarization and steam), the use of natural products from plants and biological control agents (Sasanelli, 1992; Vannacci & Gullino, 2000; Atungwu, 2005; Castillo *et al.*, 2006; Riga *et al.*, 2007; Sasanelli *et al.*, 2009; Riga, 2011).

Among these alternative control strategies the soil organic amendments is particularly interesting because of their low cost and the more general positive agronomical effect on plant growth and on physical, chemical and biological properties of the soils (Davey, 1996). Moreover, it can suppose the management of large amounts of wastes generated by urban settlements and agro-industrial processes, after their transformation by composting process, and in addition it can improve plant resistance and plant protection by stimulating root development by recycling plant nutritive elements (De Bertoldi, 2008). Many organic material wastes represent an important resource of nitrogen, phosphorous, calcium and other elements as zinc, copper, magnesium essential to plant growth (Tester, 1990).

There are sufficient data to indicate that organic materials have positive effect on soil structure, improve plant growth and yields and reduce disease impact caused by a wide range of plant pests including bacteria, soil-borne pathogens and phytoparasitic nematodes species (Akhtar & Mahmood, 1996; D'Addabbo & Sasanelli 1996a, 1997, 1998; Abawi & Widmer, 2000; Renčo *et al.* 2007, 2009, 2010; Atungwu, 2012). In particular, the suppressive effect of soil amendments, with a wide range of composted waste materials, on plant parasitic nematodes was largely and frequently documented, although an inconsistent nematode control or variable effects were also described in literature (Szczecz *et al.*, 1993; McSorley & Gallagher, 1995; Akhtar & Malik, 2000).

Therefore the nematicidal effect of compost amendments is sorely predictable because of depending on the using of

raw materials, the type of composting process, the maturity of the final product incorporated into the soil, nematode species present and season or rate of application (Rodríguez-Kábana *et al.*, 1987; Rivera & Aballay, 2008; Renčo *et al.* 2007, 2010). Many mechanisms can be involved in this suppressive effect such as decomposition of the compost into the soil and ammonia production, stimulation of soil microbial biomass and release of biocidal substances which have nematicide activity (Oka & Yermiyahu, 2002). The nematicidal activity, therefore, should be specifically assessed for different composts.

This paper discusses about the use of different organic amendment on soil quality, plant growth as well as on control the most important plant parasitic nematodes and factors caused its response.

The organic amendments effect on soil quality and plant growth

It is necessary to mention that organic fertilizer has a great impact on soil fertility which is essential for good plant growth because of fertile soil providing nutrients necessary to grown plants. If absence of nutrients in the soil is obvious, we can add those to soil by the two types of soil amendment – organic (made from natural products) and inorganic (man made chemicals). However, organic manure compared with inorganic has many advantages because organic matter improve the physical properties of

soil, including water retention, water infiltration, permeability and aeration as well as increase soil fertility and provide a better environment for roots (Bulluck *et al.*, 2002b; Mandal *et al.*, 2007). The common organic amendments are cow, chicken and horse manure, compost or green manure (Riga & Collins, 2004). These increase the organic constituents of the soil thus providing favourable environment for bacteria and earth worms that enrich the soil. However, the content of nutrients in cow manure are generally lower than in chicken and horse manure. The inorganic amendments are man made and they include chemicals that are used for making the soil fertile. Though they are used for good output they will reduce the natural nutrients of the soil in the long run. On the other hand, organic manures often provide more than one of the many nutrients needed by plants but inorganic manures provide only one of the many nutrients needed by plants.

The soil amendments depend greatly on the soil requirements, types of crops that grow in the soil, texture of the soil and its salinity but from requirements of growers for soil improvement. Almost any kind of organic matter may be used as manure, but some kinds are better than others. Organic manures vary widely in the amount of plant nutrients that they contain. Some are more concentrated than others. That the various organic amendments improve plant growth and yield was confirmed in many studies (Table 1).

Table 1. Organic amendment positive effect on plant growth and production

Amendment	Plant	Parameter	Refferences
Poultry manure	Chilli	Yield ↑	Khan <i>et al.</i> , 2001
Oilcakes of neem, castor, composted manure	Pigeonpea	Fresh weight, dry weight and height ↑	Akhtar and Mahmood, 1996
Domestic garbage, dead vegetation, vegetable and fruit processing wastes, sugarcane trash, corn shucks, groundnut hay, groundnut hulls, paddy straw and husk, pressmud, spent tea, tobacco rettes	Tomato	Growth of plants ↑	Akhtar, 1993
Oil cakes of cotton, flax, olive, sesame and soybean	Tomato	Growth of plants ↑	Radwan <i>et al.</i> , 2009
Cattle manure, green manure , pigeon-dung, sewage sludge, horse manure and cotton root wastes	Tomato	Growth of plants ↑	Maareg <i>et al.</i> , 2000
Cattle dung, bean and wheat straw compost	Tomato	Yield ↑	Korayem, 2003
Vermicompost	Chinesse cabbage	Growth of plants ↑	Wang <i>et al.</i> , 2010
Onion bulb envelope, dry leaves of sugar beet, fleabane and jojoba, filter cake or mud as sugar cane industrial residue and nile fertile mineral bio-fertilisers	Banana	Yield ↑	Youssef and El-Nagdi, 2010
Compost from poato waste, sawdust, beef manure; beef manure	Potato	Yield ↑	Kimpinski <i>et al.</i> , 2003
Fermented pig manure commercially name Difert	Broccoli	Yield ↑	Kováčik <i>et al.</i> , 2008
Fermented pig manure commercially name Difert	Sunflower	Yield ↑	Kováčik <i>et al.</i> , 2010
Vermicomposts from food wastes, paper wastes and cattle manure	Peper	Yield, growth of plants, leaf areas, plant shoot biomass ↑	Arancon <i>et al.</i> , 2005
Vermicomposts from food wastes, paper wastes and cattle manure	Tomato	Yield ↑	Arancon <i>et al.</i> , 2003a
Vermicomposts from food wastes, paper wastes and cattle manure	Strawberries	Yield, leaf areas, numbers of strawberry suckers, numbers of flowers, shoot weights ↑	Arancon <i>et al.</i> , 2003a

The organic amendments effect on plant parasitic nematodes

The control of plant parasitic nematodes is more difficult in comparison to other pests because they usually live in the soil and attacks the underground parts (roots) of the plant. A lot of nematode control strategies such as nematicides, resistant varieties, crop-rotation, non-hosts, antagonistic crops, biological control (predators and parasites of nematodes) have been used successfully but each method has some limitation to implementation (Akhtar, 1997). Probably for those reason, a wide variety of organic matters (incorporated to soil) have been tested as potential and alternative control of plant parasitic nematodes.

The most studies worldwide are focused on root-knot nematodes of the genus *Meloidogyne* because of approximately 2000 plants are known to be hosts of these nematodes from grass to trees where they cause the galls on roots. They are occurring mainly in temperate areas with short winters, especially in sandy soils. Because of crop rotation as a control tactic of these nematodes is rather difficult due to a wide range of their hosts, the alternative organic control is main investigated method for their regulation (Table 2). Sasser and Carter (1985) noted that *Meloidogyne* nematodes account for approximately 5 % of global yield loss.

The genus *Meloidogyne* includes more than 60 species, however four *Meloidogyne* species (*M. javanica*, *M. arenaria*, *M. incognita*, *M. hapla*) are considered as major plant pests' worldwide (Eisenback & Triantaphyllou, 1991). D'Addabbo (1995) found 160 literature sources on the effect of organic amendments on nematodes of the genus *Meloidogyne* under different host plants. For example, on tomato roots, the reduction of *M. incognita* population by the application of chicken manure was observed by D'Addabbo *et al.* (2000); by the application of water hyacinth compost, mustard straw, rice husk and asparagus compost (Sharma *et al.*, 1997); by olive pomace (D'Addabbo & Sasanelli, 1996a; D'Addabbo *et al.*, 2011); by grape pomace (D'Addabbo & Sasanelli, 1998) or pepper crop residues (Buena *et al.*, 2007). On the other hand, not all types of organic amendments were beneficial in the suppression of root-knot nematodes. For instance, Bulluck *et al.*, (2002a) observed that *Meloidogyne incognita* populations were not affected by amendments with swine manure or composts water extract prepared from bean or wheat straw, poultry or fish wastes (Korayem, 2003). Vermicompost showed no inhibitory effect on the number of *M. hapla* galls on cabbage and tomato roots; incorporation of compost consisted of cull waste potatoes, sawdust and beef manure had no efficacy on *M. hapla* populations in potatoes (Kimpinski *et al.*, 2003). No suppressive effect of organic amendment was observed on the population of rice root-knot nematode *M. graminicola* (Gergon *et al.*, 2001).

Another most important worldwide are cyst nematodes. Therefore, their control is difficult because they are more resistant than endoparasitic, ectoparasitic and sedentary ectoparasitic nematodes, because of the presence of the layer of dead cuticle of females which serves to protect the

eggs and second-stage juveniles that are retained within (Zunke & Eisenback, 1998). In every case, several studies were focused on this group of plant parasitic nematodes with positive results (Table 2). For instance, Van der Laan (1956) found that development of *Globodera rostochiensis* on potato roots was delayed by application of organic material in comparison to untreated control. Similarly to it, Renčo *et al.* (2007, 2011) observed reduced reproduction of females of *G. rostochiensis* patotype Ro1 and *G. pallida* patotypes Pa2 and Pa3 by use of nine type composts applied at four doses, when compared to the untreated control. Also, steer and chicken manures reduced the numbers of cyst *G. pallida* and resulted in increased yields of potatoes (Gonzalez & Canto-Sanenz, 1993). Contrary, vermicompost don't reduce *Heterodera schachtii* in study of Szczech *et al.* (1993). Kimpinski *et al.* (2003) observed an increase in the number of *Heterodera trifolii* juvenile in barley plots however this species parasitized on red clover crop. Similar increase in egg hatching of the species was observed by Kunelius *et al.* (1988). The authors attributed this support of hatching to increased aeration in conventionally tilled soil compared to non-tilled soil.

Several studies were aimed at the control (reduction) of several other endo and ectoparasitic nematode species. The nematode suppression after and organic amendments was recorded, for example at *Pratylenchus* species (Khan *et al.*, 1986; LaMondia *et al.*, 1999; Abawi & Widmer, 2000; Kimpinski *et al.*, 2003); *Helicotylenchus* species (Subba Rao *et al.*, 1996; Khan & Shaukat, 1998) and many other (see Table 2). Contrary to that, no suppression of *Pratylenchus* sp. after the application of swine manure was observed by Bulluck *et al.* (2002a); sewage sludge (Weiss & Larink, 1991); yard-waste compost on vegetable crops (McSorley & Gallaher, 1995). Also, *Xiphinema* spp., *Criconemella* spp. and *Paratrichodorus minor* was unaffected by application of yard-waste compost on vegetable crops (McSorley & Gallaher, 1995). Soil treatments by solid waste compost did not affect the population densities of *Criconemoidea* spp. and *Paratrichodurus minor* as well, however the population densities *M. incognita* increased in compost-amended plots (McSorley *et al.*, 1997). Sewage sludge treatment produced no suppressive effect on *Helicotylenchus dihystera* (Sharma *et al.*, 2000).

The organic amendments effect on nematode community changes

In addition to studies examining the impact of application of different organic materials on particular plant parasitic nematodes, during the last decades there has been an increasing interest deal with impacts of organic amendments on soil nematode community changes, in general. For example, Akhtar and Mahmood (1996) found a significant reduction of plant parasite and increase of predatory and free-living nematodes after application of all tested materials after an application of different rates of oilcakes of neem (*Azadirachta indica*) and castor (*Ricinus communis*), composted manure and urea, as well as using of composted manure combined with *Tagetes erecta*

Table 2. Documented suppressions of plant parasitic nematodes by different types of organic amendment

Nematode species	Plant	Organic material	References
<i>Meloidogyne incognita</i>	Tomato	Chicken manure	D'Addabbo <i>et al.</i> , 2000, 2003
		Chicken manure	López-Pérez <i>et al.</i> , 2005
		Water hyacin compost, mustard straw, rice husk, asparagus compost	Sharma <i>et al.</i> , 1997
		Composted dry cork	Nico <i>et al.</i> , 2004
		Olive pomace	D'Addabbo and Sasanelli, 1996a
		Olive pomace	D'Addabbo <i>et al.</i> , 1997, 2000, 2003, 2011
		Grape pomace	D'Addabbo and Sasanelli, 1998
		Olive pomace, straw, urea	D'Addabbo and Sasanelli, 1997
		Olive residues	D'Addabbo <i>et al.</i> , 1997
		Grape pomace	D'Addabbo <i>et al.</i> , 2000
		Multi varied compost	D'Addabbo <i>et al.</i> , 2006
		Municipal green wastes, sewage sludge, spent mushroom substrate	D'Addabbo <i>et al.</i> , 2011
		Sewage sludge	Castagnone-Sereno and Kermarrec, 1991
		Peper crop residues	Buena <i>et al.</i> , 2007
<i>Meloidogyne incognita</i>	Cotton	Oil cakes of cotton, flax, olive, sesame and soybean	Radwan <i>et al.</i> , 2009
		Chicken manure	Riegel <i>et al.</i> , 1996; Riegel and Noe, 2000
		Banana	<u>Sundararaju <i>et al.</i>, 2002</u>
		Destillery sludge, vermicompost, neem cakee, poultry manure	
		Onion bulb envelope, dry leaves of sugar beet, fleabane and jojoba, filter cake or mud as sugar cane industrial residue and nile fertile mineral bio-fertilisers	Youssef and El-Nagdi, 2010
		Pea	Pandey and Singh, 1990
		Tomato	Nico <i>et al.</i> , 2004
		Corn	Verma <i>et al.</i> , 1997
		Cacao	Orisajo <i>et al.</i> , 2008
		Soybean	Atungwu <i>et al.</i> , 2009
<i>Meloidogyne javanica</i>	Tomato	Neem leaf powder	Atungwu <i>et al.</i> , 2011
		Neem and Sunshine organic fertilizer	Akhtar and Alam, 1992
		Chili	Akthar, 1993
		Tomato	
		Domestic garbage, dead vegetation, vegetable and fruit processing wastes, sugarcane trash, corn shucks, groundnut hay, groundnut hulls, paddy straw and husk, pressmud, spent tea, tobacco rettes	
		Broiler litter, cottonseed meal, feather meal, soybean oilcake	Oka <i>et al.</i> , 2007
		Cattle manure, grape marc compost	Oka and Yermiyahu, 2002
		Dry cork, dry-grape marc	Nico <i>et al.</i> , 2004
		Sheep manure, cattle manure, horse manure, pigeon-dung, chicken manure, sewage sludge, green manure, cotton root wastes, sawdust and humic acid coffee pulp compost	Maareg <i>et al.</i> , 2000
		Lettuce	Ribeiro <i>et al.</i> , 1998
<i>Meloidogyne hapla</i>	Groundnut	Groundnut	Joshi and Patel, 1995
		Peat	Coosemans, 1982
<i>Meloidogyne arenaria</i>	Tomato	Compost tea, vermicompost tea	Edwards <i>et al.</i> , 2007
		Green manure by Sudan grass	Viaene and Abavi, 1998
		Oil cakes, chicken litter	Mian and Rodriguez-Kabana, 1982
		Chicken litter	Kaplan <i>et al.</i> , 1992
<i>Meloidogyne</i> sp.	Cowpea	Chicken litter	Kaplan and Noe, 1993
		Composted manure	Olabiyi <i>et al.</i> , 2007
		Poultry manure, pigeon manure, sawdust	Khan <i>et al.</i> , 2001
<i>Globodera rostochiensis</i>	Chili	Organic material	Van der Laan, 1956
<i>Globodera pallida</i> <i>Heterodera schachtii</i>	Potato	Composts of different origin	Renčo <i>et al.</i> , 2007
		Freshly-crushed conifer bark	Matveeva <i>et al.</i> , 2002
		Steer and chicken manures	Gonzalez and Canto-Sanenz, 1993
<i>Heterodera carotae</i> <i>Heterodera oryzicola</i>	Carrot	Compost	Schlange, 1993
		GFT compost	Ryckeboer and Coosemans, 1996
		Exhausted olive pomace	D'Addabbo and Sasanelli, 1996b
<i>Heterodera avenae</i> <i>Heterodera</i> sp.	Rice	Distillery sludge, vermicompost, neem cake, poultry manure	<u>Sundararaju <i>et al.</i>, 2002</u>
		Sewage sludge, lime, dehydrated pig slurry	López-Robles <i>et al.</i> , 2006
		Sewage sludge	Weiss and Larink, 1991
	Cereals	Municipal green compost	Renčo <i>et al.</i> , 2009

<i>Pratylenchus penetrans</i>	Bean Fallow plot Potato	Chicken manure Poultry litter Poultry litter Mushroom compost Maize	Abawi and Widmer, 2000 Everts <i>et al.</i> , 2006 Conn and Lazarovits, 1999 LaMondia <i>et al.</i> , 1999 Min <i>et al.</i> , 2007
<i>Pratylenchus coffeae</i>	Coffee	Anaerobically digested slurry, cow, pig and biowaste slurry Distillery sludge, vermicompost, neem cake, poultry manure	Sundararaju <i>et al.</i> , 2002
<i>Pratylenchus scribneri</i>	Rice	Poultry litter	Khan <i>et al.</i> , 1986
<i>Pratylenchus zeae</i>	Maize	Poultry litter	Khan and Shaukat, 2000
<i>Pratylenchus</i> sp.	Maize	Garden waste compost	Leroy <i>et al.</i> , 2007
<i>Paratylenchus</i> sp.	Cereals	Liquid dairy manure	Timper <i>et al.</i> , 2004
<i>Tylenchus mirus</i>	Mustard	Municipal green compost	Renčo <i>et al.</i> , 2009
<i>Psilenchus haki</i>	Mustard	Poultry manure	Khan <i>et al.</i> , 1986
<i>Tylenchus</i> sp.	Maize	Poultry manure, pigeon manure, sawdust	Hassan <i>et al.</i> , 2008
<i>Ditylenchus</i> sp.		Garden waste compost	Leroy <i>et al.</i> , 2007
<i>Bitylenchus</i> sp.	Cereals	Poultry manure	Khan <i>et al.</i> , 1986
<i>Helicotylenchus multicinctus</i>	Banana	Municipal green compost, penicillin residues compost	Renčo <i>et al.</i> , 2009
<i>Helicotylenchus indicus</i>	Betelvine	Distillery sludge, vermicompost, neem cake, poultry manure	Sundararaju <i>et al.</i> , 2002
	Garlic	Sawdust, NPK, neem cake combination	Subba Rao <i>et al.</i> , 1996
	Chili	Poultry manure	Khan <i>et al.</i> , 1986
<i>Helicotylenchus</i> sp.	Cereals	Pigeon and poultry manure	Khan and Shaukat, 1998
	Maize	Pigeon and poultry manure, sawdust	Khan <i>et al.</i> , 2001
	Cowpea	Municipal green compost, penicillin residues compost	Renčo <i>et al.</i> , 2009
<i>Tylenchorhynchus curvus</i>	Chilly	Poultry litter	Summer <i>et al.</i> , 2002
<i>Rotylenchulus</i> sp.	Cereals	Decomposed and composed manure	Olabiyi <i>et al.</i> , 2007
<i>Geocenamus</i> sp.	Cereals	Pigeon and poultry manure, sawdust	Khan <i>et al.</i> , 2001
<i>Melinius brevidens</i>	Garlic	Municipal green compost, penicillin residues compost	Renčo <i>et al.</i> , 2009
<i>Hoplolaimus seinhorsti</i>	Garlic	Pigeon and poultry manure	Khan and Shaukat, 1998
<i>Hoplolaimus indicus</i>	Rice	Poultry manure	Khan and Shaukat, 1998
<i>Hoplolaimus columbues</i>	Cotton	Poultry litter	Khan and Shaukat, 2000
<i>Xiphinema index</i>	Grapevine	Olive and grape pomace	Koenning <i>et al.</i> , 2003
<i>Xiphinema</i> spp.	Cowpea	Decomposed and composed manure	D'Addabbo <i>et al.</i> , 1999
<i>Hemicyclophora</i> sp.	Vegetable	Solid waste compost	Olabiyi <i>et al.</i> , 2007
<i>Paratrichodorus</i> sp.	Maize	Poultry litter	McSorley <i>et al.</i> , 1997
		Liquid dairy manure	Summer <i>et al.</i> , 2002
			Timper <i>et al.</i> , 2004

(Akhtar, 1998). Dmowska and Kozlowska (1988) recorded the increase in bacteriovorous nematodes after using a pig and cattle manure, especially *Rhabditida* – saprobionts. The increase in bacteriovorous and fungivorous nematodes is apparently assigned to bacterial and fungal populations that appear in higher abundance after the organic amendments of soil and afford the food base for these nematodes (Griffiths *et al.*, 1994). After adding of organic matter to the soil, organic residues must be decomposed to release nutrients for plant uptake. This decomposition can be divided into two channels, a faster-bacterial channel and a slower fungal-based channel. Soil ecosystem types and nutrient forms (C:N ratio) determine the predominant decomposition channels (Ingham *et al.*, 1985). As an extension of these decomposition channels, when the bacteriovorous and fungivorous nematodes graze on these microbes, they give off CO₂ and NH₄⁺ and other nitrogenous compounds, affecting C and N mineralization directly (Ingham *et al.*, 1985).

The suppression of plant parasitic nematodes and improving of number of free-living (beneficial) nematodes were

found also in many other studies (Akhtar, 1999; McSorley & Frederick, 1999; Valocká *et al.*, 1999, 2000; Bulluck *et al.*, 2002a; Arancon *et al.*, 2003b; YingXia *et al.*, 2003; Wang *et al.*, 2006; Nahar *et al.*, 2006; Yao *et al.*, 2006).

On the other hand, the application of chemical fertilizer decreased the number of genera of bacterivores and omnivores-predators. The numbers of total nematodes, bacterivores, plant parasites and omnivores-predators were significantly positively correlated with the contents of total organic carbon, total N, alkali-hydrolysable N, available P and available K (Cheng & Zhi-Ping, 2008).

However, Wasilewska (1995) stated that manuring increased the proportion of bacteriovorous, fungivorous but also plant parasitic nematodes and decreased the number of omnivores and predators. Renčo *et al.* (2010) found that bacteriovorous nematodes decreased after sewage sludge and municipal green residues compost application, while at compost derived from penicillin production significantly increased the number of these nematodes. A significant reduction in number of plant parasitic nematodes in soil was observed in all tested composts compared to untreated

soil, with a similar behaviour of tested composts for root-fungal feeding nematodes. García-Álvarez *et al.* (2004) found that the application of mature compost did not alter the structural diversity of the nematode population during the six-year study. The similar results were obtained by Biederman *et al.* (2008) where the application of untreated urban wood waste did not affect the nematode density, family diversity and family richness by the amendment treatments. However, the number of bacterivorous, plant parasitic, omnivorous and predatory nematodes significantly increased during a 3-year study.

The effect of applied doses on nematode suppression

There are several factors which determine the effect of organic fertilizer on plant parasitic nematodes. Besides the quality of applied organic matter (maturity), soil structure and target nematode species, much important factor for intensity of suppression is applied doses as well, because of at higher doses more efficacious substances are added. For example, Gutpa and Kumar (1997) stated that level of reduction of *Tylenchorhynchus* spp. and *Helicotylenchus* spp. in soil increased at higher doses and the longer periods of treatment by compost, fenugreek and chickpea straw or groundnut and mustard cakes. Renčo *et al.* (2009) also found that relationship between applied doses and number of parasitic nematodes of genera *Bitylenchus*, *Helicotylenchus*, *Heterodera*, *Paratylenchus* and *Rotylenchulus* showed a significantly high negative correlation. That the applied doses can be consider as important factor for intensity of reduction of plant parasitic nematodes was confirmed in several other particular studies where increasing dose increase plant parasite nematode suppression (Akhtar & Mahmood, 1996; Nico *et al.*, 2004; Renčo *et al.*, 2007, 2010; Rawdan *et al.*, 2009)

Ammonium (N) and C:N ratio

Effectiveness of organic amendments suppression on plant parasitic nematode varies and depending mainly upon the nematode species and type of organic material (Akhtar & Alam, 1993). Although, the exact mechanism(s) of action of organic matter compounds is not exactly known at this time (Nico *et al.*, 2004), (Oka *et al.*, 2000) stated, that ammonia released from organic amendments during microbial composition plays an important role in nematode control, though the environmental conditions, such as soil pH, temperature and humidity influence the nematicidal activity of ammonia.

Rodríguez-Kábana *et al.*, (1987) pointed out, that the most effective amendments are those which have generally high nitrogen contents relative to carbon. Noe (1993) and Akhtar and Mahmood (1996) also stated, that application of composted manure, oilcakes of neem and castor with low C:N ratios (6 – 10:1) and high ammonium nitrogen content resulted in a decrease of plant parasitic nematodes. Castagnone-Sereno and Kermarrec (1991) or Nico *et al.* (2004) also attributed the suppression of *M. incognita* and *M. javanica* to ammonia contained in sewage sludge treatments or dry cork compost (C:N < 20). Renčo *et al.* (2010)

found, that composts with the highest native NH_4^+ content (C:N 20 – 23:1) suppressed plant parasitic nematode in great extent, and there was a positive relationship between plant parasitic nematode suppression and ammoniacal N content in the soil. However, the greatest extent of suppression of plant nematodes was recorded at compost with C:N ratio 4:1, though the NH_4^+ content were lower. In study of Agu (2008) plants of African yam bean treated with poultry and farmyard manures (C:N 1 – 2:1) gave significantly higher yields than those of other organic manures with wider C:N ratios. This was because rare root-galls caused by *M. incognita* occurred at those treatments. Otiefa and Elgindi (1962) wrote that plants with fewer root-galls would translocate more nutrients to vegetative organs than heavily galled roots. Miller and Donahue (1990) stated that organic residues with C:N ratios of 20:1 or narrower have sufficient nitrogen to supply to the decomposing microorganisms and also to release for plant use.

Urea ($330 \text{ kg N y ha}^{-1}$) was also nematode toxic and improved plant growth when was applied alone or in combination with the neem-based products (Achook, Suneem G) because neem contains triterpene that acts by delaying the rapid transformation of ammonium N to nitrate N (nitrification inhibitor). This ensures slow and continuously available nitrogen during plant growth (Akhtar, 2000). Wang *et al.* (2006) observed the increase of bacterivorous, fungivorous and occasionally omnivorous nematodes after incorporation of sunn hemp hay into soil, however the plant parasitic nematodes was suppressed relative to ammonium nitrate fertilizer. The abundance of bacterivores, fungivores and predatory nematodes, and total nematode abundance increased with the increasing dose of sunn hemp hay applied. In comparison to that, fertilization with ammonium nitrate increased the percentage of herbivores, but reduced percentage and abundance of omnivores.

Suppressiveness of organic amendments on plant parasitic nematodes generally resulted from different contributory mechanisms (Stirling, 1991). It seems that ammonia is one best suppressive or toxic. But also other mechanisms of action are found in decaying plant material such as components directly toxic to nematodes (chitin, phenols, tannins, azadirachtin, ricin, rutin, terpenes) (Rodríguez-Kábana, 1986; Spiegel *et al.*, 1987; Rich *et al.*, 1989; Sasanelli & D'Addabbo, 1995; Atungwu *et al.*, 2009; Maistrello *et al.*, 2010; Renčo *et al.*, 2012).

Other alternative methods for plant parasitic nematode control

That organic amendments reduce the number of parasitic nematodes in the soil has been demonstrated many times, but first the producers would have to protect their land before the infection and transfer of parasitic nematodes from infected plots. Nematodes have a limited ability to move and spread their own activity and therefore are due to passive transfer of man-the most common way of spreading. Therefore, the most important protection against plant nematodes consider prevention, it means the use the

pathogen-free planting material from uninfected nematode soils (e.g potato tubers, plant transplants). In the event that we have in the garden soil infected with nematodes, we can either directly limit their ability to grow and reproduce, thus increasing population, an indirect support growth of crops. For example, the use of resistant cultivar, grafting, biological control (by naturally occurring antagonists such as nematophagous fungi, endoparasitic fungal parasites, AMF arbuscular mycorrhizal fungi, the obligate parasite *Pasteuria penetrans*, predaceous organisms), soil solarization (Sasanelli *et al.*, 1997), biofumigation, nematicidal plants, soil steam sterilization, fumigants and non-fumigants nematicides (Sasanelli & D'Addabbo 1992, 1993; Sasanelli, 2009).

Conclusion

Farmers are constantly under pressure of naturalists, biologists, environmentalists or hydrologist to reduce use of pesticides (nematicides) and synthetic fertilizers. However, they must maintain the profitability of crops and crop quality. Annual global loss in agriculture due to damage by plant parasitic nematodes has been estimated as US\$100 billion worldwide (Oka *et al.*, 2000). For effective control of parasitic nematodes of plants in soil is necessary to choose an appropriate combination of several methods. Despite the fact that each control method has limited use because different developmental cycle of nematodes (e.g. cyst or root-gall forming nematodes) and varying range of host plants with different growth, an appropriate combination of methods can lead to successful reduction in the number of parasitic nematodes in soil and plants.

It is clear, that organic soil amendments stimulate the development of population of soil microorganisms and reduce the plant parasitic nematode population or plant diseases as well as improve soil fertility, physical properties of soil, water retention, water infiltration, permeability, aeration and plant growth. The majority of studies have focused on the different types of organic amendments as suppressants of plant parasitic nematodes of economic importance, especially root-knot nematodes, because their hosts' range and reproduction rate is large.

Because the price of pesticides (nematicides) and synthetic fertilizers is high, those can be related to increase of cost for cultivation of crops and may lead to large increases in food prices for example, in the poor harvest years (in the dry or very rainy). In addition to this, the pesticides are usually selective and destroying only targeted organisms. They react quickly and strongly (Deasaeger *et al.*, 2011), but the protection of plants is not long, because their effect is short without some other positive effects on plant growth and soil quality. For this reason, the use of organic fertilizer as a tool for control of parasitic nematodes and other soil pathogens is beneficial because it is a natural material, low cost (usually made by the growers), from which nutrients and nematicidal substances are released gradually throughout the whole vegetation period.

Acknowledgement

The author acknowledge the support of the scientific grant agency VEGA (Grant N° 2/0079/13).

References

- ABAWI, G. S., WIDMER, T. L. (2000): Impact of soil health management practices on soil born pathogens, nematodes and root diseases of vegetable crops. *Appl. Soil Ecol.*, 15: 37 – 47. DOI: 10.1016/S0929-1393(00)00070-6
- AGU, C. M. (2008): Effects of organic manure types on root-gall nematode disease and African yam bean yield. *J. Am. Sci.*, 4: 76 – 79
- AKHTAR, M. (1993): Utilization of plant-origin waste materials for the control of plant parasitic nematodes. *Biores. Technol.*, 46: 255 – 257. DOI: 10.1016/0960-8524(93)90129-Y
- AKHTAR M. (1997): Current options in integrated management of plant-parasitic nematodes. *Integrated Pest Manag. Rev.*, 2: 187 – 197. DOI: 10.1023/A:1018409303298
- AKHTAR, M. (1998): Effect of two Compositae plant species and two types of fertilizer on nematodes in an alluvial soil, India. *Appl. Soil Ecol.*, 10: 21 – 25. DOI: 10.1016/S0929-1393(98)00046-8
- AKHTAR, M. (1999): Plant growth and nematode dynamics in response to soil amendments with neem products, urea and compost. *Biores. Technol.*, 69: 181 – 183. DOI: 10.1016/S0960-8524(98)00158-8
- AKHTAR, M. (2000): Effect of organic and urea amendments in soil on nematode communities and plant growth. *Soil Biol. Biochem.* 32: 573 – 575. DOI: 10.1016/S0038-0717(98)00147-3
- AKHTAR, M., ALAM, M. M. (1992): Effect of crop residues amendments to soil for the control of plant-parasitic nematodes. *Biores. Technol.*, 41: 81 – 83
- AKHTAR, M., ALAM, M. M. (1993): Utilization of waste materials in the nematode control: a review. *Biores. Technol.*, 45: 1 – 7. DOI: 10.1016/0960-8524(93)90134-W
- AKHTAR, M., MAHMOOD, I. (1996): Control of plant-parasitic nematodes with organic and inorganic amendments in agricultural soil. *Appl. Soil Ecol.*, 4: 243 – 247. DOI: 10.1016/S0929-1393(96)00114-X
- AKHTAR, M., MALIK, A. (2000): Roles of organic amendments and soil organisms in the biological control of plant parasitic nematodes: a review. *Biores. Technol.*, 74: 35 – 47. DOI: 10.1016/S0960-8524(99)00154-6
- ARANCON, N. Q., EDWARDS, C. A., BIERNAN, P., METZGER, J. M., LUCHT, CH. (2003a): Effects of vermicomposts on growth and marketable fruits of field-grown tomatoes, peppers and strawberries. The 7th international symposium on earthworm ecology · Cardiff · Wales · 2002. *Pedobiologia* 47: 731 – 735. DOI: 10.1078/0031-4056-00251
- ARANCON, N. Q., GALVIS, P., EDWARS, C. A., YARDIM, E. (2003b): The trophic diversity of nematode communities in soil treated with vermicompost: The 7th international symposium on earthworm ecology · Cardiff · Wales · 2002.

- Pedobiologia*, 47: 736 – 740. DOI: 10. 078/0031-4056-00752
- ARANCON, N. Q., EDWARDS, C. A., BIERMAN, P., METZGER, J. M., LUCHT, CH. (2005): Effects of vermicomposts produced from cattle manure, food waste and paper waste on the growth and yield of peppers in the field. *Pedobiologia*, 49: 297 – 306. DOI: 10.1016/j.pedobi.2005.02.001
- ATUNGWU, J. J. (2005): An overview of the impact of organic manure as plant parasitic nematode suppressant. *Proceedings, 1st National Conference on Organic Agriculture, UNAAB, Abeokuta, Nigeria, October 25 – 28*, pp. 149 – 157
- ATUNGWU, J. J., ADEMOLA, A. A., AIYELAAGBE, O. O. (2009): Evaluation of organic materials for inhibition of nematode reproduction in soybean. *Afr. Crop Sci. J.*, 17: 167 – 173
- ATUNGWU, J. J., OLABIYI, T. I., OLATUNJI, J. O., FASANU, A. (2011): Assessment of varietal resistance and two organic fertilizers in the management of southern root-knot nematode in soyabean (*Glycine max*). *Biol. Agric. Hortic.*, 27: 231 – 239
- ATUNGWU, J. J., LAWAL O., AFOLAMI, S., ADEJUYIGBE, CH. (2012): Appraisal of composts for suppression of *Meloidogyne* species and enrichment of micro-arthropods in soybean fields. *Biol. Agric. Hortic.*, 28: 1-10. DOI:10.1080/01448765.2012.681348
- BIEDERMAN, L. A., BOUTTON, T. W., WHISENANT, S. G. (2008). Nematode community development early in ecological restoration: The role of organic amendment. *Soil Biol. Biochem.*, 40: 2366 – 2374. DOI: 10.1016/j.soilbio.2008.05.017
- BULLUCK L. R., BARKER, K. R., RISTAINO, J. B. (2002a): Influences of organic and synthetic soil fertility amendments on nematode trophic groups and community dynamics under tomatoes. *Appl. Soil Ecol.*, 21: 233 – 250. DOI: 10.1016/S0929-1393(02)00089-6
- BULLUCK, L. R., BROSUS, M., EVANYLO, G. K., RISTAINO, J. B. (2002b): Organic and synthetic fertility amendments influence soil microbial, physical and chemical properties on organic and conventional farms. *Appl. Soil Ecol.*, 19: 147 – 160. DOI: 10.1016/S0929-1393(01)00187-1
- BUENA, A. P., GARCÍA-ÁLVAREZ, A., DÍEZ-ROJO, M. A., ROS, C., FERNÁNDEZ, P., LACASA, A., BELLO, A. (2007): Use of pepper crop residues for the control of root-knot nematodes. *Biores. Technol.*, 98: 2846–2851. DOI: 10.1016/j.biortech.2006.09.042
- CASTILLO, P., NICO, A. I., AZCON-AGUILAR, C., DEL RIO RINCON, C., CALVET, C., JIMENEZ-DIAZ, R. M. (2006): Protection of olive planting stocks against parasitism of root-knot nematodes by arbuscular mycorrhizal fungi. *Plant Pathol.*, 55(5): 705 – 713. DOI: 10.1111/j.1365-3059.2006.01400.x
- CASTAGNONE-SERENO, P., KERMARREC, A. (1991): Invasion of tomato roots and reproduction of *Meloidogyne incognita* as affected by raw sewage sludge. *J. Nematol.*, 23: 724 – 728
- CHENG, H., ZHI-PING, C. (2008): Nematode community structure under compost and chemical fertilizer management practice, in the north china plain. *Exp. Agr.*, 44:485 – 496. DOI: 10.1017/S0014479708006716
- CONN, K. L., LAZAROVITS, G. (1999): Impact of animal manures on *Verticillium* wilt, potato scab, and soil microbial population. *Can. J. Plant Pathol.*, 21: 81 – 92
- COOSEMANS, J. (1982): Influence of organic material on the population dynamics of *Meloidogyne hapla* Chitwood. *Agr. Wastes*, 4: 193 – 201
- D'ADDABBO, T. (1995): The nematicidal effect of organic amendments: a review of the literature, 1982 – 1994. *Nematol. Mediterr.*, 23: 299 – 305
- D'ADDABBO, T., FONTANAZZA, G., LAMBERTI, F., SASANELLI, N., PATUMI, M. (1997): The suppressive effect of soil amendments with olive residues on *Meloidogyne incognita*. *Nematol. Mediterr.*, 25, 195 – 198
- D'ADDABBO, T., SASANELLI, N. (1996a): Effect of olive pomace soil amendment on *Meloidogyne incognita*. *Nematol. Mediterr.*, 24: 91 – 94
- D'ADDABBO, T., SASANELLI, N. (1996b): The effect of olive pomace soil amendment on *Heterodera carotae*. *Nematol. Mediterr.*, 24: 205 – 207
- D'ADDABBO, T., SASANELLI, N. (1997): Suppression of *Meloidogyne incognita* by combinations of olive pomace or wheat straw with urea. *Nematol. Mediterr.*, 25: 159 – 164
- D'ADDABBO T., FONTANAZZA G., LAMBERTI, F., SASANELLI, N., PATUMI, M. (1997): The suppressive effect of soil amendments with olive residues on *Meloidogyne incognita*. *Nematol. Mediterr.*, 25: 195 – 198.
- D'ADDABBO, T., SASANELLI, N. (1998): The suppression of *Meloidogyne incognita* on tomato by grape pomace soil amendments. *Nematol. Mediterr.*, 26: 145 – 149
- D'ADDABBO, T., SASANELLI, N., COIRO, M. I. (1999): Suppression of *Xiphinema index* by olive and grape pomace. *Nematol. Mediterr.*, 27: 257 – 260
- D'ADDABBO, T., SASANELLI, N., LAMBERTI, F., CARELLA, A. (2000): Control of root-knot nematodes by olive and grape pomace soil amendment. *Acta Hortic.*, 532: 53 – 57
- D'ADDABBO, T., SASANELLI, N., LAMBERTI, F., GRECO, P., CARELLA, A. (2003): Olive pomace and chicken manure amendments for control of *Meloidogyne incognita* over two crop cycles. *Nematoptica* 33: 1 – 7
- D'ADDABBO, T., PAPAJOVÁ, I., SASANELLI, N., RADICCI, V. (2006): Suppressivity of selected composts on *Meloidogyne incognita*. In: Proceedings of the 12th Congress of the Mediterranean Phytopathological Union, Rodos, Greece, June 11 – 15, pp. 552 – 554
- D'ADDABBO, T., PAPAJOVÁ, I., SASANELLI, N., RADICCI, V., RENČO, M. (2011): Suppression of root-knot nematodes in potting mixes amended with different composted bio-wastes. *Helminthologia*, 48: 278 – 287. DOI: 10.2478/s11687-011-0039-x
- DAVEY, C. B. (1996): Nursery soil management – organic amendments. In: Landis, T.D.Douth, D.B. (Tech. Coordinators), *National Proceedings, Forest and Conservation Nursery Associations*. General Technical Report PNW-GTR-389: USDA Forest Service PNWRS, pp. 6 – 18
- DE BERTOLDI, M. (2008): Production and utilization of suppressive composts: environmental, food and health bene-

- fit. In: Insam H., Franke-Whittle & Goberna M. (Eds). Microbes at Work from Wastes to Resource. Pp. 153 – 170. DOI: 10.1007/978-3-642-04043-6_8
- DMOWSKA, E., KOZLOWSKA, J. (1988): Communities of nematodes in soil treated with semi-liquid manure. *Pedobiologia*, 32: 323 – 330
- EDWARDS, C. A., ARANCON, N. Q., EEMERSON, E., PULLIAM, R. (2007): Suppressing plant-parasitic nematodes and arthropod pests with vermicompost teas. *BioCycle*, 48: 38 – 39
- EISENBACK, J. D., TRIANTAPHYLLOU, H. H. (1991): Root-knot Nematodes: *Meloidogyne* species and races. In: Nickle, W. R. (Eds) *Manual of Agricultural Nematology*. Marcel Dekker, New York. pp 281 – 286
- EVERTS K. L., SARDANELLI S., KRATOCHVIL R. J., ARMENTROUT D. K., GALLAGHER L. E. (2006): Root-knot and root-lesion nematode suppression by cover crops, poultry litter, and poultry litter compost. *Plant Dis.*, 90: 487 – 492. DOI: 10.1094/PD-90-0487
- GARCÍA-ÁLVAREZ, A., ARIAS, M., DÍEZ-ROJO., BELLO, A. (2004): Effect of agricultural management on soil nematode trophic structure in a Mediterranean cereal system. *Appl. Soil. Ecol.*, 27: 197 – 210. DOI: 10.1016/j.apsoil.2004.06.002
- GERGON, E. B., MILLER, S. A., DAVIDE, R. G., OPINA, O. S., OBIEN, S. R. (2001): Evaluation of cultural practices (surface burning, deep ploughing, organic amendments) for management of rice root-knot nematode in rice - onion cropping system and their effect on onion (*Allium cepa* L.) yield. *Int. J. Pest Manage.*, 47: 265 – 272
- GONZALEZ, A., CANTO-SANENZ, M. (1993): Comparison of live organic amendments for the control of *Globodera pallida* in microplots in Peru. *Nemotropica* 23, 133 – 139
- GRIFFITHS, B. S., RITZ, K., WHEATLEY, R. E. (1994): Nematodes as indicators of enhanced microbiological activity in a Scottish organic farming system. *Soil Use Manage*, 10: 24 – 24
- GUTPA, M., KUMAR, S. (1997): Efficacy of certain organic amendments and nematicides against *Tylenchorhynchus* spp. and *Helicotylenchus* spp. in soil. *Indian J. Nematol.*, 27: 139 – 142
- HASSAN, J., CHISTHTI, M. Z., RASHEED, M., AHMAD, F. (2008): Nematodes Associated with *Brassica campestris* and Their Control. *World Appl. Sci. J.*, 5: 543 – 545
- INGHAM, R. E., TROFYMOW, J. A., INGHAM, E. R., COLEMAN, D. C. (1985): Interactions of bacteria, fungi, and their nematode grazers: Effects on nutrient cycling and plant growth. *Ecol. Monogr.* 55: 119 – 140
- JIOSHI, P. R., PATEL, H. R. (1995): Organic amendments in management of *Meloidogyne javanica* on groundnut. *Indian J. Nematol.*, 25: 76 – 78
- KAPLAN, M., NOE, J. P., HARTEL, P. G. (1992): The role of microbes associated with chicken litter in the suppression of *Meloidogyne arenaria*. *J. Nematol.*, 24: 522 – 527
- KAPLAN M., NOE J. P. (1993): Effect of chicken excrement amendments on *Meloidogyne arenaria*. *J. Nematol.*, 25: 71 – 77
- KHAN, A., RAJPUT, T., BILQEES, F. M. (1986): Influence of some fertilizers on plant parasitic nematodes. *Pakistan J. Zool.*, 18: 311 – 316
- KHAN, A., SHAUKAT, S. S. (1998): Effect of some organic amendments on density of nematodes associated with garlic (*Allium sativum* L.). *Appl. Entomol. Phytopathology*, 66: 13 – 19
- KHAN, A., SHAUKAT, S. S. (2000): Effect of some organic amendments and carbofuran on population density of four nematodes and growth and yield parameters of rice (*Oryza sattiva* L.) var. IRRI-6. *Pakistan J. Zool.*, 32: 145 – 150
- KHAN, A., SHAUKAT, S. S., QAMAR, F., ISLAM, S., HAKRO, A. A., JAFFRY, A. F. (2001): Management of Plant Parasitic Nematodes Associated with Chilli Through Organic Soil Amendments. *Pakistan J. Biol. Sci.*, 4: 417 – 418
- KIMPINSKI J., GALLANT C. E., HENRY R., MACLEOD J. A., SANDERSON J. B., STURZ A. V. (2003): Effect of compost and manure soil amendments on nematode and on yields of potato and barley: a 7-years study. *J. Nematol.*, 35: 289 – 293
- KOENNING, S. R., EDMISTEN, K. L., BARKER, K. R., BOWMAN, D. T., MORRISON, D. E. (2003): Effects of rate and time of application of poultry litter on *Hoplolaimus columbus* on cotton. *Plant Dis.*, 87: 1244 – 1249. DOI: 10.1094/PDIS.2003.87.10.1244
- KORAYEM, A. M. (2003): Effect of some organic wastes on *Meloidogyne incognita* development and tomato tolerance to the nematode. *Egypt. J. Phytopathol.*, 31: 119 – 127
- KOVÁČIK, P., UHER, A., LOŠÁK, T., TAKÁČ, P. (2008): The effect of quickly fermented pig manure on the broccoli yield parameters and selected soil parameters. *Acta Univ. Agric. et Silvitic. Mendel. Brun.*, 56: 119 – 124
- KOVÁČIK, P., KOZÁNEK, M., TAKÁČ, P., GALLIKOVÁ, M., VARGA, L. (2010): The effect of pig manure fermented by larvae of house flies on the yield parameters of sunflowers. *Acta Univ. Agric. Silvitic. Mendel. Brun.*, 58: 147 – 154
- KUNELIUS, H. T., CARTER, M. R., KIMPINSKI, J., SANDERSON, J. B. (1988): Effect of seeding methods on alfalfa and red clover establishment and growth, soil physical condition and nematode populations. *Soil Till. Res.*, 12: 136 – 175
- LAMONDIA, J. A., GENT, M. P. N., FERRANDINO, F. J., ELMER, W. H., STONER, K. A. (1999): Effect of compost amendment or straw mulch on potato early dying disease. *Plant Dis.*, 83: 361 – 366
- LEROUY, B. L. M. M., BOMMELE, L., REHEUL, D., MOENS, M., DE NEVE, S. (2007): The application of vegetable, fruit and garden waste (VFG) compost in addition to cattle slurry in a silage maize monoculture: Effect on soil fauna and yield. *Eur. J. Soil Biol.*, 43: 91 – 100. DOI: 10.1016/j.ejsobi.2006.10.005
- LÓPEZ-PÉREZ, J. A., ROUBTSOVA, T., PLOEG, A. (2005): Effect of three plant residues and chicken manure used as biofumigants at three temperatures on *Meloidogyne incognita* infestation of tomato in greenhouse experiments. *J. Nematol.*, 37: 489 – 494
- LÓPEZ-ROBLES, J., OLALLA, C., RAD, C., ARRIBAS, Y., NAVARRO, M., ISABEL LÓPEZ-FERNÁNDEZ J., GONZÁLEZ-CARCEDO, S. (2006): Use of different manures and organic

- wastes in the suppression of the cereal cyst nematode *Heterodera avenae* by biofumigation. 12th Ramiran International Conference, Technology for recycling of manure and organic residues in a whole-farm perspective, 11 – 13 September, The historic open-air museum “The Old Town”, Aarhus, Denmark
- MAISTRELLI, L., VACCARI, G., PAPAJOVÁ, I., SASANELLI, N. (2010): Controllo di *Meloidogyne javanica* mediante l’uso di tannini. *At. Giorn. Fitopatol.*, 1: 333 – 336
- MAAREG, M. F., SALEM, F. M., EBIEDA, E. M. (2000): Effect of certain organic and inorganic amendments on *Meloidogyne javanica* in sandy soil. *Egyptian Journal of Agronematology*, 4: 82 – 94.
- MANDAL, A., PATRA A. K., SINGH, D., SWARUP, A., MASTO, R. E. (2007): Effect of long-term application of manure and fertilizer on biological and biochemical activities in soil during crop development stages. *Biores. Technol.*, 98: 3585 – 1592. DOI: 10.1016/j.biortech.2006.11.027
- MATVEEVA, E. M., GRUZDEVA, L. I., KOVALENKO, T. E. (2002): Potato cyst nematode control by wastes of logging and wood industry. 2nd Conference Internationale sur les moyens alternatifs lutte contre les organismes nisibles aux vegetaux, Lille, 4 – 7 Mars, pp. 162 – 169
- MCSORLEY, R., FREDERICK, J. J. (1999): Nematode population fluctuation during decomposition of specific organic amendments. *J. Nematol.*, 31: 37 – 44
- MCSORLEY, R., GALLAHER, R. N. (1995): Effect of yard waste compost on plant-parasitic nematode densities in vegetable crops. *J. Nematol.*, 27: 545 – 549
- MCSORLEY, R., STANSLY, P. A., NOLING, J. W., OBREZA, T. A., CONNER, J. M. (1997): Impact of organic amendments and fumigation on plant-parasitic nematodes in a southwest Florida vegetable fields. *Nematropica*, 27: 181 – 189
- MIAN I. H., RODRÍGUEZ-KÁBANA R. (1982): Soil amendments with oil cakes and chicken litter for control of *Meloidogyne arenaria*. *Nematropica*, 12: 205 – 220
- MILLER, R. W., DONAHUE R. L. (1990): Organic matter and container media. Soils: An introduction to Soils and Plant Growth. 6th (Ed). Prentice Hall, Inc., Englewood Cliffs, N. J., U.S.A. 181 – 225pp
- MIN, Y. Y., SATO., SHIRAKASHI, T., WADA, S., TOYOTA, K., WATENABE, A. (2007): Suppressive effect of anaerobically digested slurry on the root-lesion nematode *Pratylenchus penetrans* and its potential mechanisms. *Jpn. J. Nematol.*, 37, 93 – 100
- NAHAR, M. S., GREWAL, P. S., MILLER, S. A., STINNER, D., STINNER, B. R., KLEINHENZ, M. D., WSZELAKI, A., DOOHAN, D. (2006): Differential effects of raw and composted manure on nematode community, and its indicative value for soil microbial, physical and chemical properties. *Appl. Soil Ecol.*, 34: 140 – 151. DOI: 10.1016/j.apsoil.2006.03.011
- NICO, A. I., JIMÉNEZ-DÍAZ, R. M., CASTILLO, P. (2004): Control of root-knot nematodes by composted agro-industrial wastes in potting mixtures. *Crop Prot.*, 23: 581 – 587. DOI: 10.1016/j.cropro.2003.11.005
- NOE, J. P. (1993): Damage functions and population changes of *Hoplolaimus Columbus* on cotton and soybean. *Journal of Nematology*, 25: 440 – 445
- OLABIYI, T. I., AKANBI, W. B., ADEPOJU, I. O. (2007): Control of certain nematode pests with different organic manure on cowpea. *American-Eurasian J. Agri. & Environ. Sci.*, 2: 523 – 527
- OKE, Y., KOLTAI, H., BAR-EYAL, M., MOR, M., SHARON, E., CHET, I., SPIEGEL, Y. (2000): New strategies for the control of plant parasitic nematodes. *Pest Manag. Sci.*, 56: 983 – 988
- OKE, Y., SHAPIRA, N., FINE, P. (2007): Control of root-knot nematodes in organic farming systems by organic amendments and soil solarization. *Crop Prot.*, 26: 1556 – 1565. DOI: 10.1016/j.cropro.2007.01.003
- OKE Y., YERMIYAHU U. (2002): Suppressive effect of compost against the root-knot nematode *Meloidogyne javanica* on tomato. *Nematology*, 4: 891 – 898
- ORISAO, S. B., AFOLAMI, S. O., FADEMI, O., ATUNGWU, J. J. (2008): Effects of poultry litter and carbofurane soil amendments on *Meloidogyne incognita* attacks on cacao. *J Appl. Biosci.*, 7: 214 – 221
- OTIEFA, B. A., ELGINDI O. N. (1962) Influence of parasitic duration of *Meloidogyne javanica* on host nutrient uptake. *Nematologica*, 8: 216 – 200
- PANDEY, G., SINGH, K. P. (1990): Effect of organic amendments on soil microflora and nematode fauna with specia reference to *Meloidogyne incognita* in chick pea. *New Egriulturist*, 1: 65 – 70
- RADWAN, M. A., EL-MAADAWY, E. K., KASSEM, S. I., ABU-ELAMAYEM, M. M. (2009) Oil cakes soil amendment effects on *Meloidogyne incognita*, root-knot nematode infecting tomato. *Arch. Phytopathol. Plant Prot.*, 42: 58 – 64. DOI: 10.1080/032354006009 40830.
- RENČO M., D'ADDABBO T., SASANELLI N., PAPAJOVÁ I. (2007): The effect of five compost of different origin on the survival and reproduction of *Globodera rostochiensis*. *Nematology*, 9: 537 – 543. DOI: 10.1163/156854107781487260
- RENČO M., SASANELLI N., ŠALAMÚN, P. (2009): The effect of two compost soil amendments based on municipal green and penicillin production wastes, on plant parasitic nematodes. *Helminthologia*, 46, 3: 190 – 197. DOI 10.2478/s11687-009-0035-6
- RENČO M., SASANELLI N., D'ADDABBO T., PAPAJOVÁ I. (2010): Soil nematode community changes associated with compost amendments. *Nematology*, 12: 681 – 692. DOI: 10.1163/138855409X12584413195491
- RENČO M., SASANELLI N., KOVÁČIK, P. (2011): The effect of soil compost treatments on potato cyst nematodes *Globodera rostochiensis* and *Globodera pallida*. *Helminthologia*, 48: 184 – 194. DOI: 10.2478/s11687-011-0027-1
- RENČO M., SASANELLI N., PAPAJOVÁ I., MAISTRELLI, L. (2012): The nematicidal effect of chestnut tannin solutions on the potato cyst nematode *Globodera rostochiensis* (Woll.) Barbens. *Helminthologia*, 49: 108 – 114. DOI: 10.2478/s11687-012-0022-1
- RIBEIRO, R. C. F., MIZOBUTSI, E. M., SILVA, D. G., PEREIRA, J. C. R., ZAMBOLIM, L. (1998): Control of

- Meloidogyne javanica* on lettuce with organic amendments. *Fitopatol. Bras.*, 23: 42 – 44
- RIEGEL, C., FERNANDEZ, F. A., NOE, J. P. (1996): *Meloidogyne incognita* infested soil amended with chicken litter. *J. Nematol.*, 28: 369–378
- RIEGEL, C., NOE J. P. (2000): Chicken litter soil amendment effects on soilborne microbes and *Meloidogyne incognita* on cotton. *Pl. Soil*, 100: 237 – 247
- RIGA, E., COLLINS, H. (2004): Green manure effects on *Meloidogyne chitwoodi* and *Paratrichodorus allius*, economically important nematodes of potatoes in the Pacific Northwest of the USA. *Agroindustria*, 3: 321 – 322
- RIGA, E., LACEY L., GUERRA, N (2007): The potential of the fungus *Muscador albus* as a bio-control agent against economically important plant-parasitic nematodes of potatoes in Washington State *J. Nematol.*, 39: 98 – 98
- RIGA, E. (2011): The effects of Brassica green manures on plant parasitic and free living nematodes used in combination with reduced rates of synthetic nematicides. *J Nematol.*, 43: 119 – 121
- RICH, J. R., RATH, G. S., OPPERMANN, G. H., DAVIS, E. L. (1989): Influence of the castor bean (*Ricinus communis*) lectin (ricin) on motility of *Meloidogyne incognita*. *Nemato-tropica*, 19: 99 – 103
- RIVERA, L., ABBALAY, E. (2008): Nematicide Effect of Variuos Organic Soil Amendments on *Meloidogyne ethiopica* Whitehead, 1968, on Potted Vine Plants. *Chil. J. Agric. Res.*, 68(3): 290 – 296. DOI: 10.4067/S0718-58392008000300009
- RODRÍGUEZ-KÁBANA, R. (1986): Organic and inorganic nitrogen amendments to soil as nematode suppressants. *J. Nematol.*, 18: 129 – 135
- RODRÍGUEZ-KÁBANA, R., MORGAN-JONES, G., CHET, I. (1987): Biological control of nematodes: soil amendments and microbial antagonists. *Pl. Soil*, 100: 237 – 247
- RYCKEBOER, J., COOSEMANS, J. (1996): The influence of the GFT-compost extracts on the motility of juveniles of *Heterodera schachtii* in vitro. *Med Fac Landbouww Univ Gent*, 60: 25 – 29
- SASANELLI, N. (1992): Nematicidal activity of aqueous extracts from leaves of *Ruta graveolens* on *Xiphinema index*. *Nematol. mediterr.*, 20: 53 – 55.
- SASANELLI, N. (2009): Olive nematodes and their control. In: CIANCIO, A., MUKERJI, K. G. (Eds) *Integrated management of fruits crops and forest nematodes*. Springer Science+Business Media B.V. pp. 275 – 315.
- SASANELLI, N., BASILE, M., LAMBERTI, F. (1997): Soil solarization for the control of *Ditylenchus dipsaci* on onion in Southern Italy. Second International Conference on Soil Solarization and Integrated Management of Soilborne Pests. March 16 – 21. ICARDA, Aleppo, Syria.
- SASANELLI, N., D'ADDABBO, T. (1992): The effect of *Cineraria maritima*, *Ruta graveolens* and *Tagetes erecta* extracts on the hatching of *Heterodera schachtii*. *Nematol. mediterr.*, 20: 49 – 51
- SASANELLI, N., D'ADDABBO, T. (1993): Effect of *Cineraria maritima*, *Ruta graveolens* and *Tagetes erecta* leaf and root extracts on Italian populations of *Meloidogyne* species. *Nematol. mediterr.*, 21: 21 – 25
- SASANELLI, N., D'ADDABBO, T. (1995): Effect of aqueous solutions of rutin on the beet cyst nematode *Heterodera schachtii*. *Nematol. mediterr.*, 23: 31 – 34
- SASANELLI, N., TAKÁCS, A., D'ADDABBO, T., BIRÓ, I., MALOV, X. (2009): Influence of arbuscular mycorrhizal fungi on the nematicidal properties of leaf extracts of *Thymus vulgaris* L. *Helminthologia*, 46: 230 – 240. DOI 10.2478/s11687-009-0043-6
- SASSER, J. N., CARTER, C. C. (1985): Overview of the International *Meloidogyne* Project 1975–1984. In: SASSER, J. N., CARTER, C. C. (Eds) *An Advanced Treatise on Meloidogyne*. Raleigh: North Carolina State University Graphics, 19 – 24
- SCHLANG, J. (1993): Controlling nematodes by composting. *DLG- Mitteilungen Agrar – Inform.*, 108: 30 – 31
- SHARMA, S. K., SHARMA, G. L., BAHETI, B. L. (1997): Management of root-knot nematode, *Meloidogyne incognita* on tomato through soil amendment with various composts. *Indian J. Nematol.*, 26: 263 – 265
- SHARMA, S. K., DA SILVA, J. E., RESCK, D. V. S., GOMES, A. (2000): Nematode population dynamics in sewage sludge amended soil under maize cultivation. *Nematol. Bras.*, 24: 37 – 40
- SPIEGEL, Y., CHET, I., COHN, E. (1987): Use of chitin for controlling plant parasitic nematodes. II. Mode of action. *Plant Soil*, 98: 337 – 345.
- STIRLING, G. R. (1991): *Biological control of plant-parasitic nematodes*. Wallingford, UK, CABI Publishing, 282 pp.
- SUBBA RAO, D. V., SITARAMAIAH, K., MAITI, S. (1996): Management of plant parasitic nematodes in betelvine gardens through non-chemicals methods. *Indian J. Nematol.*, 26: 93 – 97
- SUMNER, D. R., HALL, M. R., GAY J. D., MACDONALD, G., SAVAGE, S. I., BRAMWELL, R. K. (2002). Root diseases, weeds, and nematodes with poultry litter and conservation tillage in a sweet corn-snap bean double crop. *Crop Prot.*, 21: 963 – 972. DOI: 10.1016/S0261-2194(02)00075-3
- SUNDARARAJU P., MUSTAFFA, M. M., KUMAR, V., CANNAYANE I., TANUJA PRIYA, B. (2002): Effect of organic farming on plant-parasitic nematodes infesting banana cv. Karpuravalli, *Current Nematol.*, 13: 39 – 43
- SZCZECH, M., RONDOMANSKI, W., BRZESKI, M. W., SMOLINSKA, U., KOTOWSKI, J. F. (1993): Suppressive effect of a commercial earthworm compost on some root infecting pathogens of cabbage and tomato. *Biol. Agric. Hortic.*, 10: 47 – 52
- TESTER, C. F. (1990): Organic amendment effects on physical and chemical properties of a sandy soil. *Soil Sci. Soc. Am. J.*, 65: 827 – 831. DOI: 10.2136/sssaj1990.543827x
- TIMPER, P., NEWTON, G. L., JOHNSON, A. W., GASCHO, G. J. (2004): Nematode densities in year-round forage production systems utilizing manure fertilization. *Nemato-tropica* 34: 219 – 227
- VANNACCI, G., GULLINO, M. L. (2000): Use of biological agents against soil borne pathogens: Results and limitations. *Acta Hortic.*, 532: 79 – 87
- VALOCKÁ, B., DUBINSKÝ, P., PAPAJOVÁ, I., SABOVÁ, M.

- (2000): Effect of anaerobically digested pig slurry from lagoon on soil and plant nematode communities in experimental conditions. *Helminthologia*, 37: 53 – 57
- VALOCKÁ, B., SABOVÁ, M., DUBINSKÝ, P. (1999): Effect of anaerobically digested pig slurry on the structure of soil and plant nematode communities. *Ekologia* (Bratislava), 18: 134 – 142
- VAN DER LAAN, P. A. (1956): Influence of organic manuring on the development of the potato root eelworm, *Heterodera rostochiensis*. *Nematologica*, 1: 112 – 125
- VERMA, R. D., MAHENDRA, S., SAMAR, R., SHARMA, G. L. (1997): Effect of soil amendment against root-knot nematode (*Meloidogyne incognita*) on bottlegourd. *Indian J. Nematol.*, 27: 255 – 256.
- VIAENE, N. M., ABAWI, G. S. (1998). Management of *Meloidogyne hapla* on lettuce in organic soil with sudan-grass as a cover crop. *Plant Dis.*, 82: 945 – 952
- WANG, K. H., MCSORLEY, R., MARSHALL, A., GALLAHER, R. N. (2006): Influence of organic *Crotalaria juncea* hay and ammonium nitrate fertilizers on soil nematode communities. *Appl. Soil Ecol.*, 31: 186 – 198. DOI: 10.1016/j.apsoil.2005.06.006
- WANG, D., SHI, Q., WANG, X., WEI, M., HU, J., LIU, J., YANG, F. (2010): Influence of cow manure vermicompost on the growth, metabolite contents, and antioxidant activities of Chinese cabbage (*Brassica campestris* ssp. *chinensis*). *Biol. Fertil. Soils*, 46: 689 – 696. DOI 10.1007/s00374-010-0473-9
- WASILEWSKA, L. (1995): Direction of changes in communities of soil nematodes in mandisturbed ecosystems. *Acta Zool. Fennica*, 196: 271 – 274
- WEISS, B., LARINK, O. (1991): Influence of sewage sludge and heavy metals on nematodes in arable soil. *Biol. Fertil. Soils*, 12: 5 – 9
- YAO, S., MERWIN, I. A., ABAWI, G. S., THIES, J. E. (2006): Soil fumigation and compost amendment alter soil microbial community composition but do not improve tree growth or yield in an apple replant site. *Soil Biol. Biochem.*, 38: 587 – 599. DOI: 10.1016/j.soilbio.2005.06.026
- YING XIA, Z., QI ZHI, L., ZHI PING, C., WEN LIANG, W. (2003): Effect of fertilizer on population dynamics of plant parasitic nematodes. *Plant Prot.*, 29: 19 – 22
- YOUSSEF, M. M. A., EL-NAGDI, W.M.A. (2010): Effect of certain organic materials in controlling *Meloidogyne incognita* root-knot nematode infesting banana. *Arch. Phytopathol. Plant Prot.*, 43: 660 – 665
- ZUNKE, U., EISENBACK, J. D. (1998): Morphology and ultrastructure. In: SHARMA S. B. (Ed). *The Cyst nematodes*. Kluver Academy Publisher, London U.K., Pp. 31 – 56

RECEIVED OCTOBER 24, 2012

ACCEPTED DECEMBER 5, 2012