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*Original article (Orijinal araştırma)*

# Investigation of reactions of some watermelon and melon genotypes and varieties to *Meloidogyne incognita* (Kofoid & White, 1919) Chitwood, 1949 race 1 and *Meloidogyne javanica* (Treub, 1885) Chitwood, 1949 (Tylenchida: Meloidogynidae) races 1 and 3[1]

## Bazı karpuz ve kavun genotip ve çeşitlerinin *Meloidogyne incognita* (Kofoid & White, 1919) Chitwood, 1949 ırk 1 ile *Meloidogyne javanica* (Treub, 1885) Chitwood, 1949 (Tylenchida: Meloidogynidae) ırk 1 ve 3'e karşı reaksiyonlarının araştırılması

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## Abstract

Root-knot nematodes are important soil-borne pathogens that cause significant economic losses in the production of melons and watermelons. In Türkiye, particularly in the Çukurova region, research into identifying resistant genotypes against these pests has been limited. This study evaluated the reactions of 12 melon genotypes, 12 watermelon genotypes, and three commercial varieties of each crop against *Meloidogyne incognita* (Kofoid & White, 1919) Chitwood, 1949 race 1, and *Meloidogyne javanica* (Treub, 1885) Chitwood, 1949 (Tylenchida: Meloidogynidae) races 1 and 3. These experiments were conducted between 2017 and 2020 in collaboration with the Department of Plant Protection at the Faculty of Agriculture, Çukurova University, and the Biological Control Research Institute Directorate in the relevant laboratories and greenhouses. According to the results, all genotypes exhibited varying degrees of susceptibility to both nematode species and races, with no complete resistance observed. However, Kav-216 (melon) and Kar-96 (watermelon) showed partial tolerance, particularly against *M. javanica* races 1 and 3, with the lowest egg counts and gall indices recorded in these genotypes. These findings are consistent with previous international studies and suggest that Kav-216 and Kar-96 could serve as genetic resources in breeding programmes aimed at developing resistant rootstocks. This study makes an important contribution to breeding programmes focused on root-knot nematode resistance.

**Keywords:** Melon, resistance, root-knot nematodes, tolerance, watermelon

## Öz

Kök-ur nematodları, kavun ve karpuz üretiminde ciddi ekonomik kayıplara yol açan önemli toprak kökenli patojenlerdir. Türkiye'de, özellikle Çukurova bölgesinde, bu zararlılara karşı dayanıklı genotiplerin belirlenmesine yönelik çalışmalar sınırlı kalmıştır. Bu çalışmada, 12 kavun genotipi, 12 karpuz genotipi ve her bir mahsulün üç ticari çeşidinin *Meloidogyne incognita* (Kofoid & White, 1919) Chitwood, 1949 ırk 1 ve *Meloidogyne javanica* (Treub, 1885) Chitwood, 1949 (Tylenchida: Meloidogynidae) ırk 1 ve 3'e karşı tepkileri değerlendirilmiştir. Denemeler 2017-2020 yılları arasında Çukurova Üniversitesi Ziraat Fakültesi Bitki Koruma Bölümü ile Biyolojik Mücadele Araştırma Enstitüsü Müdürlüğü iş birliğinde ilgili laboratuvarlar ve seralarda gerçekleştirilmiştir. Sonuçlara göre, incelenen tüm genotipler her iki nematod türü ve ırklarına karşı farklı derecelerde duyarlılık göstermiş, tam direnç gözlenmemiştir. Bununla birlikte, Kav-216 (kavun) ve Kar-96 (karpuz) genotipleri, özellikle *M. javanica* ırk 1 ve 3'e karşı kısmi tolerans sergilemiş; bu genotiplerde en düşük yumurta sayıları ve gal indeksleri kaydedilmiştir. Elde edilen bulgular, önceki uluslararası çalışmalarla paralellik göstermekte ve Kav-216 ile Kar-96'nın dirençli anaç geliştirme çalışmalarında kullanılabilecek genetik kaynaklar olabileceğini düşündürmektedir. Bu çalışma, kök-ur nematodu direnci üzerine yürütülecek ıslah programlarına önemli katkılar sunmaktadır.

**Anahtar sözcükler:** Kavun, direnç, kök-ur nematodları, tolerans, karpuz

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## Introduction

Melon, *Cucumis melo* L. and watermelon, *Citrullus lanatus* L. (Cucurbitales: Cucurbitaceae) are among the plant species with high nutritional value. These are widely used not only in the food industry, but also in the cosmetics and natural pharmaceutical industries, thanks to their high-water content and rich vitamin and mineral composition (Taşkaya & Keskin, 2004). However, the production of these economically important plants is threatened by various biotic stress factors. Root diseases, which are especially common in cucurbits, are triggered by pests that share the same ecological niche in the rhizosphere, such as soil-borne pathogenic fungi (SBPF) and plant-parasitic nematodes. These agents destroy the vascular system of their host plants, limiting water and nutrient uptake, resulting in yield and quality losses (Ayala-Doñas et al., 2020).

Plant-parasitic nematodes are among the obligate parasitic organisms of the animal kingdom and, following fungi, they constitute one of the most significant groups of plant-damaging agents (Quist et al., 2015) Within this group, root-knot nematodes are prominent economic pests due to their wide host spectrum, short generation time and high reproductive capacity (Trudgill & Blok, 2001). The second-stage juveniles (J2) of these nematodes cause the characteristic “gall” formation in plant roots, disrupting root physiology and leading to severe reduction in crop quantity and quality by preventing water and nutrient uptake (Singh et al., 2019). Moreover, the physiological stress caused by *Meloidogyne* species can facilitate the entry of other pathogens, setting the stage for secondary infections and the development of disease complexes (Smanth et al., 2018).

Annual economic losses caused by root-knot nematodes in vegetable production are reported to exceed US$ 80 billion (Blok et al., 2008). In cucurbit crops such as melon and watermelon, root-knot nematodes have been reported to cause yield losses of 18% to 65% and fruit weight reductions of 24% to 30% (Ploeg & Phillips, 2001; Davis, 2007). These data clearly indicate that root-knot nematodes are critically important pathogens in these crop groups (Thies & Levi, 2003; Pofu et al., 2011).

Although chemical nematicides commonly used against root-knot nematodes are effective in the short term, their environmental toxicity and long-term loss of efficacy are incompatible with the principles of sustainable agriculture (Ntalli & Caboni, 2012; Özevin et al., 2025). Therefore, it is of great importance to develop alternative strategies that are environmentally friendly and compatible with integrated control approaches (Ulaş et al., 2025; Yılmaz et al., 2025). In this context, the use of nematode-resistant varieties stands out as an economically and environmentally advantageous method (Roberts, 2002; Noling, 2016). While resistant plants suppress nematode populations by limiting pathogen development and multiplication, susceptible genotypes facilitate the spread of the pathogen and cause disease progression (Cook & Evans, 1987; Roberts, 2002).

Identification of resistant genotypes is a priority not only for increasing yield and reducing disease pressure, but also for supporting sustainable agriculture by reducing chemical use (Sikora & Fernandez, 2005). However, studies comparing the responses of melon and watermelon genotypes to different races of *Meloidogyne incognita* (Kofoid & White, 1919) Chitwood, 1949 and *Meloidogyne javanica* (Treub, 1885) Chitwood, 1949 (Tylenchida: Meloidogynidae), especially regionally focused studies, are limited in the literature. Taking into account the variation caused by pathogens with different races is of great importance for the correct identification of genetic resistance sources.

The objective of this study was to evaluate the reactions of 12 melon and 12 watermelon genotypes, along with three commercial cultivars, against *M. incognita* race 1 and *M. javanica* races 1 and 3, which were isolated from melon and watermelon production areas in the Çukurova Region of Türkiye. Also, to find out the levels of susceptibility exhibited by these genotypes is another objective, as well as to identify potential sources of resistance. The findings are expected to contribute to integrated plant protection strategies specific to the region and provide a scientific basis for the inclusion of resistant varieties in breeding programs.

## Materials and Methods

### Melon and watermelon genotypes and varieties

Genotypes of 12 melon (Kav-3, Kav-4, Kav-5, Kav-27, Kav-51, Kav-216, Kav-243, Kav-268, Kav-270, Kav-274, Kav-344, Kav-345) and 12 watermelon genotypes (Kar-3, Kar-4, Kar-5, Kar-96, Kar-171, Kar-172, Kar-174, Kar-191, Kar-192, Kar-200, Kar-205, Kar-213) were obtained from the Horticulture Department of Çukurova University. The three melon (Sürmeli, Tanem, Çıtırex) and 3 three watermelon (Charleston Grey, Starbust Ala watermelon, Karain Black watermelon) varieties used in the study were purchased from commercial production companies.

### Obtaining pure cultures of root-knot nematodes

Populations of *Meloidogyne* spp. collected from the Çukurova melon and watermelon fields were grown on the roots of the tomato-susceptible SC 2121 variety, and pure cultures were established. Seedlings grown in sterilized medium were inoculated with J2 into the root collar at the 2nd and 4th leaf stage. After 6-8 weeks, the egg masses formed on the roots were collected and pure culture populations were started with new seedlings. The isolated nematodes were identified by molecular and biochemical methods. Resistance tests were carried out with populations identified as *M. javanica* races 1 and 3 and *M. incognita* race 1.

### Experimental set-up and nematode inoculation

The seeds of the melon and watermelon genotypes used in the experiment were sown in the peat containing pots and to obtain seedlings. When the seedlings, to be used in the study, reached 10-15 cm, they were transplanted with one seedling into each pot. The soil mixture used in the pots was prepared with 80% sand, 5% silt and 15% clay and was disinfected in an autoclave before the experiment.

One week after transplanting the seedlings, 1000 nematode J2 per pot were inoculated into soil holes drilled about 2 cm deep in the root zone. This inoculation was made close to the root collar of the plants and this method was preferred to more accurately assess the effect of the nematodes on the roots.

### Evaluation of the experiment

In this experiment, the resistance of melon and watermelon genotypes was assessed using parameters such as the number of egg masses on roots, the density of second stage juveniles (J2) in the soil and the rate of reproduction (Ro, R = Pf/Pi). At 60th day of post inoculation, roots were washed with non-pressurized water, soaked in red food dye for 5-10 minutes and then examined under a magnifying glass to count egg masses. Resistance and susceptibility were scored on a scale of 0-5 based on the number of egg packages, with 0-2 being resistant and 3-5 being susceptible (Hartman & Sasser, 1985)

In addition, the density of J2 in soil was measured using the modified Baermann-Funnel method (Hooper, 1986) and J2 were counted under a microscope. Reproduction rate (Ro) was calculated by dividing the total number of eggs (Pf) and J2 from the soil by the initial number of nematodes (Pi) introduced into the pots (Hussey & Janssen, 2002).

### Statistical analysis

The data were analyzed by applying the analysis of variance (ANOVA) using SPSS statistical software. The significance of the differences between the means was evaluated by Duncan's multiple comparison test at the 0.05 level and the significant differences between the groups were determined. In the statistical analysis, differences with a *p*-value less than 0.05 were considered significant. This analysis was designed to reliably detect differences in performance between the genotypes used and to ensure correct interpretation of the data.

## Results

### Reaction of melon genotypes and cultivars to root-knot nematode races

When the egg masse index was analyzed, it was found that all genotypes and cultivars had 4 and 5 scale values. According to the number of egg masses, the highest mean value belonged to Kav-5 (268.25) and the lowest mean values belonged to Kav-345 (53.50) and Kav-243 (57.50) genotypes, respectively (Table 1). The highest number of eggs obtained from egg masses for *M. incognita* race 1 was obtained from the commercial variety Çıtırex (26,166). This was followed by Kav-270 (25,604), Kav-5 (25,215) genotypes, Tanem (25,061) cultivar and Kav-51 (23,924) genotype, respectively. The genotype with the lowest number of eggs was Kav-216 (6,825), followed by Kav-243 (9,085), Kav-268 (11,187), Kav-345 (12,358), Kav-274 (16,577) and Kav-4 (17,888). The number of J2 in the soil was highest in Kav-268 (3,135) and lowest in Kav-216 (190) genotypes. Melon genotypes and cultivars showed sensitive host reaction against *M. incognita* race 1 (Table 1).

Table 1. Egg mass indices, egg counts, and second-stage juveniles (J2) numbers of root-knot nematode races in melon genotypes and cultivars, and the corresponding reactions of the genotypes and cultivars

| Genotypes and variety | Number of egg mass Mean±SD | Egg mass index* Mean±SD | Average number of eggs per egg mass Mean±SD | J2 / 100 g soil Mean±SD | Host Reaction ** |
|---|---|---|---|---|---|
| | | | *Meloidogyne incognita* race 1 | | |
| Kav-3 | 64.50±8.51[c] | 4.00±0.00[b] | 16,3833.00±2,161.49[abc] | 210.00±57.45[b] | S |
| Kav-4 | 86.00±25.75[bc] | 4.25±0.25[ab] | 17,888.00±5,356.42[abc] | 350.00±112.10[b] | S |
| Kav-5 | 268.25±78.8[a] | 5.00±0.00[a] | 25,215.50±7,412.74[ab] | 795.00±275.00[b] | S |
| Kav-27 | 88.75±16.29[bc] | 4.25±0.25[ab] | 20,590.00±3,779.51[abc] | 275.00±87.70[b] | S |
| Kav-51 | 202.75±67.20[ab] | 4.75±0.25[ab] | 23,924.50±7,929.65[ab] | 380.00±136.38[b] | S |
| Kav-216 | 65.00±17.75[c] | 4.25±0.25[ab] | 6,825.00±1,863.57[c] | 190.00±34.16[b] | S |
| Kav-243 | 57.50±8.70[c] | 4.00±0.00[b] | 9,085.00±1,375.14[bc] | 450.00±174.64[b] | S |
| Kav-268 | 89.50±25.21[bc] | 4.00±0.41[b] | 11,187.50±3,151.76[abc] | 3,135.00±1,851.82[a] | S |
| Kav-270 | 173.00±27.94[abc] | 5.00±0.00[a] | 25,604.00±4,134.74[ab] | 1,095.00±368.00[b] | S |
| Kav-274 | 87.25±19.88[bc] | 4.25±0.25[ab] | 16,577.50±3,777.27[abc] | 710.00±212.99[b] | S |
| Kav-344 | 100.00±26.69[bc] | 4.50±0.50[ab] | 22,000.00±5,871.71[abc] | 950.00±305.67[b] | S |
| Kav-345 | 53.50±11.78[c] | 4.00±0.00[ab] | 12,358.50±2,721.00[abc] | 755.00±374.64[b] | S |
| Sürmeli | 113.25±20.19[bc] | 4.75±0.25[ab] | 23,103.00±4,118.39[abc] | 1,395.00±450.43[b] | S |
| Tanem | 153.75±54.46[bc] | 4.75±0.25[ab] | 25,061.25±8,876.74[ab] | 605.00±171.73[b] | S |
| Çıtırex | 147.00±24.09[bc] | 5.00±0.00[a] | 26,166.00±4,288.66[a] | 430.00±31.09[b] | S |
| | | | *Meloidogyne javanica* race 1 | | |
| Kav-3 | 248.25±58.73[a] | 5.00±0.00[a] | 25,073.25±5,931.74[ab] | 440.00±18.26[ab] | S |
| Kav-4 | 236.25±18.50[a] | 5.00±0.00[a] | 21,735.00±1,701.95[abc] | 450.00±38.73[ab] | S |
| Kav-5 | 52.00±10.55[b] | 4.00±0.00[b] | 10,296.00±2,089.19[def] | 430.00±78.53[ab] | S |
| Kav-27 | 107.50±7.77[b] | 4.75±0.25[a] | 18,920.00±1,368.02[abcd] | 1,125.00±520.79[ab] | S |
| Kav-51 | 78.25±17.68[b] | 4.25±0.25[b] | 12,676.50±2,864.83[cdef] | 420.00±137.84[ab] | S |
| Kav-216 | 29.50±0.29[b] | 3.00±0.00[c] | 2,891.00±28.29[f] | 210.00±91.47[b] | S |
| Kav-243 | 55.00±13.53[b] | 4.00±0.00[b] | 11,385.00±2,800.24[def] | 540.00±164.32[ab] | S |
| Kav-268 | 65.00±9.95[b] | 4.00±0.00[b] | 10,855.00±1,661.63[def] | 585.00±118.43[ab] | S |
| Kav-270 | 54.75±14.85[b] | 4.00±0.00[b] | 15,932.25±4,321.74[bcde] | 575.00±175.76[ab] | S |
| Kav-274 | 292.75±64.14[a] | 5.00±0.00[a] | 26,933.00±5,900.97[a] | 905.00±316.79[ab] | S |
| Kav-344 | 87.00±30.17[b] | 4.25±0.48[b] | 15,312.00±5,310.71[bcde] | 965.00±719.74[ab] | S |
| Kav-345 | 65.25±8.95[b] | 4.00±0.00[b] | 8,743.50±1,199.00[def] | 895.00±249.32[ab] | S |
| Sürmeli | 38.00±4.14[b] | 4.00±0.00[b] | 7,980.00±870.09[ef] | 1,395.00±450.43[a] | S |
| Tanem | 39.25±3.40[b] | 4.00±0.00[b] | 9,891.00±856.89[def] | 605.00±171.73[ab] | S |
| Çıtırex | 33.50±1.19[b] | 4.00±0.00[b] | 7,906.00±280.90[ef] | 430.00±31.09[ab] | S |

Table 1. Continued

| Genotypes and variety | Number of egg mass Mean±SD | Egg mass index* Mean±SD | Average number of eggs per egg mass Mean±SD | J2 / 100 g soil Mean±SD | Host Reaction ** |
|---|---|---|---|---|---|
| | | *Meloidogyne javanica* race 3 | | | |
| Kav-3 | 242.50±92.66[a] | 4.75±0.25[ab] | 24,977.50±9,544.10[a] | 2,235.00±1,130.94[a] | S |
| Kav-4 | 326.00±11.77[a] | 5.00±0.00[a] | 28,688.00±1,035.64[a] | 485.00±134.01[b] | S |
| Kav-5 | 266.50±97.69[a] | 4.75±0.25[ab] | 26,117.00±9,573.66[a] | 1,085.00±103.72[b] | S |
| Kav-27 | 265.75±41.98[a] | 5.00±0.00[a] | 24,980.50±3,946.58[a] | 2,325.00±390.25[a] | S |
| Kav-51 | 61.00±1.68[b] | 4.00±0.00[c] | 10,736.00±296.25[b] | 465.00±228.09[b] | S |
| Kav-216 | 15.00±1.41[b] | 3.00±0.00[d] | 2,400.00±226.27[b] | 95.00±29.86[b] | S |
| Kav-243 | 51.75±6.90[b] | 4.00±0.00[c] | 8,383.50±1,117.24[b] | 715.00±308.80[b] | S |
| Kav-268 | 19.00±0.91[b] | 3.00±0.00[d] | 4,484.00±215.44[b] | 70.00±20.82[b] | S |
| Kav-270 | 13.00±0.91[b] | 3.00±0.00[d] | 2,574.00±180.75[b] | 75.00±42.72[b] | S |
| Kav-274 | 57.50±2.47[b] | 4.00±0.00[c] | 9,890.00±424.23[b] | 215.00±92.87[b] | S |
| Kav-344 | 60.25±22.14[b] | 4.25±0.25[bc] | 11,086.00±4,074.66[b] | 260.00±67.82[b] | S |
| Kav-345 | 25.00±7.78[b] | 3.00±0.71[d] | 3,300.00±1,026.72[b] | 135.00±51.88[b] | S |
| Sürmeli | 70.25±8.08[b] | 4.00±0.00[c] | 8,078.75±928.79[b] | 130.00±26.46[b] | S |
| Tanem | 12.75±0.85[b] | 3.00±0.00[d] | 2,639.25±176.76[b] | 90.00±23.80[b] | S |
| Çıtırex | 32.00±0.41[b] | 4.00±0.00[c] | 4,608.00±58.79[b] | 130.00±84.26[b] | S |

* Egg mass index: 0-5, where 0 = no galling, 1 = 1-2 egg masses, 2 = 3-10 egg masses, 3 = 11-30 egg masses, 4 = 31-100 egg masses, and 5 = more than 100 egg masses.
** S: Susceptible (Egg mass index 3-5); R: Resistant (Egg mass index 1-2).
*** Within each genotype, letters in the same column indicate statistically significant differences according to Duncan's multiple range test at $p \leq 0.05$.

In the tests with *M. javanica* race 1, all melon genotypes and cultivars showed sensitive reaction. It was determined that Kav-216 genotype, which had the lowest index value, entered the 3 scale unlike the others. According to the results of the analysis of variance based on the number of egg masses, the genotype Kav-216 (29.50), which had the lowest mean value, and the varieties Çıtırex (33.50), Sürmeli (38.00) and Tanem (39.25), which are commercially sold in the market, were in the same group (p<0.05). The highest number of eggs of *M. javanica* race 1 was found in Kav-274 (26,933) genotype. This was followed by Kav-3 (25,073) and Kav-4 (21,735) genotypes, respectively. Kav-216 (2,891) genotype had the lowest mean egg count statistically, followed by Çıtırex (7,906) and Sürmeli (7,980) varieties, respectively. The number of J2 in the soil was highest in Sürmeli (1,395) and lowest in Kav-216 (210) genotypes.

The host reactions of melon genotypes and cultivars against *M. javanica* race 3 had a scale of 3, 4 and 5 and were determined to be sensitive. According to the egg mass index values, the lowest number of egg masses among the genotypes and cultivars in the 3 scale belonged to Tanem (12.75), followed by Kav-270 (13.00), Kav-216 (15.00), Kav-268 (19.00) and Kav-345 (25.00) genotypes, respectively.

The highest number of eggs for *M. javanica* race 3 was found in Kav-4 (28,688) genotype, followed by Kav-5 (26,117), Kav-27 (24,298) and Kav-3 (24,977) genotypes, respectively. The lowest number of eggs was recorded in Kav-216 (2,400) genotype ($p<0.05$). Except Kav-3 and Kav-27 genotypes, there was no difference between all other genotypes and cultivars in terms of mean larval numbers, and they were in the same group.

**Reaction of watermelon genotypes and cultivars to root-knot nematode races**

All watermelon genotypes and cultivars were susceptible to *M. incognita* race 1. When egg mass index values were analyzed, all genotypes and cultivars had index scores of 4 or 5. The lowest number of egg masses was observed in the genotype Kar-213 (42.25) ($p<0.05$). In the same trial, the highest egg count was recorded in Charleston Grey (21,266), while the lowest was observed in Karain (11,072). Among the genotypes, Kar-213 (12,421) also showed a relatively low egg count, similar to Karain. When evaluated in terms of the number of J2, the Kar-213 genotype again exhibited the lowest value.

All watermelon genotypes and cultivars exhibited a susceptible host reaction to *M. javanica* races 1 and 3. In the *M. javanica* race 1 trial, the lowest egg mass index was observed in the Kar-96 genotype, while all other genotypes and cultivars had an index score of 4 (Table 2). Kar-96 also had the lowest values in terms of both egg (4,206) and J2 (65.00) counts. In the *M. javanica* race 3 trial, the lowest number of egg masses was again observed in Kar-96 (13.00), followed closely by Kar-205 (13.50), Kar-3 (15.00), Kar-5 (15.75), and Kar-192 (17.75). Similarly, Kar-96 had the lowest egg count (2,080), while Kar-192 (2,733), Kar-205 (2,889), and Kar-3 (3,105) had values close to Kar-96. In the experiment with watermelon genotypes and varieties, it was found that the Kar-213 genotype had the lowest value against *M. incognita* race 1, while the Kar 96 genotype had the lowest number of eggs against *M. javanica* races 1 and 3.

Table 2. Egg mass indices, egg counts, and second-stage juveniles (J2) numbers of root-knot nematode races in watermelon genotypes and cultivars, and the corresponding reactions of the genotypes and cultivars

| Genotypes and variety | Number of egg mass Mean±SD | Egg mass index* Mean±SD | Average number of eggs per egg mass Mean±SD | J2 / 100 g soil Mean±SD | Host Reaction ** |
|---|---|---|---|---|---|
| | | | *Meloidogyne incognita* race 1 | | |
| Kar-3 | 49.00±6.01$^{efg}$ | 4.00±0.00$^{b}$ | 14,798.00±1,816.19$^{abc}$ | 220±40.82$^{bc}$ | S |
| Kar-4 | 63.00±5.67$^{defg}$ | 4.00±0.00$^{b}$ | 15,057.00±1,355.50$^{abc}$ | 260±61.64$^{bc}$ | S |
| Kar-5 | 101.00±8.44$^{abcd}$ | 4.50±0.29$^{ab}$ | 18,786.00±1,569.10$^{abc}$ | 530±220.53$^{abc}$ | S |
| Kar-96 | 89.00±9.72$^{bcde}$ | 4.25±0.25$^{ab}$ | 18,156.00±1,983.11$^{abc}$ | 310±85.44$^{bc}$ | S |
| Kar-171 | 76.25±10.98$^{cdefg}$ | 4.25±0.25$^{ab}$ | 19,367.50±2,788.94$^{abc}$ | 330±58.02$^{abc}$ | S |
| Kar -172 | 84.50±13.92$^{bcdef}$ | 4.25±0.25$^{ab}$ | 17,069.00±2,811.72$^{abc}$ | 245±42.72$^{bc}$ | S |
| Kar-174 | 109.00±9.06$^{abc}$ | 4.75±0.25$^{a}$ | 16,023.00±1,331.14$^{abc}$ | 425±34.03$^{abc}$ | S |
| Kar-191 | 83.25±15.23$^{bcdefg}$ | 4.25±0.25$^{ab}$ | 17,482.50±3,197.91$^{abc}$ | 420±49.67$^{abc}$ | S |
| Kar-192 | 63.25±5.92$^{defg}$ | 4.00±0.00$^{b}$ | 15,686.00±1,468.50$^{abc}$ | 435±95.35$^{abc}$ | S |
| Kar-200 | 137.50±24.92$^{a}$ | 4.75±0.25$^{a}$ | 19,937.50±3,613.62$^{ab}$ | 555±86.55$^{ab}$ | S |
| Kar-205 | 120.00±23.97$^{ab}$ | 4.75±0.25$^{a}$ | 16,320.00±3,259.75$^{abc}$ | 490±243.10$^{abc}$ | S |
| Kar -213 | 42.25±3.71$^{g}$ | 4.00±0.00$^{b}$ | 12,421.50±1,089.35$^{bc}$ | 100±21.60$^{c}$ | S |
| Charleston Grey | 62.00±8.23$^{defg}$ | 4.00±0.00$^{b}$ | 21,266.00±2,821.51$^{a}$ | 430±188.41$^{abc}$ | S |
| Starbust | 46.75±12.20$^{fg}$ | 4.00±0.00$^{b}$ | 19,868.75±4,397.52$^{ab}$ | 480±122.47$^{abc}$ | S |
| Karain | 42.75±2.95$^{g}$ | 4.00±0.00$^{b}$ | 11,072.25±765.22$^{c}$ | 770±250.93$^{a}$ | S |
| | | | *Meloidogyne javanica* race 1 | | |
| Kar-3 | 33.50±1.50$^{bc}$ | 4.00±0.00$^{b}$ | 7,839.00±351.00$^{cde}$ | 495.00±262.85$^{ab}$ | S |
| Kar-4 | 45.50±4.09$^{abc}$ | 4.00±0.00$^{b}$ | 9,464.00±851.28$^{abcde}$ | 365.00±62.38$^{ab}$ | S |
| Kar-5 | 58.00±12.92$^{ab}$ | 4.00±0.00$^{b}$ | 12,992.00±2,893.27$^{abc}$ | 260.00±82.46$^{ab}$ | S |
| Kar-96 | 23.50±11.72$^{c}$ | 3.00±0.41$^{c}$ | 4,206.50±2,098.32$^{e}$ | 65.00±20.62$^{b}$ | S |
| Kar-171 | 61.75±6.50$^{ab}$ | 4.00±0.00$^{b}$ | 14,387.75±1,514.13$^{ab}$ | 550.00±332.11$^{ab}$ | S |
| Kar-172 | 32.50±0.87$^{bc}$ | 4.00±0.00$^{b}$ | 6,727.50±179.27$^{de}$ | 85.00±12.58$^{ab}$ | S |
| Kar-174 | 44.00±6.92$^{abc}$ | 4.00±0.00$^{b}$ | 8,712.00±1,369.40$^{bcde}$ | 195.00±62.38$^{ab}$ | S |
| Kar-191 | 73.75±19.09$^{a}$ | 4.50±0.29$^{a}$ | 8,850.00±2,290.70$^{bcde}$ | 625.00±145.46$^{a}$ | S |
| Kar-192 | 34.50±2.25$^{bc}$ | 4.00±0.00$^{b}$ | 10,488.00±685.41$^{abcd}$ | 170.00±83.47$^{ab}$ | S |
| Kar-200 | 47.50±6.65$^{abc}$ | 4.00±0.00$^{b}$ | 15,057.50±2,108.71$^{a}$ | 300.00±84.85$^{ab}$ | S |
| Kar- 205 | 55.75±12.91$^{abc}$ | 4.00±0.00$^{b}$ | 5,575.00±1,291.24$^{de}$ | 265.00±139.61$^{ab}$ | S |
| Kar-213 | 45.50±7.86$^{abc}$ | 4.00±0.00$^{b}$ | 6,097.00±1,052.99$^{de}$ | 135.00±41.13$^{ab}$ | S |
| Charleston Grey | 46.50±8.17$^{abc}$ | 4.00±0.00$^{b}$ | 13,020.00±2,287.62$^{abc}$ | 165.00±72.28$^{ab}$ | S |
| Starbust | 72.00±15.46$^{a}$ | 4.00±0.00$^{b}$ | 13,608.00±2,921.87$^{abc}$ | 470.00±148.21$^{ab}$ | S |
| Karain | 51.75±6.07$^{abc}$ | 4.00±0.00$^{b}$ | 9,522.00±1,117.65$^{abcde}$ | 610.00±313.00$^{a}$ | S |

Table 2. Continued

| Genotypes and variety | Number of egg mass Mean±SD | Egg mass index* Mean±SD | Average number of eggs per egg mass Mean±SD | J2 / 100 g soil Mean±SD | Host Reaction ** |
|---|---|---|---|---|---|
| *Meloidogyne javanica* race 3 | | | | | |
| Kar-3 | 15.00±1.87$^{f}$ | 3.00±0.00$^{b}$ | 3,105.00±387.26$^{e}$ | 65.00±22.17$^{c}$ | S |
| Kar-4 | 62.25±20.63$^{ab}$ | 4.25±0.25$^{a}$ | 8,528.25±2,826.20$^{abc}$ | 415.00±211.25$^{abc}$ | S |
| Kar-5 | 15.75±3.09$^{ef}$ | 3.00±0.00$^{b}$ | 3,433.50±674.13$^{de}$ | 85.00±26.30$^{c}$ | S |
| Kar-96 | 13.00±0.91$^{f}$ | 3.00±0.00$^{b}$ | 2,080.00±146.06$^{e}$ | 90.00±20.82$^{c}$ | S |
| Kar-171 | 51.75±12.09$^{abc}$ | 4.00±0.00$^{a}$ | 7,917.75±1,850.16$^{abc}$ | 220.00±18.26$^{abc}$ | S |
| Kar-172 | 71.75±3.86$^{a}$ | 4.00±0.00$^{a}$ | 8,897.00±478.58$^{ab}$ | 415.00±201.56$^{abc}$ | S |
| Kar -174 | 22.75±2.95$^{def}$ | 3.25±0.25$^{b}$ | 5,164.25±670.68$^{cde}$ | 535.00±228.53$^{ab}$ | S |
| Kar-191 | 47.50±5.04$^{bc}$ | 4.00±0.00$^{a}$ | 6,602.50±700.77$^{bcd}$ | 95.00±27.54$^{c}$ | S |
| Kar-192 | 17.75±6.20$^{ef}$ | 3.00±0.41$^{b}$ | 2,733.50±956.32$^{e}$ | 190.00±60.28$^{bc}$ | S |
| Kar-200 | 43.00±4.08$^{bcd}$ | 4.00±0.00$^{a}$ | 7,568.00±718.52$^{abc}$ | 570.00±164.21$^{a}$ | S |
| Kar-205 | 13.50±1.19$^{f}$ | 3.00±0.00$^{b}$ | 2,889.00±254.71$^{e}$ | 100.00±29.44$^{c}$ | S |
| Kar-213 | 41.50±2.50$^{bcd}$ | 4.00±0.00$^{a}$ | 8,632.00±520.00$^{ab}$ | 295.00±145.46$^{abc}$ | S |
| Charleston Grey | 34.00±2.04$^{cdef}$ | 4.00±0.00$^{a}$ | 4,080.00±244.95$^{de}$ | 215.00±50.58$^{abc}$ | S |
| Starbust | 38.25±2.87$^{cde}$ | 4.00±0.00$^{a}$ | 10,404.00±780.27$^{a}$ | 180.00±49.67$^{bc}$ | S |
| Karain | 21.75±5.12$^{def}$ | 3.25±0.25$^{b}$ | 5,133.00±1,208.66$^{cde}$ | 90.00±12.91$^{c}$ | S |

* Egg mass index: 0-5, where 0 = no galling, 1 = 1-2 egg masses, 2 = 3-10 egg masses, 3 = 11-30 egg masses, 4 = 31-100 egg masses, and 5 = more than 100 egg masses.
** S: Susceptible (Egg mass index 3-5); R: Resistant (Egg mass index 1-2).
*** Within each genotype, letters in the same column indicate statistically significant differences according to Duncan's multiple range test at $p \leq 0.05$.

**Assessment of the reproductive potential of *Meloidogyne* races on melon and watermelon genotypes and cultivars**

The reproduction factor (Rf = Pf/Pi) is used as an indicator of the suitability of a particular host plant in terms of its resistance to nematodes. Thus, susceptible plants (where the nematode can develop, reproduce and establish populations, Noling & Ferris, 1987) have Pf/Pi > 1, whereas resistant or non-host plants have Pf/Pi < 1 (Seinhorst, 1967).

The highest reproductive coefficient of *M. incognita* race 1 on melon genotypes and cultivars was found in Kav-270 (26.70) and the lowest in Kav-216 (7.02). When *M. javanica* race 1 was analyzed, Kav-274 (27.84) was the highest and Kav-216 (3.10) was the lowest. In *M. javanica* race 3 trials, the highest result was observed in Kav-4 (29.17) and the lowest in Kav-216 (2.50) line (Figure 1).

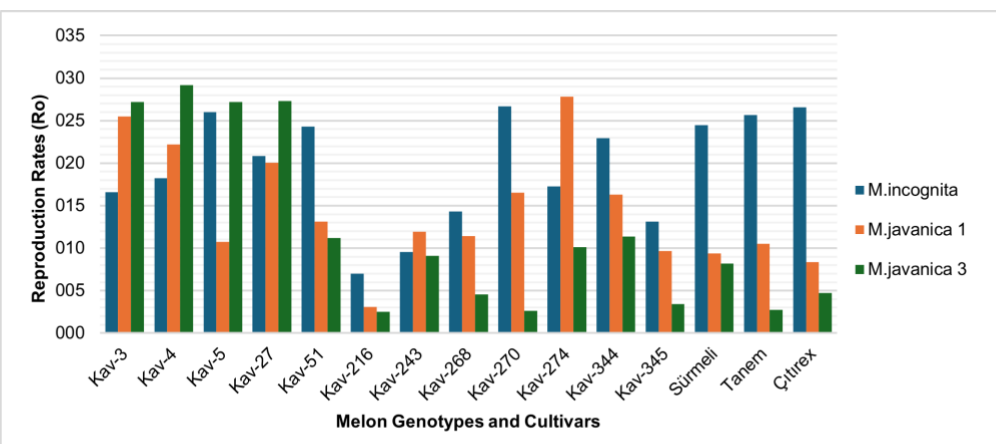


Figure 1. Reproduction rates of *Meloidogyne incognita* race 1, *Meloidogyne javanica* race 1, and race 3 on tested melon genotypes and cultivars.

The highest reproduction coefficient of *M. incognita* race 1 on watermelon genotypes and cultivars was found in Charleston Grey (21.70) and the lowest in Karain (11.84). When *M. javanica* race 1 was analyzed, this ratio was highest in Kar-171 (14.94) and lowest in Kar-96 (4.27). In *M. javanica* race 3 trials, the highest result was observed in Starbust (4.27) and the lowest in Kar-96 genotype (Figure 2).

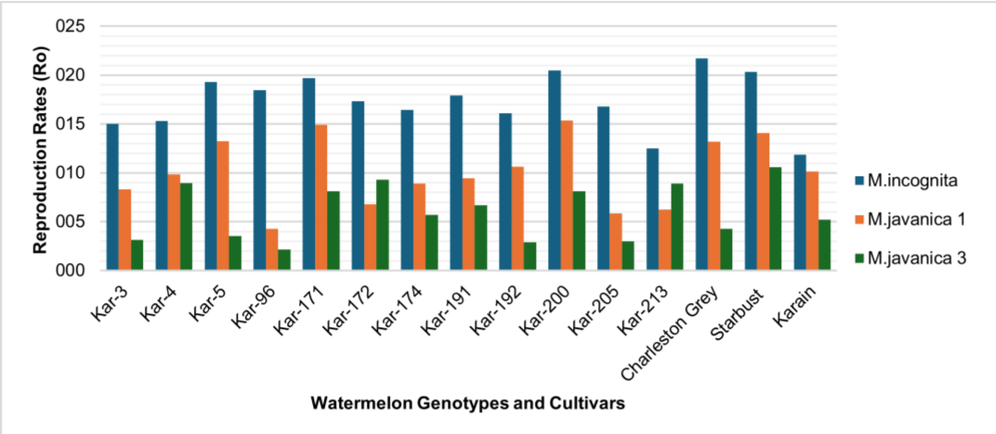


Figure 2. Reproduction rates of *Meloidogyne incognita* race 1, *Meloidogyne javanica* race 1, and race 3 on tested watermelon genotypes and cultivars.

## Discussion

There is no previous study on the responses of melon cultivars to root-knot nematodes in Türkiye. In this respect, this study fills the existing knowledge gap in some degrees based on the evaluated genotypes in Türkiye and contributes to the literature as one of the first studies on this topic. On the other hand, in recent years, several studies have been conducted in different parts of the world to identify resistant genotypes against root-knot nematodes in melons (Bitencourt & Silva, 2010; Marques et al., 2012; Galatti et al., 2013; López-Gómez & Verdejo-Lucas, 2014). Santos et al. (1999) evaluated 54 melon genotypes against *M. incognita* and reported that only two were resistant. Paiva et al. (2004) found that 8 out of 30 cantaloupe melon genotypes were resistant to *M. incognita*.

Ito et al. (2014) reported that the CNPH 01-962, CNPH 01-963 and 'Gaucho Redondo' melon genotypes exhibited resistance to *Meloidogyne incognita*, and that the Redondo Amarelo genotype demonstrated resistance to *Meloidogyne javanica*. These findings were reported in a study conducted with the objective of identifying resistant genotypes in cucurbits against *Meloidogyne incognita* and *Meloidogyne javanica*. According to Diniz et al. (2016), eight out of 15 melon genotypes (AC 29, Nantais Oblong, PI 124112, PMR-5, PMR-6, Charentais Fom1, PI 157082 and PI 420145) were resistant to *M. javanica*, but all these genotypes were susceptible to *M. incognita*. In addition, it was emphasized that no melon genotypes were found to be resistant to both nematode species.

In watermelon, *M. incognita*, *M. javanica* and *M. arenaria* are known to cause significant damage (Thies & Levi, 2003; Anwar & McKenry, 2010; Thies et al., 2010). To date, no cultivar with a high level of resistance to these species has been identified in watermelon. For example, Winstead & Riggs (1959) found that all genotypes were susceptible to root-knot nematodes in their study of 78 watermelon cultivars and 5 breeding lines. Similarly, Montalvo & Esnard (1994) evaluated 10 different watermelon cultivars and reported that all were susceptible to Puerto Rican populations of *M. incognita*. However, some cultivars (Sugar Baby, Florida Giant, Seedless) were less affected than others, while Charleston 76 and Charleston Gray were among the most susceptible genotypes.

Thies & Levi (2003, 2007) tested the response of different *Citrullus* spp. lines to *M. incognita* race 3 and *M. arenaria* races 1 and 2 under greenhouse conditions and reported that some *C. lanatus* var. *citroides* lines showed moderate resistance. These lines performed as well as rootstocks used in commercial watermelon production (Thies et al., 2010, 2015a, b). Thies et al. (2016), in the first field study involving 23 lines of *C. lanatus* var. *citroides*, *C. lanatus* var. *lanatus* and *C. colocynthis* from different countries, observed that some *C. lanatus* var. *citroides* lines were resistant to *M. incognita*. The similar performance of these lines (galling, egg clusters, root volume) under nematicide-treated and untreated conditions suggests that the resistance is genetic.

In pot trials conducted by Cohen et al. (2014), the responses of watermelon lines to *Fusarium* wilt, root collar rot, *M. javanica* and *M. incognita* were evaluated and it was found that some lines showed a high level of resistance, and these lines could be used as resistant rootstocks without any negative effect on fruit quality.

When evaluated in the light of the relevant literature, the results of this study are largely consistent with the available information. All melon and watermelon genotypes were susceptible to *M. incognita* race 1, *M. javanica* race 1 and 3. However, the lowest egg number and galling rate against *M. javanica* races 1 and 3 were found in the Kav-216 genotype in melon and the Kar-96 genotype in watermelon. This shows that Kav-216 and Kar-96 are more tolerant to *M. javanica* and can therefore be considered as potential resistant genotypes in further breeding studies.

The low level of galling and number of eggs shown by the Kar-96 genotype is similar to the watermelon genotypes showing partial resistance to *M. javanica* previously reported by Ito et al. (2014). In the study conducted by Özarslandan et al. (2018), 23 watermelon genotypes were evaluated against *M. incognita* and all genotypes were found to be susceptible; the lowest galling rate was found in lines 126 and 132 and the highest rate was found in 12 different lines. When compared with these data, it is understood that the findings of this study are consistent with the results reported in the literature.

In conclusion, this study revealed the susceptibility levels of both melon and watermelon genotypes to *M. incognita* and *M. javanica*, and the positive responses of Kav-216 and Kar-96 genotypes to *M. javanica* races 1 and 3 were found to be remarkable. These genotypes can be used as rootstocks in breeding programmes if their resistance mechanisms are detailed in future genetic characterization studies. At the same time, these results are important to provide a scientific basis for the development of resistant varieties against root-knot nematodes, which are a significant problem in melon and watermelon production in Türkiye.

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