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Original article (Orijinal araştırma)

Response of eggplant genotypes to avirulent and virulent populations of *Meloidogyne incognita* (Kofoid & White, 1919) Chitwood, 1949 (Tylenchida: Meloidogynidae)[1]

Melodidogyne incognita (Kofoid & White, 1919) Chitwood, 1949 (Tylenchida: Meloidogynidae)'nın virülent ve avirülent popülasyonlarına patlıcan genotiplerinin tepkisi

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Abstract

Eggplant is widely grown throughout the world. However, some eggplant genotypes are susceptible to *Meloidogyne* spp., so *Solanum torvum* (Sw.) is commonly used as a resistant rootstock for root-knot nematodes. Further investigations of resistant sources to root-knot nematodes are still necessary for breeding programs. In this study, a total of 60 eggplant genotypes, including wild sources, wild rootstocks, wild × wild eggplant rootstocks, wild × cultivated eggplant rootstocks, cultivated eggplant rootstocks, pure lines, standard commercial cultivars and commercial hybrids, were tested with avirulent S6 and *Mi-1* virulent V14 populations of *Meloidogyne incognita* (Kofoid & White, 1919) Chitwood, 1949 (Tylenchida: Meloidogynidae) under controlled conditions. The study was conducted in 2016-2017. The seedlings were inoculated with 1000 second-stage juveniles of *M. incognita.* Plants were uprooted 8 weeks after nematode inoculation, and the numbers of egg masses and galls on the roots and juveniles in the soil of pots were counted. *Solanum torvum* (Y28) was found to be resistant to S6 and V14 populations of *M. incognita.* The remaining genotypes were susceptible to both populations. These results could be used for breeding and management purposes for the control of root-knot nematode.

Keywords: Eggplant, *Meloidogyne incognita,* resistance, *Solanum torvum*

Öz

Patlıcan dünyada yaygın bir şekilde yetiştirilmektedir. Bununla birlikte bazı patlıcan genotipleri kök-ur nematodlarına (*Meloidogyne* spp.) karşı duyarlıdır. Bu nedenle *Solanum torvum* (Sw.) dünyada kök-ur nematodlarına karşı dayanıklı anaç olarak yaygın bir şekilde kullanılmaktadır. Kök-ur nematodlarına dayanıklı yeni patlıcan genetik kaynaklarının araştırılması ıslah için gereklidir. Bu çalışmada yabani kaynaklar, yabani anaçlar, yabani x yabani anaçlar, yabani x kültür formu patlıcan anaçları, kültür formu anaçlar, saf hatlar, standart ticari çeşitler ve ticari hibritler olmak üzere toplam 60 genotip *Meloidogyne incognita* Kofoid & White, 1919) Chitwood, 1949 (Tylenchida: Meloidogynidae)'nın avirülent S6 ve *Mi-1* virülent V14 popülasyonu ile kontrollü koşullar altında testlenmiştir. Çalışma 2016-2017 yıllarında yürütülmüştür. Patlıcan fideleri *M. incognita*'nın 1000 ikinci dönem larvası ile inokulasyon yapılmış ve bitkiler inokulasyondan 8 hafta sonra sökülmüştür. Köklerdeki yumurta ve ur sayıları ile topraktaki larva sayıları sayılmıştır. *Solanum torvum* (Y28)'un *M. incognita*'nın S6 ve V14 popülasyonlarına dayanıklı, diğer genotiplerin tümümün ise her iki popülasyona duyarlı olduğu belirlenmiştir. Bu sonuçlar kök-ur nematodlarının kontrolü için yapılacak olan ıslah ve mücadele çalışmalarında kullanılabilir.

Anahtar sözcükler: Patlıcan, *Meloidogyne incognita*, dayanıklılık, *Solanum torvum*

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Introduction

Eggplant is belonging to the Solanaceae and its fruits have enormous diversity in shape, color and size (Collonnier et al., 2001; Sadilova et al., 2006). First cultivated in India and China (Lester & Hasan, 1991; Doğanlar et al., 2002), eggplant is a good source of minerals and vitamins (Russo, 1996; Sadilova et al., 2006). In addition, the related some species of eggplant have been used as valuable genetic resources for eggplant breeding and rootstocks (Bletsos et al., 1998; Johnson et al., 2014; Petran & Hoover, 2014). Worldwide, eggplant is grown on 1.7 Mha, with a total production of 51 Mt. Turkey is the world's fourth eggplant producer, after China, India and Egypt, with an annual production of 0.8 Mt (FAO, 2016).

Eggplant production is adversely affected by *Meloidogyne* spp. Root-knot nematodes (RKNs) induce the formation of specialized feeding sites (galls) in the roots of infected plants (Di Vito et al., 1986; Khan & Haider, 1991). Severe infestations cause considerable yield losses of eggplant crops and can also affect consumer acceptance of the produce. RKNs are soil borne pathogens (Starr et al., 1989; Manzanilla-López & Starr, 2009) and have a wide range of hosts (Hussey, 1985; Khurma et al., 2008; Jones et al., 2013); consequently, their management is difficult. RKN management strategies include the use of nematicides and resistant cultivars and rootstocks (Devran et al., 2010). However, the use of some nematicides has been limited because of health and environmental problems (Devran et al., 2008; Moens et al., 2009; Devran et al., 2013). In contrast, resistant plants can serve as environmentally and eco-friendly alternatives for management of RKNs (Boerma & Hussey, 1992; Rahman et al., 2002; Devran et al., 2013).

Eggplants cultivated are susceptible to RKNs; however, some wild eggplant species are resistant to some RKN species (Daunay & Dalmasso, 1985; Hebert, 1985; Ali et al., 1992; Boiteux & Charchar, 1996; Rahman et al., 2002; Uehara et al., 2016; 2017; Öçal et al., 2018). At present, *Solanum torvum* (Sw.) is commonly used as a rootstock (Uehara et al., 2017). This species also shows resistance to high-salinity soils and several serious soilborne pathogens, such as *Ralstonia solanacearum* (Smith) (Burkholderiales: Burkholderiaceae), *Fusarium oxysporum* Schlechtendal (Hypocreales: Nectriaceae) and *Verticillium dahlia* Klebahn (Hypocreales: Hypocreaceae) (Stravato & Cappelli, 2000; Collonnier et al., 2001; Gousset et al., 2005; Zhang et al., 2015). However, *S. torvum* has a long germination time (Liu et al., 2009), which causes problems in grafting and seedling production. Therefore, the investigation of new genotypes that are resistant to RKNs is critical for eggplant breeding. Here, we investigated the responses of 60 eggplant genotypes to avirulent and virulent populations of *M. incognita* under controlled conditions.

Materials and Methods

Plant material

The eggplant genotypes used in this study are listed in Table 1. In the experiments, *Solanum torvum* cv. Hawk (Solanales: Solanaceae) (Vilmorin, France) and *Solanum melongena* L. (Solanales: Solanaceae), the commercial eggplant cv. Faselis F_1 (Seminis, MO, USA) were used as resistant and susceptible entries, respectively.

Table 1. Eggplants genotypes assessed in this study

Plant Code	Genotype	Property	Species
Y1	S-IN-F-11	Wild rootstock	*Solanum integrifolium*
Y2	Eggplant Rootstock-4	Wild x wild eggplant rootstock	*S. integrifolium* x *S. incanum*
Y4	LS2436	Pure lines	*Solanum melongena*
Y5	Eggplant Rootstock -1	Wild rootstock	*Solanum incanum*
Y6	Eggplant Rootstock -2	Wild rootstock	*Solanum incanum*
Y7	Eggplant Rootstock -3	Wild rootstock	*Solanum integrifolium*
Y8	P-1	Wild genotype	*Solanum integrifolium*
Y9	P-2	Standard commercial cultivars	*Solanum melongena*
Y10	P-3	Standard commercial cultivars	*Solanum melongena*
Y11	P-4	Standard commercial cultivars	*Solanum melongena*
Y12	P-5	Standard commercial cultivars	*Solanum melongena*
Y13	P-6	Standard commercial cultivars	*Solanum melongena*
Y14	12 T 233	Wild genotype	*Solanum aethiopicum*
Y15	11-T-235	Wild genotype	*Solanum incanum*
Y16	Genotype-78	Wild genotype	*Solanum incanum*
Y17	Ls2436 x S00019	Cultivated x wild eggplant rootstock	*S. melongena x S. aethiopicum*
Y18	P-AN-33872 x ls2436	Wild x cultivated eggplant rootstock	*S. aethiopicum x S. melongena*
Y19	09-T-82	Pure line	*Solanum melongena*
Y20	11-T-331-12	Pure line	*Solanum melongena*
Y21	S-0002 x LS-2436	Cultivated x wild eggplant rootstock	*S. melongena x S. aethiopicum*
Y22	SS-PL-2 x Genotype 78	Cultivated x wild eggplant rootstock	*S. melongena x S. incanum*
Y23	LS2436 x S00830	Wild x cultivated eggplant rootstock	*S. aethiphicum* x *S. melongena*
Y24	P-AN-33871 x ls2436	Wild x cultivated eggplant rootstock	*S. aethiopicum* x *S. melongena*
Y25	Genotype x Genotip 78	Wild x wild eggplant rootstock	*S. aethiopicum* x *S. incanum*
Y26	09 T 80	Pure line	*Solanum melongena*
Y27	11 T 295	Pure line	*Solanum melongena*
Y28	Hawk	Wild rootstock	*Solanum torvum*
Y29	Köksal Rootstok	Wild x cultivated eggplant rootstock	*S. melongena* x *S. incanum*
Y30	P-AN33873 wild	Wild genotype	*Solanum aethiopicum*
Y31	*S. integrifolium*	Wild genotype	*Solanum integrifolium*
Y32	Cultivated Rootstok	Cultivated eggplant rootstock	*Solanum melongena*
Y33	MM195006T44 x *S. integrifolium*	Wild x wild eggplant rootstock	*S. integrifolium* x *S. integrifolium*
M1	Faselis F1	Commercial hybrids	*Solanum melongena*
M2	Anamur F1	Commercial hybrids	*Solanum melongena*
M3	Sicilia F1	Commercial hybrids	*Solanum melongena*
M4	Brigitte F1	Commercial hybrids	*Solanum melongena*
M5	Darko F1	Commercial hybrids	*Solanum melongena*
M6	Karaok F1	Commercial hybrids	*Solanum melongena*
M7	Karanta F1	Commercial hybrids	*Solanum melongena*
M8	Aykara F1	Commercial hybrids	*Solanum melongena*
M9	Karnaz F1	Commercial hybrids	*Solanum melongena*
M10	Oriental F1	Commercial hybrids	*Solanum melongena*
M11	Doyran Karası F1	Commercial hybrids	*Solanum melongena*
M12	Me39 F1	Commercial hybrids	*Solanum melongena*
M13	Volta F1	Commercial hybrids	*Solanum melongena*
M14	Aydın Siyahı	Standard commercial cultivars	*Solanum melongena*
M15	Pala Yalova 49	Standard commercial cultivars	*Solanum melongena*
M16	Kemer 27	Standard commercial cultivars	*Solanum melongena*
M17	Yamula Patlıcanı	Standard commercial cultivars	*Solanum melongena*
M18	Korkuteli Söğüt	Standard commercial cultivars	*Solanum melongena*
M19	Topan 374	Standard commercial cultivars	*Solanum melongena*
M20	Bursa Topan	Standard commercial cultivars	*Solanum melongena*
M21	AGR 703	Cultivated eggplant rootstocks	*Solanum melongena*
M22	Ahtapot F1	Wild x wild eggplant rootstocks	*S. incanum* x *S. aethiopicum*
M23	Vista F1	Wild x cultivated eggplant rootstocks	*S. melongena* x *S. incanum*
M24	16SP3143	Wild rootstocks	Unknown
M25	16SP3144	Wild rootstocks	Unknown
M26	16SP3145	Wild rootstocks	Unknown
M-27	Wild Eggplant 4	Wild rootstocks	Unknown
M-28	Kumluca Patlıcan	Pure lines	*Solanum melongena*

Nematode culture

Avirulent S6 and *Mi-1* virulent V14 populations of *M. incognita* were used in this study. The S6 population were identified in previous studies (Devran & Söğüt, 2009, 2010, 2011) and V14 has been used as laboratory culture since 2015 (unpublished data). Each RKN isolate was established as a single mass for pure cultures according to previous studies (Mıstanoğlu et al., 2016; Özalp & Devran, 2018).

Nematode inoculation and evaluation

The study was conducted at the Nematology Laboratory of the Department of Plant Protection, Faculty of Agriculture, Akdeniz University in 2016-2017. Eggplant seedlings at the two true-leaf stage were transplanted into 250 ml plastic pots, containing sterilized sandy. One thousand J2s were inoculated into holes surrounding the root. Five plants for each genotype were tested with each nematode population. The pots were incubated in a growth chamber at 25±0.5°C, 65% RH and 8:16 h L:D photoperiod. The seedlings were uprooted 8 weeks after nematode inoculation and evaluated according to Özalp & Devran (2018).

The J2s from the soil of each pot were extracted using a modified Baermann funnel technique (Hooper 1986). The reproduction factor (Rf) was calculated by the formula, Rf = Pf/Pi, where Pf = final *M. incognita* population and Pi = initial *M. incognita* population (Ferris, 1985).

The number of egg masses and galls on each plant root was counted and assessed on a 0-5 scale, according to Hartman and Sasser (1985).

Statistical analyses

The entries were separated into eight groups for statistical analysis, since eggplant genotypes have very different genetic backgrounds. The data were log transformed [log10(x+1)] and analyzed by ANOVA. The statistical analyses were conducted with the general linear model procedure (PROC GLM) of the statistical package SAS (v. 9.0 for Windows; SAS Institute, Inc., Cary, NC, USA). Significant differences with in treatments were tested using Duncan's test.

Results

Sixty eggplant genotypes, including wild source, wild rootstocks, wild × wild eggplant rootstocks, wild × cultivated eggplant rootstocks, cultivated eggplant rootstocks, pure lines, standard commercial cultivars and commercial hybrids were tested with avirulent S6 and *Mi-1* virulent V14 populations of *M. incognita*. At the end of the experiments, the numbers of juveniles (J2s), egg masses and galls were evaluated in all plants.

Wild genotypes (Group 1)

Six wild eggplant genotypes, Y8, Y14, Y15, Y16, Y30 and Y31, were tested with the S6 and V14 populations of *M. incognita* (Table 2). The S6 population of *M. incognita* produced a few egg masses and galls on the Y8 genotype, whereas, the V14 population of *M. incognita* multiplied very well on the Y8 genotype. The Rf value of the S6 population of *M. incognita* on Y8 was <1, whereas the Rf value of the V14 population of *M. incognita* on Y8 was >1. The Y8 genotype was only resistant to the S6 population of *M. incognita,* based on the egg mass index. However, the Y8 genotype was susceptible according to the gall index (Hartman & Sasser, 1985) (Table 2). The Y14, Y15, Y16 Y30 and Y31 genotypes were susceptible to both the V14 and S6 populations of *M. incognita* (Table 2). Although the Y15 genotype was susceptible to the V14 population, the Rf <1. Significant differences were noted among some wild genotypes based on the numbers of egg masses and galls on the roots, juveniles in the soil and the 0-5 scale scores (Table 2).

Table 2. Number of egg masses, galls and Rf values in wild genotypes against avirulent S6 and virulent V14 populations of *M. incognita*

Plant Code	*M. incognita* avirulent S6 population									
	Egg Mass		Egg Mass Index*		Gall		Gall Index*		Rf	
Y8	14.80	d	2.80	c	23.60	d	3.20	c	0.404	c
Y14	113.40	a	4.60	a	370.00	a	5.00	a	2.590	a
Y15	40.75	bc	3.50	b	61.00	c	4.00	b	3.074	a
Y16	97.00	a	4.60	a	219.20	b	5.00	a	2.982	a
Y30	30.00	c	3.50	b	210.70	b	5.00	a	1.042	bc
Y31	52.60	b	3.80	b	435.00	a	5.00	a	1.486	ab
Plant Code	*M. incognita* virulent V14 population									
	Egg Mass		Egg Mass Index*		Gall		Gall Index*		Rf	
Y8	63.20	b	4.00	b	111.80	a	5.00	a	5.340	a
Y14	85.00	b	4.40	ab	128.00	a	5.00	a	3.620	a
Y15	19.25	c	3.00	c	22.00	b	3.00	c	0.990	b
Y16	193.80	a	4.80	a	128.40	a	4.60	b	3.270	a
Y30	104.50	ab	4.75	a	162.50	a	4.80	a	4.750	a
Y31	74.80	b	4.00	b	178.80	a	5.00	a	1.090	b

* 0-5 Scale (Hartman & Sasser 1985). 0-2: Resistance, 3-5: Susceptible. Rf: Reproduction factor. Means in columns followed by the same letter are not significantly different ($P \leq 0.05$) according to Duncan's test.

Wild rootstocks (Group 2)

Nine wild eggplant rootstocks, Y1, Y5, Y6, Y7, Y28, M24, M25, M26 and M27, were tested with the S6 and V14 populations of *M. incognita*. Both *M. incognita* populations produced a few egg masses and galls on Y28. The Rf values of the V14 and S6 populations of *M. incognita* on Y28 were <1. The V14 population of *M. incognita* produced a few egg masses on the Y7 genotype, but produced many galls on Y7. The Y7 genotype was resistant to the V14 population of *M. incognita* based on the egg mass index; however, this genotype was susceptible according to the gall index (Hartman and Sasser 1985) (Table 3). In addition, the Rf value of the V14 population of *M. incognita* on Y7 was <1 (Table 3). Nevertheless, Y7 was susceptible to the S6 population of *M. incognita* according to the gall index, egg mass index and Rf value. The other rootstocks were susceptible to the V14 and S6 populations of *M. incognita* (Table 3). Although the M24, M25, M26 and M27 genotypes were susceptible to the S6 populations, with Rf <1, results showed that Y28 was resistant according to the 0-5 scale score (Hartman & Sasser, 1985) (Table 3). Significant differences were observed among the wild rootstocks with respect to egg masses, galls, juveniles in the soil and the 0-5 scale scores (Table 3).

Wild x wild eggplant rootstocks (Group 3)

Three eggplant rootstocks (Y2, Y33 and M22) obtained from wild × wild eggplant rootstocks crosses were tested with the S6 and V14 populations of *M. incognita*. Both populations produced many egg masses and galls on the roots of all plants. The Rf value of the S6 population on M22 was <1. However, the Rf values of both populations on the other plants were >1. All rootstocks were susceptible to both populations of *M. incognita* according to the 0-5 scale scores (Hartman & Sasser, 1985) (Table 4). Significant differences were noted among the wild rootstocks with respect to egg masses, galls, juveniles in the soil and the 0-5 scale scores (Table 4).

Table 3. Number of egg masses, galls and Rf values in wild rootstocks against avirulent S6 and virulent V14 populations of *M. incognita*

Plant Code	*M. incognita* avirulent S6 population									
	Egg Mass		Egg Mass Index*		Gall		Gall Index*		Rf	
Y1	104.20	a	4.80	a	271.60	b	5.00	a	6.206	a
Y5	20.60	c	3.00	c	49.60	e	4.00	c	2.412	b
Y6	54.00	b	4.00	b	191.20	c	5.00	a	2.744	ab
Y7	41.00	b	4.00	b	68.80	e	4.00	c	3.154	ab
Y28	2.40	d	1.20	d	12.20	f	2.60	d	0.242	d
M24	109.80	a	4.80	a	259.60	b	5.00	a	0.470	cd
M25	93.50	a	4.25	ab	384.20	a	5.00	a	0.302	c
M26	39.80	b	3.80	b	173.00	c	5.00	a	0.216	d
M27	49.20	b	3.60	b	124.20	d	4.60	b	0.764	c
Plant Code	***M. incognita* virulent V14 population**									
	Egg Mass		Egg Mass Index*		Gall		Gall Index*		Rf	
Y5	21.20	d	3.00	b	25.60	f	3.20	d	2.230	c
Y6	209.60	a	5.00	a	233.20	a	5.00	a	15.720	a
Y7	7.25	d	2.25	c	41.75	e	4.00	c	0.610	cd
Y28	1.20	d	0.60	d	1.60	g	0.80	e	0.034	d
M24	159.80	b	5.00	a	79.20	d	4.20	bc	8.016	b
M25	117.50	c	5.00	a	99.20	c	4.75	ab	2.170	c
M26	135.20	bc	4.80	a	152.60	b	5.00	a	10.140	ab

* 0-5 Scale (Hartman & Sasser 1985). 0-2: Resistance, 3-5: Susceptible. Rf: Reproduction factor. Means in columns followed by the same letter are not significantly different (P ≤ 0.05) according to Duncan's test.

Table 4. Number of egg masses, galls and Rf values in wild x wild eggplant rootstocks against avirulent S6 and virulent V14 populations of *M. incognita*

Plant Code	*M. incognita* avirulent S6 population									
	Egg Mass		Egg Mass Index*		Gall		Gall Index*		Rf	
Y2	56.20	b	4.00	b	335.00	b	5.00	a	1.840	b
Y33	113.80	a	4.80	a	193.60	c	5.00	a	7.770	a
M22	107.20	a	4.60	a	562.80	a	5.00	a	0.450	c
Plant Code	***M. incognita* virulent V14 population**									
	Egg Mass		Egg Mass Index*		Gall		Gall Index*		Rf	
Y2	80.60	a	4.00	b	75.00	b	4.00	b	1.074	c
Y33	96.33	a	4.60	a	81.60	b	4.00	b	9.003	a
M22	58.20	b	4.00	b	110.80	a	4.60	a	4.746	b

* 0-5 Scale (Hartman & Sasser 1985). 0-2: Resistance, 3-5: Susceptible. Rf: Reproduction factor. Means in columns followed by the same letter are not significantly different (P ≤ 0.05) according to Duncan's test.

Wild x cultivated eggplant rootstocks (Group 4)

Nine eggplant rootstocks (Y17, Y18, Y21, Y22, Y23, Y24, Y25, Y29 and M23) obtained from wild × cultivated eggplants crosses were tested with the S6 and V14 populations of *M. incognita*. Both populations multiplied very well on all rootstocks. The Rf values of two populations on seven rootstocks except for M23 and Y22 were >1 (Table 5). However, Rf value of S6 population on M23 and V14 population on Y22 were <1 and (Table 5). Results showed that all rootstocks were susceptible to two populations of *M. incognita* according to scale score (Hartman & Sasser, 1985) (Table 5). Significant differences were observed among rootstocks with respect to egg masses, galls, juveniles in the soil and 0-5 scale scores (Table 5).

Table 5. Number of egg masses, galls and Rf values in wild x cultivated eggplant rootstocks against avirulent S6 and virulent V14 populations of *M. incognita*

Plant Code	*M. incognita* avirulent S6 population									
	Egg Mass		Egg Mass Index*		Gall		Gall Index*		Rf	
Y17	149.40	b	5.0	a	293.8	d	5.00	a	2.660	bc
Y18	303.20	a	5.0	a	396.2	c	5.00	a	3.810	b
Y21	100.40	c	4.60	b	325.20	d	5.00	a	3.340	b
Y22	71.40	d	4.00	c	215.20	e	5.00	a	1.190	d
Y23	65.40	d	4.00	c	158.40	f	5.00	a	2.830	bc
Y24	141.80	b	5.00	a	405.60	c	5.00	a	4.220	b
Y25	68.20	d	4.00	c	515.20	a	5.00	a	1.690	cd
Y29	72.80	d	4.20	c	241.40	e	5.00	a	9.250	a
M23	113.40	bc	4.80	ab	457.00	b	5.00	a	0.440	e
Plant Code	*M. incognita* virulent V14 population									
	Egg Mass		Egg Mass Index*		Gall		Gall Index*		Rf	
Y17	149.40	bc	4.80	a	123.00	b	5.00	a	4.650	a
Y18	125.00	abc	4.80	a	123.40	b	4.80	a	3.640	a
Y21	142.80	ab	4.80	a	155.40	ab	4.80	a	2.020	ab
Y22	145.80	ab	5.00	a	159.80	ab	5.00	a	0.780	b
Y23	87.50	c	4.25	b	120.25	b	5.00	a	2.010	ab
Y24	96.40	c	4.20	b	163.20	ab	5.00	a	2.280	ab
Y25	57.50	d	4.00	b	114.25	b	5.00	a	1.810	ab
Y29	52.00	d	3.75	b	138.50	ab	4.75	a	2.400	ab

* 0-5 Scale (Hartman & Sasser 1985). 0-2: Resistance, 3-5: Susceptible. Rf: Reproduction factor. Means in columns followed by the same letter are not significantly different ($P \leq 0.05$) according to Duncan's test.

Cultivated eggplant rootstocks (Group 5)

Two eggplant rootstocks Y32 and M21 were tested with the S6 and V14 populations of *M. incognita*. Both populations produced many egg masses and galls on Y32 and M21. Rf values of two populations on Y32 and M21 were >1 (Table 6). Results indicated that two rootstocks were susceptible to two populations of *M. incognita* according to 0-5 scale scores (Hartman & Sasser, 1985) (Table 6). Significant differences were noted among cultivated eggplant rootstocks with respect to egg masses, galls, juveniles in the soil and 0-5 scale values (Table 6).

Table 6. Number of egg masses, galls and Rf values in cultivated eggplant rootstocks against avirulent S6 and virulent V14 populations of *M. incognita*

Plant Code	*M. incognita* avirulent S6 population									
	Egg Mass		Egg Mass Index*		Gall		Gall Index*		Rf	
Y32	80.00	b	4.20	a	144.60	b	4.80	a	1.448	b
M21	219.20	a	5.00	a	263.60	a	5.00	a	7.014	a
Plant Code	*M. incognita* virulent V14 population									
	Egg Mass		Egg Mass Index*		Gall		Gall Index*		Rf	
Y32	172.20	a	5.00	a	145.60	a	5.00	a	5.118	a
M21	144.40	b	4.60	a	129.20	b	5.00	a	4.234	a

* 0-5 Scale (Hartman & Sasser 1985). 0-2: Resistance, 3-5: Susceptible. Rf: Reproduction factor. Means in columns followed by the same letter are not significantly different (P ≤ 0.05) according to Duncan's test.

Pure lines (Group 6)

Six pure lines eggplants (Y4, Y19, Y20, Y26, Y27 and M28) were tested with the S6 and V14 populations of *M. incognita.* Both populations multiplied very well on all lines. Rf values of the S6 population on all genotypes except Y27 were >1 (Table 7). In addition, Rf values of S6 and V14 populations on M28 were not counted. All pure lines were susceptible to two populations of *M. incognita* according to 0-5 scale (Hartman & Sasser, 1985) (Table 7). Significant differences were observed among some pure lines with respect to egg masses, galls, juveniles in the soil and 0-5 scale values (Table 7).

Table 7. Number of egg masses, galls and Rf values in pure lines against avirulent S6 and virulent V14 populations of *M. incognita*

Plant Code	*M. incognita* avirulent S6 population									
	Egg Mass		Egg Mass Index*		Gall		Gall Index*		Rf	
Y4	75.80	a	4.00	a	230.60	a	5.00	a	2.634	a
Y19	67.00	a	4.00	a	229.60	a	5.00	a	2.564	a
Y20	67.00	a	4.00	a	230.80	a	5.00	a	1.970	a
Y26	91.30	a	4.00	a	81.30	a	4.30	b	2.176	ab
Y27	35.50	b	3.75	b	73.50	b	4.00	c	0.598	b
M28	97.40	a	4.60	a	244.00	a	5.00	a	-	
Plant Code	*M. incognita* virulent V14 population									
	Egg Mass		Egg Mass Index*		Gall		Gall Index*		Rf	
Y4	127.20	ab	5.00	a	107.60	cd	4.80	a	2.852	b
Y19	134.00	ab	4.75	a	141.50	abc	4.75	a	4.238	b
Y20	79.60	c	4.20	b	80.60	d	4.20	b	1.392	c
Y26	116.60	b	4.80	a	130.80	bc	5.00	a	13.820	a
Y27	114.80	b	5.00	a	163.60	ab	5.00	a	14.230	a
M28	184.80	a	5.00	a	179.60	a	5.00	a	-	

* 0-5 Scale (Hartman & Sasser 1985). 0-2: Resistance, 3-5: Susceptible. Rf: Reproduction factor. Means in columns followed by the same letter are not significantly different (P ≤ 0.05) according to Duncan's test. - indicates no nematode test.

Standard commercial cultivars (Group 7)

Twelve standard commercial cultivars (Y9, Y10, Y11, Y12, Y13, M14, M15, M16, M17, M18, M19 and M20) were tested with the S6 and V14 populations of *M. incognita.* The S6 population multiplied on all plants and produced many egg masses and galls. Rf values of S6 on all cultivars except Y11 were >1. Results showed that all pure lines were susceptible to the S6 population of *M. incognita* according to 0-5 scale (Hartman & Sasser, 1985) (Table 8). Significant differences were noted among some standard commercial cultivars with respect to egg masses, galls, juveniles in the soil and 0-5 scale values (Table 8).

Table 8. Number of egg masses, galls and Rf values in standard commercial cultivars against avirulent S6 and virulent V14 populations of *M. incognita*

Plant Code	*M. incognita* avirulent S6 population									
	Egg Mass		Egg Mass Index*		Gall		Gall Index*		Rf	
Y9	125.00	ab	4.80	a	434.80	a	5.00	a	2.854	a
Y10	94.50	bc	4.50	a	300.70	bc	5.00	a	1.580	abcd
Y11	95.00	bc	4.40	a	313.20	b	5.00	a	0.910	d
Y12	78.40	bc	4.20	a	279.60	bc	5.00	a	2.392	ab
Y13	66.40	c	4.20	a	261.00	bcd	5.00	a	1.872	abc
M14	157.80	a	4.80	a	252. 40	bcd	5.00	a	2.254	ab
M15	65.00	c	4.20	a	152.75	f	5.00	a	2.208	ab
M16	94.00	bc	4.40	a	128.80	f	5.00	a	2.406	ab
M17	125.00	ab	4.60	a	333.30	b	5.00	a	8.633	cd
M18	127.40	bc	4.40	a	205.80	de	5.00	a	2.598	ab
M19	100.60	bc	4.20	a	208.80	cde	5.00	a	1.376	bcd
M20	90.80	bc	4.20	a	159.60	ef	5.00	a	1.270	bcd
Plant Code	*M. incognita* virulent V14 population									
	Egg Mass		Egg Mass Index*		Gall		Gall Index*		Rf	
Y9	169.80	a	5.00	a	226.8	a	5.00	a	13.490	a
Y10	113.60	abc	4.80	a	139.0	b	4.80	ab	12.580	ab
Y11	106.00	abc	4.60	ab	64.40	c	4.00	c	8.440	bc
Y12	1.20	d	0.80	c	16.00	d	3.00	d	0.240	f
Y13	89.40	bc	4.40	ab	111.80	b	4.80	ab	5.680	c
M14	161.60	a	5.00	a	154.60	b	5.00	a	8.470	abc
M15	96.40	bc	4.40	ab	74.80	c	4.40	bc	4.670	de
M16	104.60	abc	4.60	ab	62.60	c	4.00	c	2.250	de
M18	158.50	ab	4.75	a	160.25	b	4.75	ab	6.670	c
M19	78.25	c	4.00	b	79.00	c	4.25	c	2.540	e
M20	144.40	ab	5.00	a	129.20	b	5.00	a	2.660	de

* 0-5 Scale (Hartman & Sasser 1985). 0-2: Resistance, 3-5: Susceptible. Rf: Reproduction factor. Means in columns followed by the same letter are not significantly different (P ≤ 0.05) according to Duncan's test.

V14 population multiplied and produced many egg masses all genotypes except Y12. Rf values of V14 populations of *M. incognita* on all genotypes except Y12 were >1 (Table 8). All genotypes except Y12 were susceptible to the V14 population. Y12 was resistance to according to egg mass index, but it was susceptible to according to gall index (Hartman & Sasser, 1985) (Table 8)**.** Significant differences were observed among standard commercial cultivars according to egg masses, galls, juveniles in the soil and 0-5 scale values (Table 8).

Commercial hybrids (Group 8)

Thirteen commercial hybrids M1, M2, M3, M4, M5, M6, M7, M8, M9, M10, M11, M12 and M13 were tested with the S6 and V14 populations of *M. incognita.* Both populations produced many egg masses and gals on roots of all hybrids. Rf values of two populations on all hybrids except M10 were >1 (Table 9). Only Rf value of S6 population on M10 <1. All hybrids were susceptible to two populations of *M. incognita* according to 0-5 scale (Hartman & Sasser, 1985) (Table 9).

Table 9. Number of egg masses, galls and Rf values in commercial hybrids against avirulent S6 and virulent V14 populations of *M. incognita*

Plant Code	*M. incognita* avirulent S6 population									
	Egg Mass		Egg Mass Index*		Gall		Gall Index*		Rf	
M1	90.80	d	4.30	b	159.60	ef	5.00	a	1.266	cde
M2	103.00	cd	4.80	ab	222.20	cd	5.00	a	3.112	ab
M3	175.20	ab	4.80	ab	339.20	a	5.00	a	2.880	ab
M4	94.40	d	4.60	ab	241.80	cd	5.00	a	2.834	ab
M5	107.20	cd	4.80	ab	265.00	bc	5.00	a	1.284	de
M6	189.80	ab	5.00	a	255.40	bcd	5.00	a	2.680	bc
M7	155.20	abc	4.60	ab	205.20	cd	5.00	a	2.302	b
M8	97.40	d	4.40	ab	132.40	f	5.00	a	2.196	bcd
M9	200.40	a	5.00	a	197.00	de	5.00	a	1.322	cde
M10	142.40	abc	5.00	a	308.00	ab	5.00	a	0.806	e
M11	195.60	a	4.80	ab	307.60	ab	5.00	a	1.962	bcd
M12	131.50	bcd	5.00	a	225.20	cd	5.00	a	2.165	bcd
M13	178.00	ab	5.00	a	235.40	cd	5.00	a	4.906	a
Plant Code	*M. incognita* virulent V14 population									
	Egg Mass		Egg Mass Index*		Gall		Gall Index*		Rf	
M1	210.60	ab	5.00	a	213.20	ab	5.00	a	4.478	c
M2	87.00	c	4.40	b	88.80	d	4.40	b	4.210	c
M3	250.80	a	5.00	a	230.20	a	5.00	a	9.934	abc
M4	256.60	a	5.00	a	208.80	abc	5.00	a	14.940	ab
M5	169.00	b	4.80	a	174.00	bc	5.00	a	12.760	ab
M7	241.40	a	5.00	a	190.40	abc	5.00	a	11.700	ab
M8	205.40	ab	5.00	a	179.20	abc	5.00	a	9.914	abc
M9	196.00	ab	5.00	a	157.60	c	4.80	a	7.902	bc
M10	168.20	b	5.00	a	192.40	abc	5.00	a	18.160	a
M11	168.00	b	5.00	a	189.60	abc	5.00	a	13.120	ab
M12	214.40	ab	5.00	a	181.60	abc	5.00	a	14.430	ab
M13	237.20	ab	5.00	a	225.40	ab	5.00	a	14.540	ab

* 0-5 Scale (Hartman & Sasser 1985). 0-2: Resistance, 3-5: Susceptible. Rf: Reproduction factor. Means in columns followed by the same letter are not significantly different (P ≤ 0.05) according to Duncan's test.

Discussion

Global eggplant production has increased in recent years (FAO, 2016); however, RKNs continue to pose a significant threat to eggplant growth in infested areas. Sikora & Fernandez (2005) reported that root nematodes cause 17-20% product losses in eggplant. Therefore, the use of resistant eggplant genotypes is required for management of RKN. In the present study, 60 eggplant genotypes with different genetic backgrounds were tested with avirulent S6 and *Mi-1* virulent V14 populations of *M. incognita*.

Solanum integrifolium Poir. Y8 and Y7 genotypes were resistant to S6 and V14 according to the egg mass index but were susceptible according to the gall index. Several studies have shown that *S. integrifolium* is susceptible to *M. incognita* (Daunay & Dalmasso, 1985; Ali et al., 1992; Rahman et al., 2002; Uehara et al., 2016). In the present study, *Solanum aethiopicum* L. Y14 and Y30 genotypes were susceptible to both the avirulent and virulent populations of *M. incognita.* Hebert (1985) previously reported that *S. aethiopicum* genotypes were resistant to *M. incognita,* although other studies have reported that *S. aethiopicum* genotypes were susceptible or moderately resistant to *M. incognita* (Gisbert et al., 2011; Dhivya et al., 2014). In the present study, *S. torvum* was resistant to both the avirulent S6 and virulent V14 populations of *M. incognita,* in agreement with previous studies that showed resistance of *S. torvum* to *M. incognita* populations (Daunay & Dalmasso, 1985; Hebert, 1985; Ali et al., 1992; Rahman et al., 2002; Dhivya et al., 2014). Gonzalez et al. (2010) found that *S. torvum* was resistant to both *M. incognita* and *M. arenaria*, while other studies demonstrated that the *S. torvum* cvs Tonashimu, Torero and Torvum Vigor were resistant to populations of *M. incognita* (Uehara et al., 2016, 2017). Recent work has shown that *S. torvum* was resistant to both avirulent and virulent populations of *M. incognita* (Öçal et al., 2018). The present findings agree with these previous studies.

In this study, all *S. incanum* genotypes were susceptible to the S6 and V14 populations of *M. incognita*, in agreement with the findings of Gisbert et al. (2011), who showed susceptibility of a *Solanum incanum* L. genotype to a population of *M. incognita*. In other studies, the *S. incanum* genotype was found resistant or moderately resistant to a population of *M. incognita* (Hebert, 1985; Dhivya et al., 2014). These different responses may reflect differences in the genetic backgrounds of the studied plants. In the present study, the eggplant cross combinations showed differences in susceptibility to RKN populations. For example, *S. integrifolium* × *S. incanum* (Y2), *S. integrifolium* × *S. integrifolium* (Y33) and *S. aethiopicum* × *S. incanum* (M22) were susceptible to both the S6 and V14 populations of *M. incognita,* as were the *S. melongena* × *S. aethiopicum* combinations Y17, Y18, Y21, Y22, Y23, Y24 and Y25 and the *S. melongena* × *S. incanum* genotypes Y29 and M23. Gisbert et al. (2011) reported that *S. melongena* × *S. aethiopicum* and *S. melongena* × *S. incanum* combinations were susceptible in fields infested with *M. incognita*. Similarly, Ali et al. (1992) showed that cultivar eggplant × wild eggplant genotype crosses were susceptible to a population of *M. incognita*.

In this study, a total of 32 of 33 *S. melongena* genotypes, including cultivated eggplant rootstocks, pure lines, standard commercial cultivars and commercial hybrids, were susceptible to the *Mi-1* virulent V14 and avirulent S6 populations of *M. incognita.* Only the Y12 genotype was resistant to the *Mi-1* virulent V14 population of *M. incognita,* according to the egg mass numbers. Gisbert et al. (2011) reported that rootstock AGR 703 F_1 was susceptible to a population of *M. incognita*. In previous studies, *S. melongena* genotypes were reported to be either susceptible or resistant to populations of *M. incognita* (Ullah et al., 2011; Nayak & Sharma 2013; Begum et al., 2014; Nayak & Pandey, 2015). Local genotypes ANS6 and ASIS1 were susceptible, but IVIA371 and PI263727 were resistant (Gisbert et al., 2011). The cultivated eggplant cv. Senryo 2 gou was susceptible to populations of *M. incognita* (Uehera et al., 2016; 2017), while the rootstock cultivar Daitaro was susceptible to the virulent *M. incognita* Chiba and Niigata populations (Uehara et al., 2016). In another study, *S. melongena* cultivars, including Pusa Purple Long, Purple Cluster and Purple Round, were susceptible to *M. incognita* (Alam et al., 1974; Dhawan & Sethi, 1976; Ravichandra et al., 1988; Nayak & Sharma, 2013).

In the present study, the Rf values were calculated for the two populations of *M. incognita* on all genotypes, and all Rf values of the populations on resistant genotypes were <1. However, although the Y15 and Y22 genotypes were susceptible to the V14 population of *M. incognita,* their Rf values were <1. Similarly, although the M10, M22, M23, M24, M25, M26, M27, Y11 and Y27 genotypes were susceptible to the S6 population of *M. incognita*, their Rf values were <1. These differences may reflect the life cycle of the nematodes, the plant-nematode interaction and/or the root structures of the plants.

In conclusion, many commercial eggplant cultivars are grown throughout the world, but none are resistant to RKNs. *Solanum torvum* is widely employed commercially as a rootstock to protect against RKNs (Lee, 1994). Recently, the *SacMi* gene from *Solanum aculeatissimum* Jacq., which has been reported to confer resistance to *M. incognita,* has been cloned and characterized (Zhou et al., 2018). The investigation of new resistant sources, such as *S. aculeatissimum,* is needed for management in fields infested with RKNs. A more in-depth knowledge of the responses of different eggplant genotypes to RKNs would be valuable, so future research should test resistant genotypes against different RKN species to establish better integrated management practices. The findings could then be used in RKN breeding and management approaches.

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