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Characterizing races of *Meloidogyne incognita*, *M. javanica* and *M. arenaria* in the West Mediterranean region of Turkey

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ABSTRACT

A total of 95 samples of *Meloidogyne incognita* (60), *Meloidogyne javanica* (28) and *Meloidogyne arenaria* (7) collected from West Mediterranean region of Turkey were tested for identifying races of the nematodes using the North Carolina Differential Host Test. Races 2 and 6 of *M. incognita* were identified in 58 and 2 samples, respectively. Race 1 of *M. javanica* was identified from all 28 samples. Races 2 and 3 of *M. arenaria* were identified in 5 and 2 samples, respectively. The results also showed that two races of *M. incognita* and all races of *M. javanica* did not attack on pepper cv. California Wonder. These findings may contribute to improving resistant varieties and may also provide basis for developing a cropping system to control root-knot nematodes.

1. Introduction

Management of root-knot nematodes, *Meloidogyne* spp., is extremely difficult since they are soilborne pathogens. The use of pre-planting soil fumigants is highly effective in controlling root-knot nematodes. However, a number of fumigant nematicides are no longer available in Turkey and many other countries because of their toxicity to the environment. Furthermore, the control of nematodes through the use of non-fumigant nematicides has also been restricted in areas of protected vegetable cultivation due to chemical residue and pollution problems (Devran and Söğüt, 2010; Devran et al., 2010). As a result, alternative methods for control of root-knot nematodes in commercial vegetable crops are required.

Root-knot nematodes in the genus of *Meloidogyne* spp. are one of the most economically damaging groups of plant-parasitic nematodes on crops. The genus includes more than 90 species, with some species having various virulent races. Four *Meloidogyne* species, *Meloidogyne javanica* (Treub) Chitwood, *Meloidogyne arenaria* (Neal) Chitwood, *Meloidogyne incognita* (Kofoid et White) Chitwood and *Meloidogyne hapla* Chitwood, are major pests worldwide. The North Carolina Differential Host Test is commonly used in identifying races of these species. Previous studies using this method identified 4 races of *M. incognita*, 2 races of *M. javanica*, 2 races of *M. arenaria* and 2 races of *M. hapla* (Fargette, 1987; Taylor and Sasser, 1978; Hartman and Sasser, 1985; Netscher and Sikora, 1990; Decker and Fritzsche, 1991). More recent studies reported that new races of some species are present in the different parts of world (Rammah and Hirschmann, 1990; Carneiro et al., 2003; Robertson et al., 2009).

Plant resistance is an environmentally friendly method for control of root-knot nematodes on vegetable crops. Resistant varieties to root-knot nematodes have been developed in tomato, pepper and cucumber, which have high commercial rankings among vegetables worldwide (Roberts, 1992; Walters and Wehner, 1997; Thies and Fery, 1998). For example, previous studies reported the effectiveness of the *Mi-1* resistance gene in controlling the three major root-knot nematode species, *M. incognita*, *M. javanica* and *M. arenaria*. The *Mi-1* resistance gene is now in commercially grown tomato varieties (Roberts and Thomason, 1986; Bleve-Zacheo et al., 2007). In cucumber, resistant varieties to *M. arenaria* races 1 and 2, and *M. javanica* have been improved (Walters et al., 1996, 1997; Walters and Wehner, 1997). Resistant genes to root-knot nematodes on pepper varieties have also been reported (Di Vito et al., 1991, 1993; Thies and Fery, 2000; Djian-Caporalino et al., 2001, 2007; Thies et al., 2008; Wang and Bosland, 2006).

Tomato, pepper and cucumber are intensively cultivated in protected vegetable fields in the West Mediterranean region of Turkey. The root-knot nematodes are major pathogens to these crops, affecting both the quantity and quality of yield (Devran and Söğüt, 2009; Devran et al., 2010). Additionally, root-knot nematodes interact with other soilborne pathogens, which can further increase the damage on crops. Therefore, knowledge on root-knot

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Table 1
Determination of races of *Meloidogyne incognita*, *M. javanica* and *M. arenaria* from Turkey according to North Carolina Differential Host Test.

Nematode population			Galling index (0–10) on differential hosts[a]					Nematode species[b]	Nematode reaction[c]	Race
Code	Location	Host plant	Tobacco 'NC95'	Cotton 'DP61'	Pepper 'C. Wonder'	Tomato 'Tueza F1'	Peanut 'Florunner'			
G2	Gazipaşa	Tomato	5.3 ± 0.9	0	4.5 ± 0.7	5.2 ± 1.1	0	*M. incognita*	Avirulent	2
G3	Gazipaşa	Cucumber	4.5 ± 0.7	0	5.7 ± 1.2	4.2 ± 1.3	0	*M. incognita*	Avirulent	2
G4	Gazipaşa	Eggplant	5.0 ± 0.4	0	4.7 ± 0.9	4.8 ± 0.9	0	*M. incognita*	Avirulent	2
G7	Gazipaşa	Tomato	5.3 ± 1.0	0	6.3 ± 0.9	6.2 ± 0.8	0	*M. incognita*	Avirulent	2
A2	Alanya	Tomato	7.0 ± 0.9	0	4.2 ± 1.1	4.7 ± 0.9	0	*M. incognita*	Avirulent	2
A3	Alanya	Cucumber	7.0 ± 0.7	0	6.2 ± 1.5	6.7 ± 0.7	0	*M. incognita*	Avirulent	2
A6	Alanya	Cucumber	5.3 ± 0.6	0	5.2 ± 1.3	4.5 ± 0.6	0	*M. incognita*	Avirulent	2
A8	Alanya	Cucumber	5.8 ± 0.9	0	4.5 ± 0.7	3.5 ± 0.7	0	*M. incognita*	Avirulent	2
S1	Serik	Tomato	6.0 ± 1.1	0	5.0 ± 0.9	5.5 ± 1.1	0	*M. incognita*	Avirulent	2
S2	Serik	Tomato	4.2 ± 1.2	0	4.1 ± 0.8	5.5 ± 1.3	0	*M. incognita*	Avirulent	2
S3	Serik	Tomato	3.3 ± 0.9	0	7.0 ± 1.6	5.8 ± 1.0	0	*M. incognita*	Avirulent	2
S4	Serik	Tomato	6.8 ± 0.9	0	3.7 ± 0.9	6.3 ± 1.1	0	*M. incognita*	Avirulent	2
S5	Serik	Tomato	5.5 ± 0.6	0	4.2 ± 0.6	6.5 ± 0.6	0	*M. incognita*	Avirulent	2
S6	Serik	Pepper	4.8 ± 0.5	0	5.1 ± 0.7	5.7 ± 0.9	0	*M. incognita*	Avirulent	2
M1	Gaziler	Tomato	5.5 ± 1.0	0	4.5 ± 0.7	6.0 ± 0.7	0	*M. incognita*	Avirulent	2
M2	Gaziler	Tomato	6.0 ± 0.7	0	4.1 ± 0.8	5.8 ± 0.8	0	*M. incognita*	Avirulent	2
M3	Gaziler	Tomato	7.5 ± 0.6	0	5.7 ± 1.2	4.5 ± 0.7	0	*M. incognita*	Virulent	2
M4	Gaziler	Tomato	4.5 ± 0.7	0	5.5 ± 0.9	6.5 ± 1.1	0	*M. incognita*	Virulent	2
M5	Gaziler	Tomato	4.0 ± 0.5	0	3.5 ± 0.7	6.3 ± 0.8	0	*M. incognita*	Virulent	2
M6	Gaziler	Tomato	6.0 ± 0.7	0	5.7 ± 1.0	6.1 ± 0.9	0	*M. incognita*	Avirulent	2
M10	Altınova	Tomato	5.8 ± 0.9	0	6.7 ± 0.9	5.5 ± 0.6	0	*M. incognita*	Avirulent	2
K1	Kumluca	Eggplant	6.0 ± 0.8	0	5.0 ± 0.5	5.5 ± 1.2	0	*M. incognita*	Avirulent	2
K2	Kumluca	Pepper	6.5 ± 0.7	0	5.8 ± 0.9	5.3 ± 0.7	0	*M. incognita*	Avirulent	2
K3	Kumluca	Pepper	4.8 ± 1.0	0	6.5 ± 0.6	6.5 ± 0.6	0	*M. incognita*	Avirulent	2
K4	Kumluca	Pepper	4.5 ± 0.7	0	4.3 ± 0.7	4.8 ± 0.8	0	*M. incognita*	Avirulent	2
K5	Kumluca	Pepper	5.5 ± 0.6	0	5.2 ± 0.8	5.4 ± 1.1	0	*M. incognita*	Avirulent	2
K6	Kumluca	Pepper	7.5 ± 1.4	0	6.3 ± 1.1	4.8 ± 1.2	0	*M. incognita*	Avirulent	2
K7	Kumluca	Pepper	6.5 ± 1.3	0	5.5 ± 1.7	6.5 ± 0.8	0	*M. incognita*	Avirulent	2
K8	Kumluca	Pepper	4.3 ± 0.5	0	4.2 ± 0.6	3.7 ± 0.6	0	*M. incognita*	Avirulent	2
K9	Kumluca	Pepper	5.1 ± 0.7	0	5.1 ± 0.6	5.7 ± 1.1	0	*M. incognita*	Avirulent	2
K10	Kumluca	Tomato^{R}	5.3 ± 1.0	0	4.1 ± 0.9	6.5 ± 0.7	0	*M. incognita*	Avirulent	2
K11	Kumluca	Pepper	6.3 ± 1.2	0	3.3 ± 0.4	5.2 ± 0.9	0	*M. incognita*	Avirulent	2
K12	Kumluca	Tomato	5.3 ± 0.8	0	5.2 ± 0.9	6.5 ± 0.7	0	*M. incognita*	Avirulent	2
K14	Kumluca	Pepper	4.4 ± 0.9	0	7.5 ± 0.7	3.8 ± 0.9	0	*M. incognita*	Avirulent	2
K15	Kumluca	Eggplant	3.3 ± 0.8	0	7.0 ± 2.1	6.3 ± 1.3	0	*M. incognita*	Avirulent	2
K17	Kumluca	Tomato	5.6 ± 0.8	0	4.5 ± 0.4	4.8 ± 1.5	0	*M. incognita*	Avirulent	2
K19	Kumluca	Tomato	4.7 ± 1.2	0	6.5 ± 0.7	6.1 ± 1.1	0	*M. incognita*	Avirulent	2
D1	Demre	Tomato	5.0 ± 1.1	0	0	5.3 ± 0.9	0	*M. incognita*	Virulent	6
D2	Demre	Tomato	4.5 ± 0.7	0	0	6.7 ± 1.0	0	*M. incognita*	Virulent	6
D4	Demre	Tomato	6.0 ± 1.3	0	3.4 ± 1.1	7.7 ± 0.8	0	*M. incognita*	Avirulent	2
D5	Demre	Tomato	4.8 ± 0.8	0	4.7 ± 1.4	6.0 ± 1.2	0	*M. incognita*	Avirulent	2
D6	Demre	Bean	3.5 ± 0.6	0	5.5 ± 1.2	5.8 ± 0.8	0	*M. incognita*	Avirulent	2
D7	Demre	Bean	5.0 ± 1.4	0	4.8 ± 0.5	5.6 ± 0.6	0	*M. incognita*	Avirulent	2
KA1	Kaş	Tomato	4.2 ± 1.1	0	6.1 ± 1.3	7.5 ± 1.1	0	*M. incognita*	Avirulent	2
KA2	Kaş	Pepper	5.1 ± 1.7	0	4.7 ± 0.8	5.0 ± 0.4	0	*M. incognita*	Avirulent	2
KA3	Kaş	Pepper	4.0 ± 0.8	0	3.5 ± 0.7	5.3 ± 0.9	0	*M. incognita*	Avirulent	2
KA4	Kaş	Pepper	4.3 ± 1.2	0	5.0 ± 0.5	6.5 ± 0.6	0	*M. incognita*	Avirulent	2
KA5	Kaş	Tomato^{R}	4.7 ± 0.9	0	6.2 ± 0.5	5.5 ± 0.7	0	*M. incognita*	Avirulent	2
KA7	Kaş	Tomato^{R}	6.0 ± 0.7	0	5.3 ± 1.2	5.8 ± 0.9	0	*M. incognita*	Avirulent	2
F1	Fethiye	Tomato	5.0 ± 0.9	0	6.2 ± 0.8	3.7 ± 0.5	0	*M. incognita*	Avirulent	2
F2	Fethiye	Tomato	4.1 ± 0.9	0	5.3 ± 0.5	3.5 ± 0.7	0	*M. incognita*	Avirulent	2
F6	Fethiye	Tomato	6.5 ± 1.3	0	5.8 ± 0.9	5.5 ± 0.7	0	*M. incognita*	Virulent	2
F9	Fethiye	Tomato	5.5 ± 1.9	0	4.5 ± 0.6	5.7 ± 0.9	0	*M. incognita*	Avirulent	2
F10	Fethiye	Tomato	3.5 ± 0.8	0	4.0 ± 1.1	6.0 ± 1.1	0	*M. incognita*	Virulent	2
F11	Fethiye	Tomato	5.5 ± 1.2	0	5.7 ± 0.9	4.6 ± 0.7	0	*M. incognita*	Avirulent	2
F12	Fethiye	Tomato	4.6 ± 1.1	0	5.2 ± 0.9	5.2 ± 1.2	0	*M. incognita*	Avirulent	2
F13	Fethiye	Tomato	4.7 ± 0.9	0	4.7 ± 0.7	6.5 ± 1.1	0	*M. incognita*	Avirulent	2
F15	Fethiye	Tomato	6.1 ± 1.3	0	4.3 ± 0.5	5.2 ± 0.7	0	*M. incognita*	Avirulent	2
O2	Ortaca	Tomato	4.2 ± 0.8	0	4.5 ± 0.7	6.0 ± 0.9	0	*M. incognita*	Avirulent	2
O5	Ortaca	Tomato	3.7 ± 0.9	0	5.5 ± 1.1	6.3 ± 0.8	0	*M. incognita*	Avirulent	2
G1	Gazipaşa	Tomato	4.2 ± 0.8	0	0	6.8 ± 0.8	0	*M. javanica*	Avirulent	1
G5	Gazipaşa	Eggplant	4.1 ± 1.0	0	0	6.6 ± 0.8	0	*M. javanica*	Avirulent	1
A1	Alanya	Eggplant^{R}	4.8 ± 0.7	0	0	5.5 ± 0.9	0	*M. javanica*	Avirulent	1
A4	Alanya	Cucumber	5.0 ± 0.9	0	0	6.3 ± 1.0	0	*M. javanica*	Avirulent	1
A5	Alanya	Tomato	4.5 ± 0.7	0	0	5.5 ± 0.6	0	*M. javanica*	Avirulent	1
A7	Alanya	Cucumber	3.5 ± 0.7	0	0	6.4 ± 0.7	0	*M. javanica*	Avirulent	1
AKS1	Aksu	Tomato	5.5 ± 0.7	0	0	5.5 ± 1.1	0	*M. javanica*	Avirulent	1
AKS2	Aksu	Tomato	5.3 ± 0.9	0	0	6.2 ± 0.9	0	*M. javanica*	Virulent	1
AKS3	Aksu	Tomato^{R}	6.8 ± 1.0	0	0	6.3 ± 0.8	0	*M. javanica*	Avirulent	1
AKS4	Aksu	Tomato	5.5 ± 0.2	0	0	6.2 ± 0.9	0	*M. javanica*	Virulent	1
AKS5	Aksu	Tomato	6.4 ± 0.5	0	0	5.5 ± 0.6	0	*M. javanica*	Avirulent	1
AKS6	Aksu	Tomato	5.3 ± 0.5	0	0	5.7 ± 0.8	0	*M. javanica*	Avirulent	1