REACTIONS OF SOME SPINACH, SWISS CHARD, AND TABLE BEET CULTIVARS TO THE CYST NEMATODES *HETERODERA SCHACHTII* AND *H. TRIFOLII*

I. K. A. Ibrahim[1], Z. A. Handoo[2]*, S. M. A., Zeyadah[1], M. Kantor[2] and M. A. I. Kawanna[1]

[1]Department of Plant Pathology, Faculty of Agriculture, Alexandria University, Alexandria, Egypt; [2]Mycology and Nematology Genetic Diversity and Biology Laboratory, USDA, ARS, Beltsville, MD 20705, USA; *Corresponding author: zafar.handoo@usda.gov

ABSTRACT

Ibrahim, I. K. A., Z. A. Handoo, S. M. A., Zeyadah, M. Kantor, and M. A. I. Kawanna. 2021. Reactions of some spinach, swiss chard and table beet cultivars to the cyst nematodes *Heterodera schachtii* and *H. trifolii*. Nematropica 51:78-84.

The reactions of five spinach, four table beet, and two Swiss chard cultivars to infection with the cyst nematodes *Heterodera schachtii* and *H. trifolii* were studied under greenhouse condition. The results showed that the cultivars of spinach ('Balady', 'Barkly', 'Orient', 'Solanicy', 'Pacific'), table beet ('Balady', 'Detroit Dark Red', 'Detroit Spainal', 'Asgro Wonder') and Swiss chard ('Balady', 'Ford Hook') tested were susceptible or highly susceptible to *H. schachtii* while spinach 'Pacific' was moderately susceptible to this nematode. Reactions of the tested spinach, table beet and Swiss chard cultivars to *H. trifolii* indicated that only spinach 'Balady', table beet 'Balady' and 'Detroit Dark Red', and Swiss chard 'Balady' were susceptible whereas the other tested cultivars showed moderately susceptible and moderately resistant reactions to this nematode. Nematode infection with either *H. schachtii* or *H. trifolii* caused significant reductions in the shoot and root dry weights of the susceptible and highly susceptible spinach, table beet, and Swiss chard cultivars. This is the first study in Egypt on the pathogenicity of the cyst nematodes *H. schachtii* and *H. trifolii* on spinach, Swiss chard, and table beet.

Key words: cyst nematodes, Egypt, *Heterodera schachtii*, *H. trifolii*, pathogenicity, spinach, Swiss chard, table beet

RESUMEN

Ibrahim, I. K. A., Z. A. Handoo, S. M. A., Zeyadah, M. Kantor, and M. A. I. Kawanna. 2021. Reacciones de algunos cultivares de espinacas, acelga y remolacha de mesa a los nematodos formadores de quistes es *Heterodera schachtii* y *H. trifolii*. Nematropica 51:78-84.

Las reacciones de cinco cultivares de espinaca, cuatro de remolacha de mesa y dos de acelga a la infección por los nematodos formadores de quistes, *Heterodera schachtii* y *H. trifolii* fueron estudiadas bajo condiciones de invernadero. Los resultados mostraron que los cultivares evaluados de espinaca ('Balady', 'Barkly', 'Orient', 'Solanicy', 'Pacific'), de remolacha de mesa ('Balady', 'Detroit Dark Red', 'Detroit Spainal', 'Asgro Wonder') y de acelga ('Balady', 'Ford Hook') fueron susceptibles o altamente susceptibles a *H. schachtii*, mientras que espinaca 'Pacific' fue moderadamente susceptible a este nematodo. Las reacciones a los cultivares evaluados de espinaca, remolacha de mesa y acelga a *H. trifolii* indicaron que solamente espinaca 'Balady', las remolachas de mesa 'Balady' y 'Detroit Dark Red', y la acelga 'Balady' fueron susceptibles, mientras que los otros cultivares evaluados mostraron reacciones

moderadamente susceptibles y moderadamente resistentes a este nematodo. La infección con el nematodo sea *H. schachtii* o *H. trifolii* causaron reducciones significativas en peso seco de parte aérea y raíces en los cultivares de espinaca susceptibles o altamente susceptibles, remolacha de mesa y acelga. Este es el primer estudio en Egipto en la patogenicidad de los nematodos formadores de quistes H. schachtii y H. trifolii en espinaca, acelga y remolacha de mesa.

Palabras clave: nematodos formadores de quistes, Egipto, *Heterodera schachtii*, *H. trifolii*, patogenicidad, espinaca, acelga, remolacha de mesa

INTRODUCTION

In Egypt, plant-parasitic nematodes especially cyst (*Heterodera* spp.) and root-knot (*Meloidogyne* spp.) nematodes are considered among the most important plant pests on many crop plants (Ibrahim *et al*., 2000, 2010, 2017; Ibrahim and Handoo, 2007, 2016). Spinach (*Spinacia oleracea* L.), Swiss chard (*Beta vulgaris var. cicle* (L.) Moq.), and table beet (*Beta vulgaris* L.) are members of Chenopodiaceae and are considered important vegetable crops for their nutritional and economical values. Recent surveys demonstrated the occurrence of 15 genera of plant-parasitic nematodes associated with spinach, Swiss chard, and table beet crops grown in the Nile Delta and northwest governorates in Egypt (Basyony *et al*., 2020). The cyst nematodes *H. schachtii* and *H. trifolii* and root-knot nematodes *Meloidogyne incognita* and *M. javanica* were common on the surveyed plants. Plant-parasitic nematodes such as *Helicotylenchus labiatus, H. schachtii, M. hapla*, *M. incognita*, *M. javanica,* and *Pratylenchus penetrans* have also been reported to occur and/or infect spinach, garden beet, and other similar vegetable crops (Partyka, 1969; Olthof *et al*., 1974; Potter and Olthof, 1974; Knight *et al*. 1997; Castillo and Jimenez-Diaz, 2003; Ibrahim *et al*., 2013; Manachini *et al*., 2003; Premachandra and Gowen, 2015; Basyony *et al*., 2020).

Little information is available on the pathogenicity of plant-parasitic nematodes on spinach and other similar vegetable crops (Olthof and Potter, 1973; Steele *et al*., 1983; Castillo and Jimenez-Diaz, 2003; Manachini *et al*., 2003; Premachandra and Gowen, 2015). Therefore, the objectives of the present research were to study the effects of infection with *H. schachtii* and *H. trifolii* on some plant cultivars of spinach, Swiss chard and table beet under greenhouse conditions.

MATERIALS AND METHODS

Isolates of *H. schachtii* and *H. trifolii* were obtained from infected roots of spinach plants grown in Kafr El-sheikh governorate, Egypt. Eggs and second stage juveniles (J2) of *H. schachtii* and *H. trifolii* were increased on cabbage 'Balady' and Egyptian clover (*Trifolium alexandrum* L.), respectively, in the greenhouse for 8 wk and then mature cysts were collected from infected roots (Ayoub, 1980).

The reactions of five spinach (Balady, Barkly, Orient, Pacific, Solanicy), two Swiss chard (Balady, Ford Hook), and four table beet cultivars (Balady, Detroit Dark Red, Detroit Spainal, Asgro Wonder) to *H. schachtii* and *H. trifolii* were determined in several greenhouse tests. Seeds of the tested plant cultivars were sown in 15-cm-diam. clay pots filled with a mixture of equal volumes of steam-sterilized sand and clay soil. After emergence, seedlings were thinned to one seedling/pot. Two weeks after emergence, plants were infested with nematodes by creating holes near the plant roots and then adding an initial population (Pi) of 16 cysts/pot of *H. schachtii* or *H. trifolii.* Non-inoculated plants served as the control. All treatments were replicated five times. Pots were arranged in a randomized complete block design in a greenhouse maintained at 20-26^{o}C. The experiments were conducted twice in 2019 and 2020.

Sixty days after inoculation, experiments were terminated. Roots were washed free of soil and numbers of cysts were counted in infected roots. Final population density (Pf) estimates of *H. schachtii* and *H. trifolii* in the collected root samples represented total cysts containing eggs. The tested cultivars were rated on a 0 to 5 scale for nematode reproduction factor (Rf) = Pf/Pi. Plants with Rf = 0 were considered resistant, Rf = 0.1-0.5

moderately resistant, Rf = 0.6-1.0 moderately susceptible, Rf = 1.1-5.0 susceptible and Rf >5 highly susceptible (Ibrahim *et al*., 2019). The dry weights of the shoots and roots of the tested cultivars were determined by drying the plant material in an oven at 60ºC for 48 hr. Data of Pf (numbers of cysts/pot) of *H. schachtii* and *H. trifolii* and the dry weights of the shoots and roots of the tested spinach, Swiss chard and table beet cultivars were analyzed with analysis of variance (ANOVA) and means separated with least significant difference test (LSD; SAS Institute, 1997).

RESULTS

Results obtained from experiments in 2019 were similar to those in 2020 (Tables 1-4). The reactions of the tested spinach, Swiss chard, and table beet cultivars to infection by *H. schachtii* are presented in Table 1. Spinach 'Balady', 'Barkly', 'Orient' and 'Solanicy' were susceptible to *H. schachtii* with Rf = 1.11 - 4.95 while 'Pacific' was moderately susceptible. Swiss chard 'Balady' and 'Ford Hook' had a susceptible reaction to *H. schachtii* with Rf = 1.12 - 3.93. Table beet 'Balady', 'Detroit Dark Red' and 'Detroit Spainal' were highly susceptible to *H. schachtii* with Rf = 5.65 - 7.83 while 'Asgro Wonder' was susceptible. Nematode infection resulted in notable reductions in shoot and root dry weights of the susceptible and highly susceptible spinach, Swiss chard, and table beet cultivars (Table 2).

The reactions of the tested spinach, Swiss chard, and table beet cultivars to infection with *H. trifolii* are presented in Table 3. Spinach 'Balady' was susceptible and 'Barkly', 'Orient', and 'Pacific' were moderately susceptible with Rf = 0.82 – 2.16, while 'Solanicy' was moderately resistant to *H. trifolii*. Table beet 'Balady' and 'Detroit Dark Red' were susceptible to *H. trifolii* with Rf = 1.1-1.4 while 'Detroit Spainal' was moderately susceptible and 'Asgro Wonder' was moderately resistant. Swiss chard 'Balady' was susceptible to *H. trifolii* and 'Ford Hook' had a moderately resistant reaction to *H. trifolii* with Rf = 1.38-0.43, respectively. Nematode infection caused significant reductions in the shoot and root dry weights of the susceptible spinach, Swiss

Table 1. Reaction of spinach, Swiss chard, and table beet cultivars to the cyst nematode *Heterodera schachtii*.

	Season 2019			Season 2020		
Plant cultivar	No. of cysts/pot[w]	Rf[x]	Host reaction[y]	No. of cysts/pot[w]	Rf[x]	Host reaction[y]
Spinach:						
Balady	78.60 a[z]	4.93	S	72.20 a	4.95	S
Barkly	18.40 d	1.15	S	17.80 d	1.11	S
Orient	30.20 b	1.89	S	28.80 b	1.80	S
Salonicy	24.80 c	1.55	S	23.60 c	1.47	S
Pacific	12.80 e	0.80	MS	13.00 e	0.81	MS
Table beet:						
Balady	130.20 a	8.14	HS	125.40 b	7.83	HS
Detroit Dark Red	108.60 b	6.79	HS	110.40 b	6.90	HS
Detroit Spainal	92.40 c	5.78	HS	90.40 c	5.65	S
Asgro Wonder	43.80 d	2.74	S	42.80 d	2.67	S
Swiss chard:						
Balady	64.60 a	4.04	S	63.00 a	3.93	S
Ford Hook	19.20 b	1.20	S	17.80 b	1.12	S

[w]Means are the average of five replicates.
[x]Rf (reproduction factor) = Final population (Pf) / initial population (Pf/Pi) Pi = 16 cysts/pot.
[y]HS = Highly susceptible, MS= Moderately susceptible, S = Susceptible.
[z]Means with the same letter within a column for each cultivar are not significantly different at $P = 0.05$ according to the LSD procedure.

Table 2. Reaction of some spinach, table beet, and Swiss chard cultivars to infection with *Heterodera schachtii*.

		Season 2019		Season 2020	
		Dry weight (g)[y]		Dry weight (g)	
Cultivar	*H. schachtii*	Shoot	Root	Shoot	Root
Spinach:					
Balady	+	3.64 b[z]	1.91 b	3.72 b	1.84 b
Balady	-	5.02 a	2.48 a	4.88 a	2.36 a
Barkly	+	3.28 b	1.70 b	3.41 b	1.63 b
Barkly	-	4.10 a	2.42 a	4.04 a	2.35 a
Orient	+	4.48 b	2.16 b	4.70 b	2.21 b
Orient	-	5.50 a	2.94 a	5.36 a	2.81 a
Salonicy	+	5.12 b	2.42 b	5.23 b	2.36 b
Salonicy	-	5.74 a	3.10 a	5.62 a	2.98 a
Pacific	+	6.58 a	2.88 a	6.69 a	2.84 a
Pacific	-	6.80 a	3.06 a	6.92 a	3.15 a
Table beet:					
Balady	+	14.10 b	10.12 b	13.84 b	9.32 b
Balady	-	19.32 a	15.80 a	19.44 a	15.45 a
Detroit Dark Red	+	14.26 b	10.64 b	14.00 b	10.28 b
Detroit Dark Red	-	22.08 a	17.94 a	22.50 a	18.33 a
Detroit Spainal	+	18.86 b	14.16 b	19.01 b	14.03 b
Detroit Spainal	-	24.40 a	19.88 a	24.18 a	20.00 a
Asgro Wonder	+	10.38 b	8.56 b	10.69 b	8.74 b
Asgro Wonder	-	12.82 a	10.06 a	12.30 a	9.93 a
Swiss chard:					
Balady	+	4.08 b	2.10 b	3.93 b	1.99 b
Balady	-	5.62 a	3.04 a	5.32 a	2.85 a
Ford Hook	+	6.58 b	3.13 b	6.79 b	3.07 b
Ford Hook	-	7.94 a	3.88 a	7.87 a	3.73 a

[y]Means are the average of five replicates.
[z]Means with the same letter within a column for each cultivar are not significantly different at $P = 0.05$ according to the LSD procedure.

chard, and table beet cultivars (Table 4).

DISCUSSION

This research demonstrated that most of the chenopodiaceous plant cultivars tested were susceptible and good hosts for *H. schachtii*. The results support earlier studies indicating that *H. schachtii* can infect and reproduce on some cabbage, cauliflower, and turnip cultivars (Ibrahim *et al*., 2013). A previous study by Partyka (1969) showed the occurrence of *H. schachtii* on garden red beet in Ohio, USA. *Heterodera schachtii* significantly decreased shoot and root dry weights of the susceptible and highly susceptible spinach, Swiss chard and garden beet cultivars. Similar results were obtained by Ibrahim *et al.* (2013), who found that infection with *H. schachtii* reduced growth of some cabbage, cauliflower, and turnip cultivars. Losses in marketable yields of spinach were 29% and 35%, respectively, at densities of 6,000 and 18,000 *H. schachtii* J2/kg of soil (Olthof *et al.,* 1974). In sugar beets, yield losses due to nematode damage can range from 10-80% (Hafez and Seyedbagneri, 1997). *Heterodera schachtii* alone can cause yield losses of up to 25% and is considered the most important pest in sugar beet production worldwide (Amiri *et al.,* 2002).

Results of the pathogenicity tests with *H. trifolii* showed that the tested spinach, Swiss chard, and table beet cultivars were either moderately susceptible or moderately resistant to this nematode except spinach 'Balady' and table beet 'Balady' and 'Detroit Dark Red', which were susceptible. Infection by *H. trifolii* significantly reduced the shoot and root dry weights of the susceptible spinach and table beet cultivars. The

Table 3. Reaction of spinach, Swiss chard, and table beet cultivars to the cyst nematode *Heterodera trifolii*.

	Season 2019			Season 2020		
Plant cultivar	No. of cysts/pot[w]	Rf[x]	Host reaction[y]	No. of cysts/pot[w]	Rf[x]	Host reaction[y]
Spinach:						
Balady	36.20 a[z]	2.26	S	34.60 a	2.16	S
Barkly	14.80 b	0.93	MS	15.60 b	0.97	MS
Orient	13.20 b	0.83	MS	14.40 b	0.90	MS
Salonicy	7.60 b	0.48	MR	8.00 c	0.50	MR
Pacific	14.00 b	0.88	MS	13.20 b	0.82	MS
Table beet:						
Balady	24.60 a	1.54	S	22.40 a	1.40	S
Detroit Dark Red	18.80 a	1.18	S	17.40 a	1.10	S
Detroit Spainal	14.80 a	0.93	MS	16.00 a	1.00	MS
Asgro Wonder	5.60 b	0.35	MR	6.80 b	0.42	MR
Swiss chard:						
Balady	24.20 a	1.51	S	22.20 a	1.38	S
Ford Hook	6.40 b	0.40	MR	7.00 b	0.43	MR

[w]Means are the average of five replicates.
[x]Rf (reproduction factor) = Final population (Pf) / initial population (Pf/Pi) Pi = 16 cysts/pot.
[y]HS = Highly susceptible, MS= Moderately susceptible, S = Susceptible.
[z]Means with the same letter within a column for each cultivar are not significantly different at $P = 0.05$ according to the LSD procedure.

present results indicate that the pathogenic effects of *H. trifolii* infection on the tested spinach, Swiss chard, and garden beet cultivars were less compared to those of *H. schachtii.* It is evident that infection with *H. schachtii* induced more damaging effects on the dry weight of the shoots and roots of infected spinach, Swiss chard and table beet plant cultivars than *H. trifolii* which is primarily a pathogen on leguminous plants (Tables 2 and 4). Also, it was noted that on the tested cultivars with the name 'Balady' of spinach, Swiss chard and table beet, *H. schachtii* had high reproduction rates (Rf = 3.93-7.88) as compared to *H. trifolii* (Rf = 1.38-2.16). In a similar study, Steele *et al.* (1983) showed that *H. schachtii* and a race of *H. trifolii* were parasitic on sugar beet plant selections in the Netherlands. The present study also demonstrated that both *H. schachtii* and *H. trifolii* have high damage potentials and reproductive capacities on susceptible and highly susceptible spinach, Swiss chard, and table beet cultivars.

In Egypt, the native local cultivars of many vegetable crops have the trade name 'Balady'. The present results showed that cultivars with the name 'Balady' of spinach, Swiss chard and table beet were susceptible to *H. trifolii* as compared to the tested imported foreign cultivars (Table 3). This could be due to the long and continuous use of these 'Balady' local cultivars resulting in the loss of tolerance and/or resistance to nematode infections.

It is concluded from the study of determining the host reaction of certain spinach, Swiss chard and table beet cultivars to *H. schactii* and *H. trifolii* that resistance to these nematodes is of significance and can be useful to incorporate in breeding programs during planning control measures for cyst nematodes. More research is needed for the development of resistant or tolerant cultivars of these vegetable crops. To our knowledge, this is the

Table 4. Reaction of some spinach, table beet, and Swiss chard cultivars to infection with *Heterodera trifolii*.

		Season 2019		Season 2020	
		Dry weight (g)[y]		Dry weight (g)	
Cultivar	*H. schachtii*	Shoot	Root	Shoot	Root
Spinach:					
Balady	+	4.22 b[z]	1.98 b	4.31 b	2.04 b
Balady	-	4.96 a	2.66 a	4.88 a	2.56 a
Barkly	+	4.02 a	1.92 a	3.88 a	1.80 a
Barkly	-	4.16 a	2.08 a	4.04 a	2.00 a
Orient	+	5.08 a	2.21 a	4.99 a	2.14 a
Orient	-	5.40 a	2.52 a	5.36 a	2.61 a
Salonicy	+	6.68 a	3.10 a	6.79 a	3.01 a
Salonicy	-	6.81 a	3.22 a	6.92 a	3.15 a
Pacific	+	5.32 a	2.66 a	5.41 a	2.56 a
Pacific	-	5.48 a	2.82 a	5.62 a	2.78 a
Table beet:					
Balady	+	17.94 b	14.12 b	18.06 b	14.17 b
Balady	-	19.62 a	15.58 a	19.44 a	15.45 a
Detroit Dark Red	+	20.88 b	17.14 b	21.00 b	17.27 b
Detroit Dark Red	-	22.36 a	18.46 a	22.50 a	18.33 a
Detroit Spainal	+	23.44 a	19.28 a	23.30 a	19.15 a
Detroit Spainal	-	24.10 a	19.96 a	24.18 a	20.00 a
Asgro Wonder	+	11.94 a	9.14 a	11.85 a	9.09 a
Asgro Wonder	-	12.26 a	9.38 a	12.30 a	9.43 a
Swiss chard:					
Balady	+	4.66 b	2.44 b	4.64 b	2.37 b
Balady	-	5.72 a	3.10 a	5.52 a	2.95 a
Ford Hook	+	7.28 a	3.38 a	7.36 a	3.47 a
Ford Hook	-	7.56 a	3.52 a	7.67 a	3.63 a

[y]Means are the average of five replicates.
[z]Means with the same letter within a column for each cultivar are not significantly different at $P = 0.05$ according to the LSD procedure.

first study in Egypt on the cyst nematodes *H. schactii* and *H. trifolii* on spinach, Swiss chard, and table beet.

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