

Pathogenicity and control of *Heterodera schachtii* and *Meloidogyne* spp. on some cruciferous plant cultivars

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Abstract. The pathogenicity of the sugar beet cyst nematode *Heterodera schachtii* and the root-knot nematodes *Meloidogyne arenaria*, *M. incognita* and *M. javanica* on cabbage cvs. Balady, Brunswick and Ganzouri, cauliflower cv. Balady, turnip cv. Balady, and radish cv. Balady was determined in several greenhouse tests. The results showed that the tested cruciferous plant cultivars were either susceptible or highly susceptible to the tested nematodes except radish cv. Balady, which was moderately resistant to *H. schachtii* and moderately susceptible to the tested root-knot nematode species. Control of *H. schachtii* and *M. incognita* on cabbage cv. Balady was studied in the greenhouse. Soil treatments with dried plant material of marine algae (*Botryocladia leptopoda*, *Ulva fasciata*), castorbean, goosefoot and lantana greatly reduced the numbers of cysts of *H. schachtii* as well as root galls and egg masses of *M. incognita* on infected cabbage plants. Treatments with the tested marine algae were more effective in suppressing nematode infection and reproduction on cabbage plants than the other treatments. Also, soil treatments with Vertimec® (abamectin) and crude culture suspension and cell-free supernatant of *Bacillus thuringiensis* suppressed the numbers of *H. schachtii* cysts and root galls and egg masses of *M. incognita* developing on cabbage plants.

Keywords. Control, crucifer, Egypt, *Heterodera schachtii*, host, *Meloidogyne*, varietal resistance.

INTRODUCTION

In Egypt, plant-parasitic nematodes are among the most important agricultural pests. The cyst (*Heterodera* spp.) and root-knot (*Meloidogyne* spp.) nematodes constitute two of the most important pest groups of many economic field and vegetable crops (Ibrahim *et al.* 2010). *Heterodera* spp. are quite common and occur on several crop plants in northern Egypt (Ibrahim *et al.*, 1986, 2010). The sugar beet cyst nematode *H. schachtii* Schmidt, 1871 was found in Egypt on cabbage plants in El-Amria, Alexandria Governorate (Ibrahim and Handoo, 2007). Recently, in 2012 we isolated this nematode from a sugar beet field in El-Amria. Although *H. schachtii* is a very important parasite of sugar beet, investigations on the pathogenicity and control of this nematode on cruciferous crop plants have been somewhat limited (Abawi and Mai, 1983; Miller, 1986). In addition to the cyst nematodes, *Meloidogyne* spp. are among the most frequently encountered nematodes in Egypt, occurring in nearly two-thirds of the soil or plant samples recently surveyed (Ibrahim *et al.*, 2010). Although some studies exist on the host status of various Brassicaceae to root-knot nematodes (Khan and Khan, 1991; McSorley and

Frederick, 1995; Netscher and Sikora, 1990), little information exists on the host status of Egyptian crucifers to *Meloidogyne* spp., or control measures for them.

The objectives of the present study were to determine the pathogenicity of *H. schachtii*, *Meloidogyne arenaria* (Neal, 1889) Chitwood, 1949, *M. incognita* (Kofoid and White, 1919) Chitwood, 1949, and *M. javanica* (Treub, 1885) Chitwood, 1949 on some cabbage, cauliflower, turnip and radish cultivars; and to evaluate effects of plant-based soil amendments, the biocontrol agent *Bacillus thuringiensis* (Bt) and abamectin (Vertimec) in greenhouse tests in order to determine if they could reduce populations of root-knot nematode (*Meloidogyne incognita*), the most economically important nematode infecting cabbage cv. Balady in Egypt.

MATERIALS AND METHODS

An isolate of the cyst nematode *H. schachtii* was obtained from infected roots of cabbage in El-Amria, Alexandria, Egypt; the identity was confirmed based on morphology and morphometrics of cysts and juveniles according to the keys of Golden (1986) and Subbotin *et al.* (2010). This nematode was increased on cabbage cultivar

Table 1. Host status of certain cultivars of cabbage, cauliflower, turnip and radish to the cyst nematode *Heterodera schachtii*.^{x,y}

Cultivar	Treatment	No. of cysts/plant	Reaction	Dry weight (g)	
				Shoot	Root
Cabbage cv. Balady	<i>H. schachtii</i>	141	HS ^z	1.8 ^x b	1.8 ^x b
	Control	0		3.1 a	2.8 a
Cabbage cv. Brunswick	<i>H. schachtii</i>	124	HS	2.2 b	2.9 a
	Control	0		3.3 a	3.2 a
Cabbage cv. Ganzouri	<i>H. schachtii</i>	87	S	3.6 b	3.3 a
	Control	0		5.4 a	3.5 a
Cauliflower cv. Balady	<i>H. schachtii</i>	58	S	3.0 a	2.8 a
	Control	0		3.5 a	3.1 a
Turnip cv. Balady	<i>H. schachtii</i>	61	S	1.6 b	1.2 b
	Control	0		3.1 a	2.2 a
Radish cv. Balady	<i>H. schachtii</i>	24	MR	3.4 a	2.8 a
	Control	0		3.3 a	3.0 a

^xMeans of five replicates of two plants each.

^yMeans with the same letter in each column for each cultivar are not statistically different at $P \leq 0.05$.

^zMR = Moderately resistant, S = Susceptible, HS = Highly susceptible.

Balady in the greenhouse for 7-8 weeks, and then mature cysts were hand-picked from infected roots (Ayoub, 1980). Nematode eggs for experimental inoculations were obtained by crushing mature cysts.

Inocula of the root-knot nematodes *M. arenaria* race 1 originally isolated from peanut, and *M. incognita* race 1 and *M. javanica* originally isolated from eggplant were obtained from infected roots of tomato (*Solanum lycopersicum* L.) cultivar Rutgers grown in the greenhouse. Eggs of these nematode species were extracted from infected tomato roots with sodium hypochlorite (NaOCl) solution (Hussey and Barker, 1973).

The reactions of *Brassica oleracea* (cabbage) cvs. Balady, Brunswick and Ganzouri, *Brassica oleracea* (cauliflower) cv. Balady, *Brassica rapa* (turnip) cv. Balady, and *Raphanus sativus* (radish) cv. Balady to *H. schachtii*, *M. arenaria*, *M. incognita*, and *M. javanica* were determined in greenhouse tests. Seeds of three cabbage cultivars and one cultivar each of cauliflower, turnip and radish were sown in 12-cm-diameter plastic pots (0.75 litre) filled with equal portions of autoclave-sterilized sand and clay soil. After emergence, seedlings were thinned to two per pot. Four weeks after emergence, pots were inoculated with 5,000

eggs/pot of the tested nematode. Nematode eggs in water suspensions were added into holes in the soil around the roots of the tested plants. Non-inoculated pots served as controls. Treatments and controls were replicated five times. Pots were arranged in a randomized complete block design in a greenhouse at 20-26°C.

Experiments were terminated 45 days after inoculation, and roots were washed free of soil. The numbers of *H. schachtii* cysts, and root-knot nematode galls and egg masses were counted. Harvested plants were dried in an electric oven at 60°C for 48 hours, and the dry weights of the shoot and root systems were determined. Plants infected with *H. schachtii* were rated for susceptibility according to the numbers of cysts per plant. Plants with 0-10 cysts/plant were considered resistant, 11-30 cysts/plant moderately resistant, 31-50 cysts/plant moderately susceptible, 51-100 cysts/plant susceptible, and >100 cysts/plant highly susceptible (Golden *et al.*, 1970; Young, 1998).

Roots infected with root-knot nematodes were immersed in an aqueous solution of phloxine B (0.15g/L water) for 15 minutes to stain the nematode egg masses. Plants were rated on a 0-5 scale according to the numbers of egg masses (Taylor and Sasser, 1978). Plants with 0-2 egg masses/plant

Table 2. Host status of certain cultivars of cabbage, cauliflower, turnip and radish to the root-knot nematodes *Meloidogyne arenaria*, *M. incognita* and *M. javanica*.^{x,y}

Cultivar	Treatment	No. of galls/plant	No. of egg masses/plant	Reaction	Dry weight (g)	
					Shoot	Root
Cabbage cv. Balady	<i>M. arenaria</i>	78 b	75 b	S ^z	4.4 a	2.9 b
	<i>M. incognita</i>	121 a	128 a	HS	3.9 a	2.5 b
	<i>M. javanica</i>	82 b	82 b	S	3.6 a	2.8 b
	Control	0 c	0 c	-	4.6 a	4.4 a
Cabbage cv. Brunswick	<i>M. arenaria</i>	46 b	53 b	S	2.7 ab	2.4 ab
	<i>M. incognita</i>	76 a	77 a	S	2.5 ab	2.2 b
	<i>M. javanica</i>	52 b	50 b	S	2.1 b	2.0 b
	Control	0 c	0 c	-	3.2 a	3.1 a
Cabbage cv. Ganzouri	<i>M. arenaria</i>	72 a	63 a	S	2.8 c	2.2 b
	<i>M. incognita</i>	78 a	68 a	S	4.3 b	2.7 a
	<i>M. javanica</i>	69 a	60 a	S	4.2 b	2.4 b
	Control	0 b	0 b	-	5.4 a	3.5 a
Cauliflower cv. Balady	<i>M. arenaria</i>	74 b	88 b	S	2.0 b	1.7 b
	<i>M. incognita</i>	110 a	107 a	HS	2.2 b	1.9 ab
	<i>M. javanica</i>	63 c	64 c	S	2.4 ab	2.3 ab
	Control	0 d	0 d	-	2.9 a	2.4 a
Turnip cv. Balady	<i>M. arenaria</i>	46 b	49 b	S	2.8 b	2.3 b
	<i>M. incognita</i>	62 a	65 a	S	2.1 b	2.1 b
	<i>M. javanica</i>	51 b	52 b	S	2.8 b	2.5 b
	Control	0 c	0 c	-	4.2 a	3.4 a
Radish cv. Balady	<i>M. arenaria</i>	21 c	19 b	MS	1.0 b	0.9 b
	<i>M. incognita</i>	30 a	27 a	MS	1.0 b	0.9 b
	<i>M. javanica</i>	26 b	18 b	MS	0.9 b	0.8 b
	Control	0 d	0 c	-	1.5 a	1.2 a

^xMeans of five replicates of two plants each.

^yMeans with the same letter in each column for each cultivar are not statistically different at $P \leq 0.05$.

^zMS = Moderately susceptible, S = Susceptible, HS = Highly susceptible.

Table 3. Effects of soil amendment with the marine algae *Botryocladia leptopoda* and *Ulva fasciata* and the flowering plants *Ricinus communis*, *Chenopodium murale*, *Lantana camara* and *L. montevidensis* on *Heterodera schachtii* reproduction on cabbage cv. Balady.^{y,z}

Treatment	No. of cysts/plant	Reduction in cyst number (%)	Dry weight (g)	
			Shoot	Root
<i>B. leptopoda</i>	32 d	78	2.2 a	2.5 a
<i>U. fasciata</i>	34 d	77	2.4 a	2.7 a
<i>R. communis</i>	48 c	67	1.5 b	1.4 b
<i>C. murale</i>	52 c	64	1.4 b	1.7 b
<i>L. camara</i>	67 b	54	1.7 b	1.6 b
<i>L. montevidensis</i>	62 b	57	1.6 b	1.5 b
<i>H. schachtii</i>	146 a	-	1.7 b	1.6 b

^yMeans of five replicates of two plants each.

^zMeans with the same letter in each column are not statistically different at $P \leq 0.05$.

Table 4. Effects of soil amendment with the marine algae *Botryocladia leptopoda* and *Ulva fasciata* and the flowering plants *Ricinus communis*, *Chenopodium murale*, *Lantana camara* and *L. montevidensis* on *Meloidogyne incognita* reproduction on cabbage cv. Balady.^{y,z}

Treatment	No. of galls/plant	No. of egg masses/plant	Reduction %		Dry weight (g)	
			Galls	Egg masses	Shoot	Root
<i>B. leptopoda</i>	16 de	14 e	88	87	2.6 a	2.4 a
<i>U. fasciata</i>	11 e	12 e	91	89	2.6 a	2.3 a
<i>R. communis</i>	23 cd	22 d	82	79	2.1 ab	2 ab
<i>C. murale</i>	46 b	52 b	64	51	1.8 b	1.7 b
<i>L. camara</i>	28 c	31 c	78	71	1.8 b	1.5 b
<i>L. montevidensis</i>	30 c	28 cd	77	74	1.6 b	1.5 b
<i>M. incognita</i>	128 a	106 a	-	-	1.6 b	1.4 b

^yMeans of five replicates of two plants each.

^zMeans with the same letter in each column are not statistically different at $P \leq 0.05$.

Table 5. Effects of abamectin (Vertimec) and *Bacillus thuringiensis* (Bt) on *Heterodera schachtii* reproduction on cabbage cv. Balady.^{y,z}

Treatment	No. of cysts/plant	Reduction in cyst number (%)	Dry weight (g)	
			Shoot	Root
Vertimec 100 µg/ml 10 ml (1.8 µg/ml abamectin)	53 c	68	2.48 a	2.2 abc
Vertimec 200 µg/ml 10 ml (3.6 µg/ml abamectin)	14 e	92	2.58 a	2.34 ab
Bt 7N culture suspension 10 ml	71 b	58	2.54 a	2.28 ab
Bt 7N culture suspension 20 ml	24 d	86	2.62 a	2.18 bc
Bt 7N supernatant 10 ml	66 b	61	2.06 b	1.96 cde
<i>H. schachtii</i>	108 a	-	1.6 c	1.33 f

^yMeans of five replicates of two plants each.

^zMeans with the same letter in each column are not statistically different at $P \leq 0.05$.

Table 6. Effects of abamectin (Vertimec) and *Bacillus thuringiensis* (Bt) on *Meloidogyne incognita* reproduction on cabbage cv. Balady.^{y,z}

Treatment	No. of galls/plant	No. of egg masses/plant	% Reduction		Dry weight (g)	
			Galls	Egg masses	Shoot	Root
Vertimec 100µg/ml 10ml (1.8 µg/ml abamectin)	91 c	59 bc	40	58	2.9 ab	2.6 ab
Vertimec 200µg/ml 10ml (3.6 µg/ml abamectin)	18 e	3 e	88	98	3.06 a	2.72 ab
Bt 7N culture suspension 10ml	107 b	38 cd	29	73	2.92 ab	2.68 ab
Bt 7N culture suspension 20ml	52 d	11 e	66	92	3.1 a	2.64 ab
Bt 7N supernatant 10ml	106 b	37 cd	30	74	2.56 cd	2.30 bc
<i>M. incognita</i>	151 a	142 a	-	-	2.36 d	2.04 c

^yMeans of five replicates of two plants each.

^zMeans with the same letter in each column are not statistically different at $P \leq 0.05$.

were considered resistant; 3-10 egg masses/plant, moderately resistant; 11-30 egg masses/plant, moderately susceptible; 31-100 egg masses/plant, susceptible; and >100 egg masses/plant, highly susceptible (Taylor and Sasser, 1978).

Several soil amendments were examined in the greenhouse for their effects on the reproduction of *H. schachtii* and *M. incognita* on cabbage cv. Balady. These included dry material from marine algae (*Botryocladia leptopoda* (Agardh) Kylin and *Ulva fasciata* Delile) collected from the coast of the Mediterranean Sea in Alexandria, Egypt; leaves of castorbean (*Ricinus communis* L.) and shoots of the goosefoot (*Chenopodium murale* L.), and lantana (*Lantana camara* L. and *L. montevidensis* (Spreng.) Briq.) were collected from the Agricultural Experiment Station of Alexandria University in Abees, Alexandria, Egypt. The tested plant materials were dried in an electric oven at 60°C for 48h and then ground into a powder by an electric grinder. Plastic pots (15-cm diameter) were incorporated into the upper part of the soil of treated pots. The tested marine algae were added to the soil of treated pots at the rate of 3% (30 g/pot), while the other tested plant materials were added at the rate of 2% (20 g/pot). Two four-week-old cabbage seedlings were transplanted into each pot. One week after transplanting, pots

were inoculated with the tested nematodes at the rate of 5,000 nematode eggs/pot. Treatments were replicated five times. Pots were arranged in a randomized complete block design in a greenhouse at 20-26°C.

Experiments were terminated 45 days after soil inoculation. Roots were washed free of soil. The numbers of *H. schachtii* cysts and *M. incognita* galls and egg masses were determined, along with the dry weights of the shoots and roots.

In another greenhouse test, the effects of the biocontrol agent *Bacillus thuringiensis* Berliner (Bt) and the bionematicide Vertimec® (1.8% EC abamectin) on *H. schachtii* and *M. incognita* on cabbage plants cv. Balady were determined. The available Egyptian isolate of Bt 7N (Mohammad *et al.*, 2008) used in this study was obtained from the Agricultural Genetic Engineering Research Institute (AGERI), Agricultural Research Center, Ministry of Agriculture, Giza, Egypt. The Bt 7N isolate was cultured on T3 broth liquid medium for 72 hrs at 30°C (Travers *et al.*, 1987). The suspension of Bt was placed in sterilized Eppendorf tubes and centrifuged at 13,000 rpm for 15 min using ultracentrifugation to obtain cell-free supernatant, which was transferred to another glass tube and used for soil treatments. Clay pots with a 15-cm diameter were filled with

1 kg of equal portions of autoclave-sterilized sand and clay soil. Two one-month-old seedlings of cabbage cv. Balady were transplanted into each prepared pot, and seven days after transplanting, pots were inoculated with either *H. schachtii* or *M. incognita* at the rate of 5,000 eggs/pot added into holes in the soil around plant roots. One day after soil inoculation, the following biocontrol materials were applied into 5 cm deep holes in the soil of nematode treated pots: Vertimec solution at concentrations of 100 µg/ml and 200 µg/ml (1.8 and 3.6 µg/ml abamectin) and a volume of 10 ml/pot each, Bt culture suspension at volumes of 10 ml and 20 ml/pot, and supernatant of *B. thuringiensis* at the rate of 10 ml/pot. Treatments were replicated five times. Pots were arranged in a randomized complete block design in a greenhouse at 20-26°C. Plants were harvested 45 days after nematode inoculation. Roots were washed free of soil, the numbers of galls and nematode egg masses and cysts were enumerated, and the shoot and root dry weights were determined as in the previous test.

Analysis of variance (ANOVA) was performed on the numbers of *H. schachtii* cysts, root galls and egg masses of *Meloidogyne* spp. and the dry weights of the shoot and root systems of the tested plants, using the statistical analysis system (SAS) (SAS Institute, 1988).

RESULTS AND DISCUSSION

Cabbage cvs. Balady and Brunswick were highly susceptible to *H. schachtii*, as great numbers of nematode cysts (124-141 cysts/plant) developed on the infected plants (Table 1). Cabbage cv. Ganzouri, cauliflower cv. Balady and turnip cv. Balady were susceptible to *H. schachtii*. On the other hand, radish cv. Balady was moderately resistant to *H. schachtii*. Infection with *H. schachtii* significantly reduced the dry weight of the shoots and roots of cabbage cv. Balady and turnip cv. Balady, and the dry weights of shoots of cabbage cvs. Brunswick and Ganzouri. These results agree with those of previous studies that showed *H. schachtii* is of major economic importance on many crops such as beet, cabbage, cauliflower, radish and turnip (Evans and Rowe, 1998; Netscher and Sikora, 1990).

Cabbage cv. Balady was highly susceptible to *M. incognita* and susceptible to *M. arenaria* and *M. javanica*, and cabbage cvs. Brunswick and Ganzouri were susceptible to the tested root-knot nematode species (Table 2). Inoculation of *M. incognita* on the tested cabbage cultivars produced great numbers of galls (76-121 per plant) and egg masses (68-128 per plant), followed by the two other species: *M. javanica* infection with 50-82 galls or egg masses/plant and *M. arenaria* with 46-78 galls or egg masses/plant. Additionally, cauliflower cv. Balady was highly susceptible to *M. incognita* and susceptible to *M. arenaria* and *M. javanica*. Turnip cv. Balady and radish cv. Balady were susceptible and moderately susceptible to the tested root-knot nematodes, respectively. A range of diverse crucifers was also found to be susceptible to these three *Meloidogyne*

species (McSorley and Frederick, 1995.)

Infection with all the tested root-knot nematodes significantly reduced the root dry weight of cabbage cv. Balady, while infection with *M. incognita* and *M. javanica* reduced the root dry weight of cabbage cv. Brunswick. The shoot dry weight of cabbage cv. Brunswick was reduced by *M. javanica* infection, and the shoot dry weight of cabbage cv. Ganzouri was reduced by infection with all the tested root-knot nematodes. Infection with *M. arenaria* significantly reduced the shoot and root dry weights of the tested cauliflower, turnip and radish cultivars. Inoculation with *M. incognita* and *M. javanica* significantly decreased the shoot and dry weights of turnip cv. Balady and radish cv. Balady, while infection with *M. incognita* decreased the shoot dry weight of cauliflower cv. Balady.

Table 3 shows the effects of soil treatments with dried materials of marine algae, castorbean, goosefoot, and lantana on *H. schachtii* infection of cabbage cv. Balady. All treatments greatly reduced the numbers of nematode cysts relative to control plants. Treatments with the marine algae *B. leptopoda* and *U. fasciata* were the most effective, reducing the numbers of *H. schachtii* cysts by 77-78%. Moreover, these treatments significantly increased the dry weights of shoots and roots of cabbage plants compared to the other treatments and controls.

Table 4 displays the effects of the tested dried plant amendments on *M. incognita* infection of cabbage cv. Balady. All treatments significantly suppressed the numbers of root galls and egg masses of *M. incognita* on inoculated cabbage plants. The two dried marine algae amendments resulted in great reductions (87-91%) in the numbers of nematode root galls and egg masses, followed by treatments with castor bean (79-82%) and lantana (71-78%). On the other hand, treatments with goosefoot shoots induced the least reduction (51-64%) in the numbers of root galls and egg masses.

Paracer *et al.* (1987) demonstrated that *Botryocladia occidentalis* suppressed root-knot nematode gall formation when incorporated into soil, and lipophilic extracts of *B. leptopoda* are toxic to the mammalian-parasitic nematodes *Acanthocheilonema viteae*, *Brugia malayi* and *Litomosoides sigmodontis* (Lakshmi *et al.*, 2004). Only the marine algae treatments significantly increased the dry weights of shoots and roots of cabbage plants compared to the other treatments and control. These results are in accordance with many previous investigations of plant amendments as nematode control agents, in which control is often inconsistent and influenced by the amendment composition and soil type (Oka, 2010). Although amendments may provide control phytochemically, biologically or physically (Oka, 2010), the observed suppression of galling in our experiments is consistent with the previously observed suppression of *M. arenaria* hatching by aqueous extracts of *B. leptopoda* and *U. fasciata* (Shahda *et al.*, 1998). Among the higher plant species that reduced cyst, gall, or egg mass numbers, aqueous extracts of *C. murale* inhibited hatching of

M. incognita (Tabil and Walia, 1996; Usman and Siddiqui, 2011), and amendment of soil with a dried shoot preparation also inhibited galling of tomato (Kanwar and Walia, 2002). Amendment with *L. camara* inhibited *M. javanica* reproduction on tomato (Ahmad *et al.*, 2010a); leaf extracts paralyzed *M. incognita* juveniles (Ahmad *et al.*, 2010b), as did two flavonoids and five triterpenoids isolated from leaves (Begum *et al.*, 2000; Qamar *et al.*, 2005). Castorbean seeds have been evaluated more frequently than leaves for nematode antagonism, leaves or their extracts inhibit reproduction or movement of *M. javanica* or *M. arenaria* (Almeida *et al.*, 2012; Shahda *et al.*, 1998; Zaki and Bhatti, 1990).

Table 5 shows the effects of soil treatments with Vertimec® (abamectin) and *B. thuringiensis* culture suspension and supernatant on *H. schachtii* infection of cabbage *cv.* Balady. All abamectin and *B. thuringiensis* treatments greatly reduced the number of nematode cysts compared to controls. Treatments with Vertimec® at a concentration of 200 µg/ml (3.6 µg/ml abamectin) and the culture suspension of *B. thuringiensis* at a volume of 20 ml gave the highest reduction in nematode cysts, 92% and 86%, respectively. On the other hand, treatment with the culture suspension of *B. thuringiensis* at a volume of 10 ml induced the least reduction (58%) in the number of nematode cysts. All the applied abamectin and *B. thuringiensis* treatments significantly increased the dry weights of shoot and root systems of cabbage plants compared to control plants.

Table 6 shows that all abamectin and *B. thuringiensis* treatments suppressed the numbers of *M. incognita* root galls and egg masses on the treated cabbage plants compared to controls. Treatment with abamectin at a concentration of 200 µg/ml was the most effective, as it reduced root galls and egg masses by 88% and 98%, respectively, followed by treatment with *B. thuringiensis* culture suspension at a volume of 20 ml, which resulted in 66% and 92% reduction in root galls and egg masses, respectively. Treatments with abamectin and *B. thuringiensis* (except at 10 ml) culture suspension significantly increased the dry weights of the shoot and root systems of the treated cabbage plants compared to controls. These findings are in agreement with those of other workers who indicated that abamectin and *B. thuringiensis* can be used successfully to control some plant-parasitic nematodes (Cabrera *et al.*, 2009; Faske and Starr, 2007; López-Pérez *et al.*, 2011, Radwan *et al.*, 2004, and Zuckerman *et al.*, 1993). Abamectin applied as a seed treatment is a very promising technology for the control of root-knot nematodes in the field, since only low amounts of active ingredient are required to provide adequate protection in the most sensitive stages of tomato root growth and development at a location in close proximity to the developing root system (Cabrera *et al.*, 2009; Faske and Starr, 2007). More recently, López-Pérez *et al.* (2011) concluded that abamectin may be useful to control root-knot infections in stone wool-grown crops when applied at planting. The field and greenhouse efficacy of *B. thuringiensis* (Bt) in reducing root-knot nematode galling has been known for decades (Zuckerman *et al.*, 1993); more recently, the toxicity of Bt crystal (Cry) proteins

toward many nematode species has led to the generation of Cry-expressing transgenic plants with resistance to root-knot nematodes (Wei *et al.*, 2003; Li *et al.*, 2007). In recent studies of 70 *B. thuringiensis* isolates from Iran, Salehi Jouzani *et al.* (2008) discovered a wide range of nematode-specific toxin genotypes in 20 isolates via PCR analysis with *cry*-gene-specific primers. Similar studies with strains collected in Egypt would be fascinating and could lead to the discovery of improved biocontrol of cyst and root-knot nematodes under natural field conditions.

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