Original article (Orijinal araştırma)

Resistance of local okra cultivars against Meloidogyne incognita (Kofoid & White, 1919) (Nematoda: Meloidogynidae), effects of nematode infestation on growth parameters and leaf macro- micronutrients

Yerel bamya çeşitlerinin Meloidogyne incognita (Kofoid & White, 1919) (Nematoda: Meloidogynidae)’ya karşı dayanıklılığini, nematod enfeksiyonunun bamyanın morfolojik özellikleri ve yapraklarda makro-mikro element içeriğine etkisi

Abstract

Okra is an important species of vegetable grown in Turkey and around the world. Root-knot nematodes cause serious yield losses in vegetables. Twenty-six cultivars okra were obtained from the Aegean Agricultural Research Institute in 2002. Resistance of this cultivars to nematode was determined and changes induced with nematode infestation on plant morphology and macro- and micronutrients in leaves measured. The experiments were conducted in completely randomized design with four replicates in climate-controlled glasshouse at Alata Horticultural Research Institute in 2019. The cultivars were tested against Meloidogyne incognita (Kofoid & White, 1919) (Nematoda: Meloidogynidae) at 25 ± 2°C. After inoculation, root gall indexes varied with an average of 4.56. Compared to un inoculated controls, nematode inoculated reduced plant height by 46.0%, stem thickness by 9.06%, root lengths by 39.7%, leaf widths by 15.1%, leaf lengths by 20.5% and increase root weight by 14.5%. Leaf macro- and micronutrients were determined. Compared to the control, nematode inoculated reduced leaf N, P, K and Mg concentrations by 2.31, 5.85, 5.24 and 10.3%, respectively, and increased Ca, Fe, Zn, Mn and Cu concentrations by 7.91, 17.0, 13.4, 118 and 15.6%, respectively.

Keywords: Meloidogyne incognita, morphological traits, nutrient, okra, resistance

Öz

Bamya dünyada ve ülkemize yetiştiriciliği yapılan önemli sebze türlerinden birisidir. Kök-urmak nematodlara sebzelede önemli ürün kayıplarına neden olmaktadır. Ege Tarımsal Araştırma Enstitüsü’nün 2002 yılında getirilen 26 yerel bamya çeşidinin nematodlara karşı dayanıklılığını, bitki morfolojisinde meydana gelen değişikliklere ve bitki yapraklarındaki makro-mikro besin elemanları içeriğine bakılmıştır. Deneme teşadüf parsları deneme desenine göre 4 tekrarlamalı olarak Alata Bahçe Kültürleri Araştırma Enstitüsü Mükûnlüğü’ne ait kontrollü cam seralarda 2019 yılında yürütülmüştür. Yerel bamya çeşitleri Meloidogyne incognita (Kofoid & White, 1919) (Nematoda: Meloidogynidae), popülasyonuna karşı 25 ± 2°C'de testlenmiştir. İnokulasyondan sonra bitkiler 60. günde bitki sökümü yapılarak kâk gal indeksi değerlendirme yapılmış ve ortalaması 4.56 ur indeksi oluşturduğu belirlenmiştir. Bitkisel özelliklerde kök-ur nematod uygulamasının kontrol bitkilerine göre bitki boyunun ortalaması %46.0, gövde kalınığını %9.06, kök uzunluğunu %39.7, yaprak eni uzunluğunu %15.1, yaprak boyu uzunluğunu %20.50 oranında azalttığı ve bamya kâk ağırlığını ise ortalaması %14.5 oranında arttırdığı belirlenmiştir. Bitki yapraklarında makro-mikro besin içeriklerini ise kök-ur nematod uygulamasının kontrol bitkileri N, P, K ve Mg değerleri ortalamada sırasıyla %2.31, 5.85, 5.24 ve 10.3 oranında azalttığı belirlenmiştir. Buna karşılık kök-ur nematod uygulamasının kontrol bitkileri gövde Ca, Fe, Zn, Mn ve Cu değerleri ortalamada sırasıyla %7.91, 17.0, 13.9, 118 ve 15.6 oranında arttırdığı belirlenmiştir.

Anahtar sözcükler: Meloidogyne incognita, morfolojik özellikler, besin elementi, bamya, dayanıklılık

1 Alata Horticultural Research Institute, 33740, Erdemli, Mersin, Turkey
2 Mersin University, Applied Technology and Management School of Silifke, 33940, Mersin, Turkey
* Corresponding author (Sorulu yazar) e-mail: cetinncac@hotmail.com
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Resistance of local okra cultivars against *Meloidogyne incognita* (Kofoid & White, 1919) (Nematoda: Meloidogynidae), effects of nematode infestation on growth parameters and leaf macro- micronutrients

**Introduction**

Okra [*Abelmoschus esculentus* (L.) Moench], a member of the Malvaceae, is commonly grown in tropical and subtropical regions of the world (Marin et al., 2017). Geographical origin of okra is thought to be Ethiopia and was initially distributed from there to southern Africa, the Mediterranean Basin, the Arabian Peninsula and South Asia, then the entire world (Sathish & Eswar, 2013).

Okra is largely consumed as human food and fruits are rich in vitamins, protein and crude fiber. With its carbohydrate, protein, oil, mineral and vitamin supply, okra is an important food for human nutrition (Abd El-Kader et al., 2010). Okra seeds are used as an oil source and fruits are also used as a fiber source. Carbohydrate and pectin-containing mucilage is obtained from the fruits and used as a thickener by the food industry (Alegbejo et al., 2008). Worldwide, almost 10 Mt of okra is produced on about 2.7 Mha (FAO, 2019). Okra is cultivated in all regions of Turkey. Commercial cultivation is common in Aegean, Marmara, Mediterranean and Central Anatolia Regions. In Turkey, annually 31 kt of okra is produced on 6 kha (FAO, 2019).

Stress is defined as conditions that influences or hampers plant growth, development and metabolism. Stress factors can be biotic or abiotic. Root-knot nematodes cause plant biotic stress resulting in serious economic losses in various plant species worldwide. Among the pests and diseases affecting okra production and limiting production area, root-knot nematode (*Meloidogyne* spp.) is the most important (Hussain et al., 2011). The symptoms of nematode infestation are slow growth rate, limited root development, leaf yellowing and wilting. Root-knot nematode causes wilting, chlorosis, stunted growth, and root galling, and when the nematode population exceeds the economic threshold level, it generally results in destruction of the roots, weak growth and reduced yield (Daramola et al., 2015; Mukhtar et al., 2017). Root-knot nematode-induced yield losses of 29 to 91% have been reported (Pandey & Kalra, 2003). Mukhtar et al. (2013) indicated *Meloidogyne incognita* (Kofoid & White, 1919) (Nematoda: Meloidogynidae) as the dominant species largely influencing plant growth and yield. Sikora and Fernandez (2005) reported that *Meloidogyne* spp. caused yield loss of up to 27% in okra. Subsequent cultivation of okra in the same field allows the nematodes to become widespread and colonizing the whole field (Hussain et al., 2011). In addition to these direct impacts, nematodes also increase *Fusarium* spp. infection, resulting greater damage and loss. In Turkey, *M. incognita, Meloidogyne arenaria* (Neal, 1889) and *Meloidogyne javanica* (Treub, 1885) (Nematoda: Meloidogynidae) have been reported as the most common and economically-damaging species in vegetable production (Kaşıkvalcı & Öncüer, 1999; Özarslan & Elekçioğlu, 2010; Çetintaş & Çakmak, 2016). Also, *Meloidogyne luci* can be a serious problem in field crops and greenhouse vegetables in northern areas of Turkey (Aydinli, 2018).

For integrated management of nematodes, non-host plants are incorporated into the crop rotations, resistant cultivars are used, biological control and solarization are practiced, and nematicide and fumigants are applied. In large fields, due to the high cost, nematicides are not applied to okra. Generally non-host plants are incorporated into crop rotations in such contexts. Cultivars with nematode resistance usually give, greater yield than susceptible cultivars.

This study was conducted to determine the resistance of local okra cultivars against root-knot nematodes. Use of resistant cultivars in okra farming is the most effective, economic and practical method for control of nematodes. In this study, resistance of 26 okra cultivars against *M. incognita* was determined and nematode-induced morphological changes and effects on leaf macro- and micronutrients were determined.
Materials and Methods

Twenty-six okra from various geographic origins for Turkey were obtained from the large collection maintained at the Aegean Agricultural Research Institute, Menemen, Izmir, Turkey (Karagüllü, 2003). Twenty-four local okra cultivars, commonly cultivated in various regions of Turkey, and two commercially available and common local cultivars cv. Sultanı (Marmara and Aegean Regions) and cv. Bornova (Aegean Region) were used in this study (Table 1). Testing of okra cultivars against nematodes were conducted in climate-controlled glasshouse at Alata Horticultural Research Institute in September-November 2019.

Resistance of the okra cultivars against root-knot nematode of *M. incognita* was investigated at 25 ± 1°C and 60 ± 10% RH under controlled conditions. The root-knot nematode (*M. incognita*) used was produced on susceptible sivri pepper cv Alata F₁ (Alata Horticultural Research Institute, Mersin). At the end of nematode production period, egg masses on the roots were collected under a binocular microscope, and 2nd stage juveniles (J2s) were obtained with the aid of modified Baermann-funnel technique. J2s were counted under light microscope to prepare inoculum. Okra seeds were directly sown into pots. Experiments were conducted in a completely randomized design with four replicates. Treatments included a uninoculated control and nematode inoculation. The potting mix consisted of 80% sand, 5% silt and 15% soil disinfested by autoclaving. Each pot was inoculated with ~3,000 J2s at about 2 cm deep near plants that had grown to ~15 cm at the 2-4 leaf stage. Sixty days after inoculation (DAI), the plants were removed from the pots and root galls scored and morphological measurements made. Leaf samples were taken from the control and inoculated plants in each replicate and leaf macro- and micronutrients were determined. Nitrogen concentrations were determined in ground samples by a modified Kjeldahl method (Kacar, 1972). Phosphorus concentration were determined from the extracts obtained through wet digestion in nitric-perchloric acid mixture with the use of vanadomolybdophosphoric yellow method (Kacar & Kovancı, 1982). Potassium, calcium and magnesium, iron, zinc, manganese and copper concentrations were determined from the samen extracts using inductively coupled plasma (ICP) (Kacar, 1972).

Root gall index

Following the inoculation, plants were removed from the pots on 60 DAI and root galls were scored according to Hartman & Sasser (1985) based on 0-5 scale for number of eggs and galls. According to this scale, 0-2 indicates resistant and 3-5 indicates susceptible plants.

Plant measurements

Plant samples were arbitrary selected from each control (uninoculated) and nematode-inoculated pots 60 DAI and plant height (cm), root length (cm), leaf length (cm), leaf width (cm), fresh root weight (g) and stem thickness (mm) were measured.

Leaf macro- and micronutrients

Sixty DAI, leaf samples were taken from the control (nematode non-inoculated) and inoculated plants of each replicate and leaf macro- and micronutrients were determined. For this purpose, N, P, K, Ca and Mg as %, and Fe, Zn, Mn and Cu as ppm concentrations were determined.

Statistical Analysis

The relative effect of nematode inoculation on plant measurements and leaf macro- and micronutrients was determined with the use of Abbott formula [change = (1 – nematode-inoculated / control) × 100]. Experimental data were subjected to analysis of variance using of statistical analysis software (JMP v8.0.2.) and significant means were compared by Tukey HSD test at P = 0.05 significance level.
Results

Root gall index

Differences in root gall indexes were significant. Twenty-six okra cultivars were found to be nematode susceptible. Root gall indexes varied between 3-5 and an average value of 4.6 (Table 1). Differences between gall indexes of the cultivars were mainly attributed genetic characteristics of the plants. The greatest gall index (5) was obtained for cultivars 17, 19, 32, 40, 45, 57, 60, 62, 64, 68, 87, 88, 100 and 109 and the lowest (3.25) for cultivar 104 (Table 1). All local cultivars tested in present study were found to be susceptible to root-knot nematode (Figure 1).

Table 1. Local okra cultivars used in present study and gall indexes of 26 local okra cultivars

| Cultivar No | Cultivar name | Origin | Index |
|-------------|---------------|--------|-------|
| 3           | TR 37126      | Kastamonu | 4.5   |
| 5           | TR 39467      | Kırklareli | 4.8   |
| 11          | TR 40293      | Kırşehir | 4.0   |
| 17          | TR 42994      | Konya | 5.0   |
| 19          | TR 43092      | Kütahya | 5.0   |
| 30          | TR 57340      | Sinop | 4.0   |
| 32          | TR 57344      | Sinop | 5.0   |
| 40          | TR 61765      | Trabzon | 5.0   |
| 45          | TR 69231      | Karaman | 5.0   |
| 56          | TR 66081      | Yozgat | 4.5   |
| 57          | TR 66070      | Yozgat | 5.0   |
| 60          | TR 66087      | Yozgat | 5.0   |
| 62          | TR 66076      | Yozgat | 5.0   |
| 64          | TR 43185      | Kütahya | 5.0   |
| 67          | TR 66581      | Yozgat | 4.0   |
| 68          | TR 66594      | Yozgat | 5.0   |
| 84          | Kılıçlı III   | Mersin | 3.8   |
| 87          | Karşıyaka III | İzmir | 5.0   |
| 88          | Sultani Bamya | Marmara-Aegean Regions | 5.0   |
| 89          | Bornova Bamya | Aegean Region | 3.5   |
| 97          | Tarsus Yalamik 1 | Mersin | 4.3   |
| 100         | Şanlıurfa 1 Karaal | Şanlıurfa | 5.0   |
| 104         | Şanlıurfa 2 | Şanlıurfa | 3.2   |
| 108         | Hilvan 3 Arpali Köyü | Şanlıurfa | 4.0   |
| 109         | Siverek | Şanlıurfa | 5.0   |
| 112         | Denizli | Denizli | 4.0   |

| Mean | 4.6 |

Figure 1. Nematode infestation response of three okra cultivars (17, 60 and 68).
Plant height, stem thickness and root length

In root-knot nematode-inoculated plants, the tallest plant height (35.8 cm) was in cultivar 45 and the shortest (16.8 cm) in cultivar 5. In control plants, the tallest plant height (67.5 cm) was in cultivar 87 and the shortest (34.3 cm) in cultivar 100. The change in plant height ranged from 17.3 to 71.3% with a mean of 46.0% (Table 2).

Table 2. Effects of root-knot nematode inoculation on plant growth parameters of 26 local okra cultivars

| Cultivar No | Plant height (cm) | Stem thickness (mm) | Root length (cm) |
|-------------|------------------|---------------------|-----------------|
|             | Control* | Nematode | Change (%) | Control | Nematode | Change (%) | Control | Nematode | Change (%) |
| 3           | 42.2 eh  | 21.7 hk   | 48.7       | 2.45 ij  | 3.29 dh  | -34.3      | 19.7 ad | 9.1 cf   | 53.7       |
| 5           | 54.6 be  | 16.8 k    | 69.2       | 5.39 a   | 3.24 di  | 39.9       | 17.7 bg | 7.4 df   | 58.3       |
| 11          | 37.7 th  | 28.4 be   | 24.6       | 3.05 gj  | 2.47 hi  | 19.0       | 18.6 af | 8.9 cf   | 51.9       |
| 17          | 47.9 dg  | 23.7 ej   | 50.5       | 4.70 aj  | 3.67 cf  | 21.9       | 11.4 j  | 6.8 ef   | 40.4       |
| 19          | 49.7 df  | 23.2 fk   | 53.5       | 3.54 eh  | 3.22 di  | 9.0        | 15.8 ei | 8.3 df   | 47.5       |
| 30          | 36.9 gh  | 29.9 bc   | 19.2       | 3.50 fi  | 5.49 a   | -56.9      | 17.6 bg | 8.4 df   | 52.6       |
| 32          | 54.9 ae  | 23.2 fk   | 57.8       | 5.04 ab  | 3.22 di  | 36.1       | 16.1 di | 7.0 df   | 56.7       |
| 40          | 57.2 ad  | 31.6 ab   | 44.7       | 5.09 ab  | 3.04 ei  | 40.3       | 12.9 hj  | 10.2 be  | 20.8       |
| 45          | 64.5 ac  | 35.8 a    | 44.4       | 4.55 ae  | 3.82 ce  | 16.0       | 20.4 ab  | 13.0 ab  | 36.4       |
| 56          | 40.7 th  | 20.3 ik   | 50.1       | 4.41 af  | 2.67 gi  | 39.5       | 15.3 fi  | 8.8 cf   | 42.6       |
| 57          | 48.0 dg  | 22.1 gk   | 54.0       | 4.62 aj  | 3.82 ce  | 17.3       | 22.2 a   | 15.5 a   | 30.3       |
| 60          | 48.9 dg  | 19.5 jk   | 60.3       | 2.89 gj  | 4.99 ab  | -72.7      | 20.1 ac  | 15.1 a   | 25.1       |
| 62          | 32.8 h   | 20.6 ik   | 37.2       | 3.16 gj  | 3.64 cg  | -15.2      | 14.7 gj  | 7.5 df   | 49.1       |
| 64          | 36.9 gh  | 26.8 bg   | 27.6       | 3.56 dh  | 3.85 ce  | -8.2       | 14.5 gj  | 14.9 a   | -3.3       |
| 67          | 36.7 gh  | 26.8 ch   | 27.6       | 4.25 bf  | 3.83 ce  | 9.9        | 20.0 ac  | 7.9 df   | 60.8       |
| 68          | 67.3 ab  | 19.3 jk   | 71.3       | 4.99 ab  | 3.07 ei  | 38.5       | 16.0 ei  | 7.8 df   | 51.0       |
| 84          | 36.5 gh  | 26.3 ch   | 27.8       | 2.72 gj  | 2.92 ei  | -7.4       | 19.9 ac  | 9.2 cf   | 53.8       |
| 87          | 67.5 a   | 23.9 ej   | 64.6       | 4.61 ad  | 3.52 cg  | 23.6       | 15.1 fj  | 9.1 cf   | 39.3       |
| 88          | 33.1 h   | 27.4 bf   | 17.3       | 3.73 cg  | 3.65 cf  | 2.1        | 17.3 bg  | 14.4 a   | 17.0       |
| 89          | 37.7 fh  | 24.8 ci   | 34.1       | 5.09 ab  | 3.50 dg  | 56.7       | 15.3 fi  | 7.0 df   | 54.5       |
| 97          | 44.9 dh  | 20.7 ik   | 53.9       | 4.70 ac  | 2.75 fi  | 41.5       | 17.6 bg  | 5.7 f    | 67.7       |
| 100         | 34.3 h   | 26.0 ch   | 24.2       | 2.25 j   | 4.14 bd  | -84.0      | 12.5 ij  | 10.5 bd  | 16.4       |
| 104         | 66.0 ac  | 29.2 bd   | 55.8       | 4.41 af  | 2.71 fi  | 38.6       | 19.3 ae  | 9.0 cf   | 53.6       |
| 108         | 66.3 ac  | 21.6 hk   | 67.5       | 2.63 hj  | 2.32 i   | 11.8       | 18.7 af  | 12.2 ac  | 35.0       |
| 109         | 54.1 ce  | 23.7 ej   | 56.1       | 5.43 a   | 3.45 dg  | 36.5       | 13.5 hj  | 13.4 ab  | 0.7        |
| 112         | 54.0 ce  | 24.6 di   | 54.4       | 5.32 a   | 4.48 bc  | 15.8       | 16.5 ch  | 13.2 ab  | 20.5       |

Mean 48.1 24.5 46.0 4.20 3.49 9.1 16.9 10.0 39.7
LSD (5%) 12.76 5.04 1.05 0.97 3.71 3.59
F prob. <0.001 <0.001 <0.001 <0.001 <0.001 <0.001

* Control, uninoculated; nematode, nematode-inoculated.

In nematode-inoculated plants, the greatest stem thickness (5.49 mm) was in cultivar 30 and the lowest (2.32 mm) in cultivar 108. In control plants, the greatest stem thickness (5.43 mm) was in cultivar 109 and the lowest (2.25 mm) in cultivar 100. The change stem thicknesses ranged from -84.0% to 71.3% with mean of 9.06% (Table 2).

In nematode-inoculated plants, the greatest root length (15.1 cm) was in cultivar 57 and the lowest (5.70 cm) in cultivar 97. In control plants, the longest root length (22.2 cm) was in cultivar 57 and the shortest (11.4 cm) in cultivar 17. The change in root lengths ranged -3.3 to 67.7% with a of 39.7% (Table 2).

Root weight, leaf width and leaf length

In nematode-inoculated plants, the greatest root weight (5.77 g) was in cultivar 60 and the lowest (0.68 g) in cultivar 108. In control plants, the greatest root weight (2.56 g) was in cultivar 109 and the lowest (1.27 g) in cultivar 17. Root-knot nematode changed root weight by -258 to 60.2% with a mean of -14.5% (Table 3).
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Table 3. Effects of root-knot nematode inoculation on plant growth parameters of 26 local okra cultivars

| Cultivar No | Root weight (g) | Leaf length (cm) |
|-------------|-----------------|------------------|
| Control* | Root weight (g) | Leaf length (cm) |
| Control* | Root weight (g) | Leaf length (cm) |
| Control* | Root weight (g) | Leaf length (cm) |
| Control* | Root weight (g) | Leaf length (cm) |

In nematode-inoculated plants, the greatest leaf weight (13.4 cm) was in cultivar 112 and the lowest (6.58 cm) in cultivar 5. In control plants, the greatest leaf width (14.4 cm) was in cultivar 109 and the lowest (7.60 cm) in cultivar 11. The change in leaf width ranged from -57.2 to 54.0% with a mean of 15.1% (Table 3).

In nematode-inoculated plants, the greatest leaf length (12.2 cm) was in cultivar 112 and the lowest (6.30 cm) in cultivar 5. In control plants, the greatest leaf length (12.7 cm) was in cultivar 108 and the lowest (7.50 cm) in cultivar 97. The change in leaf length ranged from -15.5 to 44.5% with a mean of 20.5% (Table 3).

**Nitrogen, phosphorus and potassium**

In nematode-inoculated plants, the greatest N concentration (2.39%) was in cultivar 100 and the lowest (1.19%) in cultivar 17. In control plants, the greatest N concentration (2.76%) was in cultivar 109 and the lowest (1.28%) in cultivar 19. The change ranged from 47.1 to 73.4% with a mean of 2.31% (Table 4).

In nematode-inoculated plants, the greatest P concentration (0.35%) was in cultivar 11 and the lowest (0.13%) in cultivar 62. In control plants, the greatest P concentration (0.55%) was in cultivar 109 and the lowest (0.17%) in cultivar 19. The change ranged from -50% to 67% with a mean of 5.85% (Table 4).

In nematode-inoculated plants, the greatest K concentration (1.80%) was in cultivar 100 and the lowest (0.55%) in cultivar 62. In control plants, the greatest K concentration (2.43%) was in cultivar 57 and the lowest (0.60%) in cultivar 62. The change ranged from -86.1% to 63.8% with a mean of 5.24% (Table 4).
Table 4. Nematode-induced changes in leaf N, P and K concentrations of 26 local okra cultivars

| Cultivar No | N (%) Control* | Nematode | Change (%) | Control | Nematode | Change (%) | Control | Nematode | Change (%) |
|-------------|----------------|----------|------------|---------|----------|------------|---------|----------|------------|
| 3           | 2.03 gi        | 1.37 j   | 32.5       | 0.18 im | 0.14 jk  | 22.2       | 1.24 kj | 0.74 m   | 40.3       |
| 5           | 1.95 ij        | 2.24 bc  | -14.9      | 0.19 km | 0.21 df  | -10.5      | 0.86 n  | 1.60 b   | -86.1      |
| 11          | 2.11 fh        | 2.36 ab  | -11.9      | 0.28 bd | 0.36 a   | -28.6      | 0.92 mn | 1.17 fj  | -27.2      |
| 17          | 2.17 eg        | 1.19 k   | 45.2       | 0.27 be | 0.16 jk  | 40.7       | 1.39 hi | 0.69 m   | 50.4       |
| 19          | 1.28 m         | 2.22 bd  | -73.4      | 0.17 m  | 0.23 ce  | -35.3      | 0.99 m  | 1.62 b   | -63.6      |
| 30          | 1.75 k         | 2.33 ab  | -33.1      | 0.20 im | 0.30 b   | -50.0      | 0.88 n  | 1.40 cd  | -59.1      |
| 32          | 2.01 hi        | 1.56 i   | 22.4       | 0.26 dg | 0.21 df  | 19.2       | 2.28 b  | 1.14 gj  | 50.0       |
| 40          | 2.40 b         | 1.39 j   | 42.1       | 0.28 bd | 0.16 hk  | 42.9       | 1.52 fg | 1.09 ik  | 28.3       |
| 45          | 2.29 be        | 2.04 e   | 10.9       | 0.24 ei | 0.19 fh  | 20.8       | 1.31 ij | 1.02 k   | 22.1       |
| 56          | 1.82 jk        | 2.27 ac  | -24.7      | 0.20 lm | 0.24 cd  | -20.0      | 1.23 j1 | 1.40 cd  | -13.8      |
| 57          | 2.36 bc        | 1.35 j   | 42.8       | 0.30 bc | 0.17 hj  | 43.3       | 2.43 a  | 0.88 l   | 63.8       |
| 60          | 2.23 cf        | 1.72 gh  | 22.9       | 0.22 hl | 0.17 gj  | 22.7       | 1.14 kl | 1.32 de  | -15.8      |
| 62          | 2.38 b         | 1.26 jk  | 47.1       | 0.27 cf | 0.13 k   | 51.9       | 1.48 gh | 0.55 n   | 62.8       |
| 64          | 1.53 i         | 2.22 bd  | -45.1      | 0.19 km | 0.23 ce  | -21.1      | 0.87 e  | 1.20 fh  | -37.9      |
| 67          | 2.29 be        | 1.39 j   | 39.3       | 0.22 gk | 0.20 eg  | 9.1        | 1.41 gi | 1.08 jk  | 23.4       |
| 68          | 2.26 be        | 1.25 jk  | 44.7       | 0.21 lm | 0.17 hj  | 19.1       | 1.62 ef | 0.66 m   | 59.3       |
| 84          | 1.90 kc        | 2.27 ac  | -19.5      | 0.22 gk | 0.25 c   | -13.6      | 1.13 l  | 1.27 ef  | -12.4      |
| 87          | 2.03 gi        | 2.34 ab  | -15.3      | 0.21 lm | 0.25 c   | -19.1      | 1.49 gh | 1.25 eg  | 16.1       |
| 88          | 1.32 m         | 2.15 ce  | -62.9      | 0.31 b  | 0.23 ce  | 25.8       | 1.87 c  | 1.39 cd  | 25.7       |
| 89          | 2.19 df        | 2.36 ab  | -7.8       | 0.25 dh | 0.24 cd  | 4.0        | 1.34 j  | 1.20 fi  | 10.5       |
| 97          | 2.32 bd        | 2.07 de  | 10.8       | 0.23 fj | 0.23 ce  | 0.0        | 1.18 kl | 1.16 gj  | 1.7        |
| 100         | 2.22 cf        | 2.39 a   | -7.7       | 0.22 gk | 0.26 c   | -18.2      | 1.50 g  | 1.80 a   | -20.0      |
| 104         | 1.94 ij        | 1.87 f   | 3.6        | 0.21 lm | 0.21 df  | 0.0        | 1.72 de | 1.11 hk  | 35.5       |
| 108         | 1.75 k         | 1.83 fg  | -4.6       | 0.20 jm | 0.21 df  | -5.0       | 0.60 o  | 1.02 k   | -70.0      |
| 109         | 2.76 a         | 1.63 hi  | 40.9       | 0.56 a  | 0.19 fi  | 66.1       | 1.80 cd | 0.87 l   | 51.7       |
| 112         | 1.89 ik        | 2.35 ab  | -24.3      | 0.21 lm | 0.24 cd  | -14.3      | 1.69 e  | 1.68 b   | 0.6        |
| Mean        | 2.05           | 1.90     | 2.3        | 0.24    | 0.21     | 5.9        | 1.38    | 1.17     | 5.2        |

LSD (5%) 0.15 0.15 0.04 0.03 0.11 1.11
F prob. <0.001 <0.001 <0.001 <0.001 <0.001 <0.001

* Control, uninoculated; nematode, nematode-inoculated.

**Calcium, magnesium and iron**

In nematode-inoculated plants, the greatest Ca concentration (4.70%) was in cultivar 100 and the lowest (2.91%) in cultivar 56. In control plants, the greatest Ca concentration (4.84%) was in cultivar 87 and the lowest (2.73%) in cultivar 64. The change ranged from -59.0% and 24.4% with a mean of -7.9%. However, nematode inoculation generally increased Ca concentrations (Table 5).

In nematode-inoculated plants, the greatest Mg concentration (0.89%) was observed in cultivar 68 and the lowest (0.53%) in cultivar 100. In control plants, the greatest Mg concentration (0.98%) was obtained from cultivar 17 and the lowest (0.52%) from cultivar 64. The change ranged from 17.7 to -38.8% with a mean of 10.3%. However, nematode inoculation generally reduced Mg concentrations (Table 5).

In nematode-inoculated plants, the greatest Fe concentration (289 ppm) was in cultivar 100 and the lowest (76 ppm) in cultivar 19. In control plants, the greatest Fe concentration (331 ppm) was in cultivar 57 and the lowest (85 ppm) in cultivar 30. The change ranged from -155% and 56.0% and with a mean of -17.0%. However, nematode inoculation increased Fe concentrations (Table 5).
Resistance of local okra cultivars against *Meloidogyne incognita* (Kofoid & White, 1919) (Nematoda: Meloidogynidae), effects of nematode infestation on growth parameters and leaf macro-micronutrients

Table 5. Nemato-de-induced changes in leaf Ca, Mg and Fe concentrations of 26 local okra cultivars

| Cultivar No | Ca (%) | Mg (%) | Fe (ppm) |
|-------------|--------|--------|----------|
|             | Control* | Nematode | Change (%) | Control | Nematode | Change (%) | Control | Nematode | Change (%) |
| 3           | 3.39 il  | 3.98 ce | -17.4     | 0.68 j  | 0.66 eh | 2.9       | 130 f   | 82 mn   | 37.5       |
| 5           | 3.69 ei  | 3.44 i  | -6.8      | 0.85 d  | 0.70 dg | 17.7      | 105 im  | 111 jk  | -5.4       |
| 11          | 3.41 4ik | 3.87 df | -13.5     | 0.84 de | 0.71 df | 15.5      | 91 no   | 110 jk  | -21.0      |
| 17          | 4.15 Zbc | 4.37 b  | -5.3      | 0.98 a  | 0.60 hj | 38.8      | 165 d   | 110 jk  | 33.2       |
| 19          | 3.22 km  | 3.49 hi | -8.4      | 0.80 eg | 0.87 ab | -8.8      | 92 mo   | 76 n    | 17.2       |
| 30          | 3.49 hk  | 3.53 hi | -1.2      | 0.90 bc | 0.61 gj | 32.2      | 85 o    | 105 kl  | -23.4      |
| 32          | 3.90 cf  | 3.79 fg | 2.8       | 0.74 hi | 0.65 eh | 13.2      | 291 b   | 128 hi  | 56.0       |
| 40          | 3.84 dg  | 4.03 cd | -5.0      | 0.73 i  | 0.63 fi | 13.7      | 111 gk  | 228 b   | -105.1     |
| 45          | 3.60 gj  | 3.84 ef | -6.7      | 0.76 gi | 0.64 fi | 15.8      | 104 in  | 137 gh  | -31.9      |
| 56          | 3.58 gj  | 2.91 j  | 18.7      | 0.78 fh | 0.70 dg | 10.3      | 107 hl  | 186 cd  | -73.0      |
| 57          | 4.02 bd  | 4.09 c  | -1.7      | 0.84 de | 0.71 df | 15.5      | 331 a   | 180 de  | 45.6       |
| 60          | 3.97 ce  | 3.42 l  | 13.9      | 0.86 cd | 0.63 fi | 26.7      | 91 no   | 83 mn   | 8.6        |
| 62          | 4.20 bc  | 4.35 b  | -3.6      | 0.86 cd | 0.71 df | 17.4      | 112 gj  | 105 kl  | 6.1        |
| 64          | 4.84 a   | 3.66 gh | 24.4      | 0.52 l  | 0.55 ij | -5.8      | 121 fg  | 114 jk  | 6.1        |
| 67          | 3.58 gj  | 4.44 b  | -24.0     | 0.82 df | 0.77 cd | 6.1       | 94 lo   | 172 ef  | -81.8      |
| 68          | 3.31 jm  | 4.37 b  | -32.0     | 0.82 df | 0.89 a  | -8.5      | 113 gi  | 127 hi  | -13.1      |
| 84          | 3.42 lk  | 4.04 cd | -18.1     | 0.75 hi | 0.67 eh | 10.7      | 97 ko   | 198 c   | -103.1     |
| 87          | 2.73 n   | 4.34 b  | -59.0     | 0.62 k  | 0.73 de | -17.7     | 98 jo   | 138 gh  | -41.2      |
| 88          | 3.77 dh  | 3.54 hi | 6.1       | 0.77 gi | 0.65 eh | 15.6      | 173 cd  | 120 lij  | 30.3       |
| 89          | 3.01 mn  | 2.94 j  | 2.3       | 0.84 de | 0.67 eh | 20.2      | 107 il  | 108 jil  | -0.8       |
| 97          | 3.62 li  | 4.02 ce | -11.1     | 0.76 hi | 0.83 ac | -9.2      | 96 lo   | 144 g    | -50.9      |
| 100         | 4.28 b   | 4.70 a  | -9.8      | 0.63 k  | 0.53 j  | 15.9      | 114 gi  | 289 a   | -154.7     |
| 104         | 3.97 be  | 4.01 ce | -1.0      | 0.73 i  | 0.78 bd | -6.9      | 186 c   | 129 hi  | 31.0       |
| 108         | 3.69 ej  | 4.28 b  | -16.0     | 0.91 b  | 0.78 bd | 14.3      | 121 fh  | 121 jil  | -0.2       |
| 109         | 3.29 jm  | 4.27 b  | -29.8     | 0.76 gi | 0.64 ei | 15.8      | 151 e   | 162 f    | -7.1       |
| 112         | 3.09 lm  | 3.62 gh | -17.2     | 0.68 j  | 0.63 fi | 7.4       | 94 lo   | 95 lm   | -0.6       |
| Mean        | 3.66     | 3.90    | -7.9      | 0.78    | 0.69    | 10.3      | 130     | 137     | -17.0      |
| LSD (5%)    | 0.30     | 0.18    | 0.05      | 0.09    | 13.8    | 13.6      |
| F prob.     | <0.001   | <0.001  | <0.001    | <0.001  | <0.001  | <0.001    |

* Control, uninoculated; nematode, nematode-inoculated.

**Zinc, manganese and copper**

In nematode-inoculated plants, the greatest Zn concentration (113 ppm) was in cultivar 109 and the lowest (12.3 ppm) in cultivar 68. In control plants, the greatest Zn concentration (392 ppm) was in cultivar 57 and the lowest (12.5 ppm) in cultivar 19. The change ranged from -212% to 94.4% and mean increase in Zn concentrations was calculated as -13.9% (Table 6). However, nematode inoculation generally increased Zn concentrations.

In nematode-inoculated plants, the greatest Mn concentration (336 ppm) was in cultivar 30 and the lowest (41.2 ppm) in cultivar 3. In control plants, the greatest Mn concentration (98.0 ppm) was in cultivar 89 and the lowest (32.4 ppm) in cultivar 108. The change ranged from -744% to 24.8% with a mean of -118% (Table 6). However, nematode inoculation generally increased Mn concentrations.

In nematode-inoculated plants, the greatest Cu concentration (6.59 ppm) was in cultivar 100 and the lowest (1.79 ppm) in cultivar 57. In control plants, the greatest Cu concentration (8.89 ppm) was in cultivar 57 and the lowest (1.34 ppm) in cultivar 60. The change ranged from -129% to 79.9% and mean increase in Cu concentrations was calculated as -15.6% (Table 6). However, nematode inoculation generally increased Cu concentrations.
Table 6. Nematode-induced changes in leaf Zn, Mn and Cu concentrations of 26 local okra cultivars

| Cultivar No | Zn (ppm) | Mn (ppm) | Cu (ppm) |
|-------------|----------|----------|----------|
| 3           | 132.3 c  | 43.7 j   | 2.15 p   |
| 5           | 23.5 fg  | 41.2 o   | 3.90 f   |
| 11          | 17.9 gi  | 38.0 ln  | 3.38 ik  |
| 17          | 128.5 c  | 71.2 de  | 5.04 e   |
| 19          | 12.5 i   | 60.7 gh  | 3.26 jl  |
| 30          | 13.2 hi  | 336.4 a  | 1.96 p   |
| 32          | 329.4 b  | 64.6 mn  | 6.98 b   |
| 40          | 30.5 f   | 116.8 gh | 4.28 g   |
| 45          | 25.8 fg  | 68.4 ef  | 4.70 f   |
| 56          | 23.8 fi  | 48.8 no  | 2.96 mn  |
| 57          | 329.4 a  | 96.4 ik  | 8.89 a   |
| 60          | 27.1 fg  | 41.2 km  | 1.34 q   |
| 62          | 20.9 fi  | 80.1 km  | 2.66 o   |
| 64          | 20.7 fi  | 89.1 b   | 2.54 o   |
| 67          | 17.4 gi  | 109.4 gi | 2.78 no  |
| 68          | 24.2 fh  | 54.8 hi  | 2.96 mn  |
| 64          | 16.1 gi  | 57.7 hi  | 3.50 ij  |
| 87          | 20.6 fi  | 100.0 hj | 2.71 no  |
| 88          | 104.9 d  | 262.0 b  | 6.52 c   |
| 89          | 21.4 fi  | 150.4 e  | 3.61 i   |
| 97          | 24.3 fh  | 98.2 ik  | 2.64 o   |
| 100         | 15.5 gi  | 98.4 jk  | 3.20 km  |
| 104         | 78.9 e   | 88.4 jk  | 4.76 f   |
| 108         | 21.7 fi  | 83.8 jk  | 3.99 h   |
| 109         | 70.1 e   | 127.4 fg | 3.12 lm  |
| 112         | 19.5 fi  | 158.3 d  | 6.20 d   |

Mean | 60.4 | 31.5 | -13.9 | 61.5 | 124.3 | -118.0 | 3.78 | 3.66 | -15.6

LSD (5%) | 11.66 | 4.51 | 5.94 | 18.46 | 0.25 | 0.32

F prob. <0.001 <0.001 <0.001 <0.001 <0.001 <0.001

* Control, uninoculated; nematode, nematode-inoculated.

Discussion

In Turkey, resistance of local okra cultivars against *M. incognita* has not been studied previously. Okra is severely damaged by root-knot nematodes and most cultivars are susceptible to *M. incognita*. Twenty-six cultivars were not resistant to *M. incognita*. Root gall indexes for the local okra cultivars varied between 3.3 and 5 with a mean of 4.6 indicating that these cultivars as susceptible to the nematode. Similar studies have been conducted elsewhere, especially in Asian and African countries. Hussain et al. (2014) conducted a study under field conditions in three regions of Pakistan with 12 okra cultivars and reported root gall indexes as between 4 and 5. Basil et al. (2019) inoculated 10 okra cultivars and reported root gall indexes as between 3.7 and 4.2. Karajeh & Salameh (2015) conducted a nematode inoculation study in Jordan with 36 okra cultivars and reported moderate resistance against the nematode. Kedarnath et al. (2017) conducted a study in India on seven okra cultivars and reported gall indexes of 3 to 4 for plants 60 DAI and at harvest. These results are similar to the present study, but not all their results. Sheela et al. (2006) investigated root gall indexes of 123 okra cultivars and based on gall index of 3 reported that theses okra cultivars were moderately resistant. Similarly, Muhammad et al. (2017) conducted a study under field conditions in Pakistan with 12 okra cultivars and reported root gall indexes of 2-4. As seen in previous studies, okra is generally not resistant to root-knot nematodes. Although a range of research has evaluated the reaction of okra cultivars to root-knot nematodes, there are no reports of fully resistant cultivars, only those that are moderately resistant and susceptible (Mohanta & Mohanty, 2012; Hussain et al., 2014; Marin et al., 2017).
No studies similar to the present study have been reported, but a few studies examined plant growth parameters in okra, tomatoes and soybeans. In present study, effects of *M. incognita* inoculation on plant growth parameters were investigated. Compared to uninoculated control plants, root-knot nematode inoculation reduced plant height, stem thickness, root length, leaf width and leaf length but root weight was increased depending on gall formation. Kumar et al. (2012) investigated the effects of nematode inoculation on root length, shoot length, fresh and dry root weights and reported significantly effects. Root and shoot lengths were greater in control plants. Mean root length of the control and inoculated plants was reported as 40 and 32 cm, shoot length as 49 and 32 cm, root dry weights as 4.8 and 7.0 g and root fresh weights as 13.4 and 11.5 g, respectively. Odeyemi et al. (2016) reported *M. incognita*-induced reductions of between 13.7 and 75.6% in plant height, between 13.7 and 67.2% plant fresh weight and between 13.0 and 53.3% in fruit weight. In another study conducted on okra, Claudius-Cole (2018) reported mean number of fruits as 18.4 for control plants and 13.8 for *M. incognita*-inoculated plants; mean fruit weight as 167 g in control plants and 81.3 g for inoculated plants. Yield loss was reported as 51.4%. Pandey et al. (2019) reported (60 DAI) significant effects of nematode inoculation on plant length, plant diameter, root length and root diameter and reported. Plant length, plant diameter, root length and root diameter were greater in control plants in current study. Azam et al. (2011) examined *M. luci* infestation in tomatoes and reported decreased plant height and weights with increasing Pi density. Root-knot nematode symptoms in aboveground plant parts are reported to be stunted growth, chlorosis in leaves and reductions in plant weight. Gall formation-induced browning in leaves and recessed plant growth are generally encountered in nematode-infested okras and yield reductions vary between 29 and 91% (Pandey & Kalra, 2003). Studies on soybean and cucumber found that root-knot nematodes infestation increased root weights (Kayani et al., 2017). There was a general reduction in the growth parameters measured for the three okra cultivars for infested versus unininfested plants. The present findings on plant growth parameters are consistent with the findings of earlier studies. As a result, the galls formed in response to the feeding the root-knot nematodes disrupt the structure of the root and prevent uptake of water and nutrients from the soil, changing the distribution of photosynthesis products in the plant, increasing the movement of these products towards the root region, especially during the development and reproduction of the nematode. As a result, the inhibition of plant growth causes a decrease in plant height and stem diameter, and shrinkage of leaves, shortening of plant root, increase in plant root diameter and increase in plant root weight (Fortnum et al., 1991; Carneiro et al., 1999; Maleita et al., 2012).

Plant-pathogen-nutrient interactions are complex and the mechanisms have not been fully elucidated. Nutrients are essential elements for plant growth and development, and are essential for various physiological processes including protein synthesis, photosynthetic electron transfer, mitochondrial respiration, oxidative stress responses, cell wall metabolism and hormonal structure (Dordas, 2008; Santana-Gomes et al., 2013). In the present study, the concentrations of macro- and micronutrients were investigated in the leaves of okra cultivars. Compared to uninoculated control plants, nematode inoculation reduced leaf N, P, K and Mg concentrations and increased Ca, Fe, Zn, Mn and Cu concentrations. While macronutrients are generally reduced by nematode infestation, micronutrient accumulation was higher in leaf tissues.

There has been no reported study on the nematode effect of the concentrations of macro- and micronutrients in plant leaves. Similar studies have been done with plants such as tomatoes, soybeans, ridge gourd and coffee. Therefore, comparisons are made here with these plants. Miamoto et al. (2017) conducted a study on soybean and reported greater leaf Ca, Fe, Zn, Mn and Cu concentrations in nematode, *Pratylenchus brachyurus* (Godfrey, 1929) (Nematoda: Pratylenchidae), inoculated plants than in control plants. S, Cu and Zn, cofactors of plant enzymes and influencing cell wall formation and composition, produce some substances and improve plant resistance against nematodes through generating a physical barrier. Dietrich et al. (2004) reported lower N, Ca, Mg, Fe and Mn concentrations in
nematode-infested plants [Arabidopsis thaliana (L.) (Tracheophyta: Brassicaceae)] than in control plants. Activation of plant defense mechanism increased energy consumption and thus reduced the concentrations of these nutrients. In contrast, Carneiro et al. (2002) reported greater Mg, Fe, Mn and Zn concentrations in nematode-inoculated soybean plants. N and Ca concentrations were lower in shoots than in root-knot nematode-infested roots. Pathogens alters plant nutrient concentrations. Goncalves et al. (1995) indicated that M. incognita reduced P, Mg, Fe, Mn and B concentrations of coffee plants. Blevins et al. (1995) reported high Ca and low K and Mn concentrations in Heterodera glycines Ichinohe, 1952 (Nematoda: Heteroderidae) nematode-infested roots of soybean. Hajji et al. (2016) reported that nematodes significantly increased Cu, Zn, Fe, Mn, Mg and K concentrations and decreased Ca concentration in tomato roots. Carneiro et al. (2002) reported decreased N and P and increased Ca concentration in nematode-infested soybean roots. Decreased leaf size of nematode-infested plants resulted in increased Ca concentrations. Melakeberhan et al. (1985) reported that M. incognita reduced plant dry weight and increased Ca concentration of bean plants. Pandey et al. (2019) reported that as compared to the control plants, M. incognita reduced plant protein (20.4 vs 40.3%), N (20.0 vs 40.4%) and P (11.4 vs 92.0%) concentrations and increased K (27.3 vs 208%) concentration of ridge guard. Pandey et al. (2017) compared the control and M. incognita-infested mung bean plants and compared to the control plants, N concentrations of nematode-infoculated plants decreased by 4.1 to 88.6%, protein concentrations by 4.1 to 88.5%, P concentrations by 4.6 to 52.3% and K concentrations by 7.1 to 37.9%. Hurchanik et al. (2004) reported that nematode infestations significantly reduced Ca, Mg, P and B concentrations and increased Mn, Cu, Zn concentrations and Ca/B ratio in roots of coffee plants. Macro- and micronutrients present in okra are responsible for plant growth and development. According to the authors, nematode infestation causes abiotic and biotic stress in plants. As a result, nutrient uptake and accumulation of plants are affected. Root-knot nematode infestations cause physiological and biochemical changes. Such changes cause cell growth and tissue thickening in the roots, affecting the water nutrient uptake of the roots. As a result, it negatively affects plant growth and reduce yield. (Hussain et al., 2016; Débia et al., 2019).

**Conclusion**

In present study, root-knot nematode induced large and small galls on roots of local okra cultivars and all cultivars were identified as susceptible to the nematode. Similar findings were also reported for previous studies conducted in different parts of the world. Nematode damage impaired plant water and nutrient uptake from the soil, thus resulted in stunted growth. Compared to uninoculated control plants, nematode inoculation reduced plant height, stem thickness, root length, leaf width and leaf length, and increased root weight. Leaf samples were taken from the control and inoculated plants and leaf macro- and micronutrients were determined. It was observed that nematode inoculation reduced leaf N, P, K and Mg concentrations, but increased Ca, Fe, Zn, Mn and Cu concentrations. Since plant-pathogen-nutrient interactions are complex and the mechanisms involved have not been fully elucidated, further research is recommended on these mechanisms. Given environmental hazards and potential residues, nematicides are not recommended in okra production. Fumigation is hard to implement over large fields. Therefore, in control of root-knot nematode in okra fields, incorporation of non-host plants into crop rotations is recommended. Further breeding studies are recommended to identify the resistance gene of okras against root-knot nematode and to develop resistant cultivars.

**References**

Abd El-Kader, A. A., S. M. Saaban & M. S. Abd El-Fattah, 2010. Effect of irrigation levels and organic compost on okra plants (Abelmoschus esculentus L.) grown in sandy calcareous soil. Agriculture and Biology Journal of North America, 1 (3): 225-231.

Alegbejo, M., M. Ogunlana & O. Banwo, 2008. Survey for incidence of okra mosaic virus in northern Nigeria and evidence for its transmission by beetles. Spanish Journal of Agricultural Research, 6 (3): 408-411.
Resistance of local okra cultivars against Meloidogyne incognita (Kofoid & White, 1919) (Nematoda: Meloidogynidae), effects of nematode infestation on growth parameters and leaf macro- micronutrients

Aydınlı, G., 2018. Detection of the root-knot nematode Meloidogyne luci Carneiro et al., 2014 (Tylenchida: Meloidogynidae) in vegetable fields of Samsun Province, Turkey. Turkish Journal of Entomology, 42 (3): 229-237.

Azam, T., S. Hisamuddin, S. Singh & M. I. Robab, 2011. Effect of different inoculum levels of Meloidogyne incognita on growth and yield of Lycopersicon esculentum, and internal structure of infected root. Archives of Phytopathology and Plant Protection, 44 (18): 1829-1839.

Basil, H. K., E. H. Alaa, M. A. R. Asmaa & S. S. Brent, 2019. Screening for susceptibility and tolerance to Meloidogyne incognita and M. javanica in okra cultivars in Iraq. Arab Journal of Plant Protection, 37 (3): 279-283.

Blevins, D. G., V. H. Dropkin & V. D. Luedders, 1995. Macronutrient uptake, translocation, and tissue concentration of soybeans infested with the soybean cyst nematode and elemental composition of cysts isolated from roots. Journal of Plant Nutrition, 18 (3): 579-591.

Carneiro, R. G., P. Mazzafera & L. C. C. B. Ferraz, 1999. Carbon partitioning in soybean infected with Meloidogyne incognita and M. javanica. The Journal of Nematology, 31 (3): 348-355.

Carneiro, R. G., P. Mazzafera, L. C. C. B. Ferraz, T. Muraoka & P. C. O. Trevelin, 2002. Uptake and translocation of nitrogen, phosphorus and calcium in soybean infected with Meloidogyne incognita and M. javanica. Fitopatologia Brasileira, 27 (2): 141-50.

Çetintaş, R. & B. Cakmak, 2016. Meloidogyne species infesting tomatoes, cucumbers and eggplants grown in Kahramanmaras Province, Turkey. Turkish Journal of Entomology, 40 (4): 355-364.

Claudius-Cole, A. O., 2018. Comparative effect of Rotylenchulus reniformis and Meloidogyne incognita on the productivity of okra in Nigeria. Australian Journal of Basic and Applied Sciences, 12 (9): 20-25.

Daramola, F. Y., J. O. Popoola, A. O. Eni & O. Sulaiman, 2015. Characterization of root-knot nematodes (Meloidogyne spp.) associated with Abelmoschus esculentus, Celosia argentea and Corchorus olitorius. Asian Journal of Biological Sciences, 8 (1): 42-50.

Débia, P. J. G., B. C. Bolanho, H. H. Puerari & C. R. Dias-Arieira, 2019. Meloidogyne javanica parasitism and its impacts on the vegetative parameters, physicochemical composition, and antioxidant potential of beet. Pesquisa Agropecuária Brasileira, 54: e00695, 1-8.

Dietrich, R., K. Ploss & M. Heil, 2004. Constitutive and induced resistance to pathogens in Arabidopsis thaliana depends on nitrogen supply. Plant Cell and Environment, 27 (7): 896-906.

Dordas, C., 2008. Role of nutrients in controlling plant diseases in sustainable agriculture a review. Agronomy for Sustainable Development, 28 (1): 33-46.

FAO, 2019. FAOSTAT database collections. Food and Agriculture Organization of the United Nations. (Web page: http://www.fao.org/faostat/en/#data/QC) (Date accessed: 13 January 2021).

Fortnum, B. A., M. J. Kasperbauer, P. G. Hunt & W. C. Bridges, 1991. Biomass partitioning in tomato plants infected with Meloidogyne incognita. The Journal of Nematology, 23 (3): 291-297.

Godfrey G. H., 1929. A destructive root disease of pineapples and other plants due to Tylenchus brachyurus n.sp. Phytopathology, 19 (7): 611-629.

Goncalves, W., P. Mazzafera, L. C. C. B. Ferraz, M. B. Silvarolla & M. M. A. De Lima, 1995. Biochemical basis of coffee tree resistance to Meloidogyne incognita. Plantations Recherche Development, 2 (1): 54-58.

Hajii, L., M. A. Elouaer, H. Regaieg, B. N. M’Hamdi & R. N. Horrique, 2016. Biochemical and plant nutrient alterations induced by Meloidogyne javanica and Fusarium oxysporum f.sp. radicis lycopersici co-infection on tomato cultivars with differing level of resistance to Meloidogyne javanica. Springer European Journal of Plant Pathology, 148 (2): 463-472.

Hartman, K. M. & J. N. Sasser, 1985. “Identification of Meloidogyne Species on the Basis of Differential Host Test and Perennial Pattern Morphology, 69-77”. In: An Advanced Treatise on Meloidogyne. Vol II. Methodology (Eds. K. R. Barker, C. C. Carter & J. N. Sasser). Raleigh, NC: North Carolina States Graphics, 223 pp.

Hurchanik, D., D. P. Schmitt, N. V. Hue & B. S. Sipes, 2004. Plant nutrient partitioning in coffee infected with Meloidogyne konaensis. The Journal of Nematology, 36 (1): 76-84.

Hussain, M., M. Kamran, K. Singh, M. Zouhar, P. Rysánek & S. A. Anwar, 2016 Response of selected okra cultivars to Meloidogyne incognita. Crop Protection, 82: 1-6.
Hussain, M. A., T. Mukhtar & M. Z. Kayani, 2011. Assessment of the damage caused by *Meloidogyne incognita* on okra (*Abelmoschus esculentus*). The Journal of Animal and Plant Sciences, 21 (4): 857-861.

Hussain, M. A., T. Mukhtar & M. Z. Kayani, 2014. Characterization of susceptibility and resistance responses to root-knot nematode (*Meloidogyne incognita*) infection in okra germplasm. Pakistan Journal of Agricultural Sciences, 51 (2): 319-324.

Kacar, B., 1972. Bitki ve Toprağın Kimyasal Analizleri II: Bitki Analizleri, Ankara Üniversitesi Ziraat Fakültesi Yayınları, No: 453, Ankara, Türkiye, VI1+121 s (in Turkish).

Kacar, B. & İ. Kovancı, 1982. Bitki, toprak ve gübrelerde kimyasal fosfor analizleri ve sonuçlarının değerlendirilmesi. Ege Üniversitesi Ziraat Fakültesi Yayınları, No: 354, İzmir, Türkiye, 646 s (in Turkish).

Karagül, S., 2003. Yerel Bamya (*Abelmoschus esculentus* (L) Moench) Çeşit ve Tiplerinin Karekterizasyonu. Çukurova Üniversitesi Fen Bilimleri Enstitüsü, (Unpublished) Yüksek Lisans Tezi, Tez No:135698, Adana, Türkiye, 115 s (in Turkish with English abstract).

Karajeh, M. R. & N. M. Salameh, 2015. Evaluation of okra landraces and accessions response to the root-knot nematode, *Meloidogyne javanica*. Jordan Journal of Agricultural Sciences, 11 (3): 735-745.

Kaşkavalcı, G. & C. Öncüer, 1999. Investigations on distribution and economic importance of *Meloidogyne* Goeldi, 1887 (Tylenchida: Meloidogyridae) species found in the major areas of hot climate vegetables in Aydın province. Turkish Journal of Entomology, 23 (2): 149-160 (in Turkish with abstract in English).

Kayani, M. Z., T. Mukhtar & M. A. Hussain, 2017. Effects of southern root-knot nematode population densities and plant age on growth and yield parameters of cucumber. Elsevier Crop Protection, 92 (1): 207-212.

Kedarnath, N. G., D. M. Ravichandra, B. M. R. Preethi, B. S. Reddy & R. S. Pavithra, 2017. Screening of okra (*Abelmoschus esculentus*) cultivars for resistance against root knot nematode (*Meloidogyne incognita*) under field condition in Karnataka, India. International Journal of Current Microbiology and Applied Sciences, 6 (11): 3420-3426.

Kumar, V., A. U. Singh & R. K. Jain, 2012. Comparative efficacy of bioagents as seed treatment for management of *Meloidogyne incognita* infecting okra. Nematologia Mediterranea, 40 (2): 209-211.

Maleita, C. M., M. J. Simões, C. Egas, R. H. C. Curtis & I. M. O. Abrantes, 2012. Biometrical, biochemical, and molecular diagnosis of Portuguese *Meloidogyne hispanica* isolates. Plant Disease, 96 (6): 865-874.

Marin, M. V., L. S. Santos, L. A. Gaion, H. O. Rabelo, C. A. Franco, G. M. M. Diniz, E. H. C. Silva & L. T. Braz, 2017. Selection of resistant rootstocks to *Meloidogyne enterolobii* and *Meloidogyne incognita* for okra (*Abelmoschus esculentus* L. Moench). Chilean Journal of Agricultural Research, 77 (1): 58-67.

Melakeberhan, H., J. M. Webster & R. C. Brooke, 1985. Response of *Phaseolus vulgaris* to a single generation of *Meloidogyne incognita*. Nematologica, 31 (2): 190-202.

Miamoto, A., M. T. R. Silva, C. R. Dias-Arieira & H. H. Puerari, 2017. Alternative products for *Pratylenchus brachyurus* and *Meloidogyne javanica* management in soya bean plants. Journal of Phytopathology, 165 (10): 635-640.

Mohanta, S. & K. C. Mohanty, 2012. Screening of okra germplasms/varieties for resistance against *Meloidogyne incognita*. Journal of Plant Protection and Environment, 9 (1): 66-68.

Muhammad, A. U. H., M. Kamra, S. Muhammad, Z. Muhammad, Y. Faiga & S. Hania, 2017. Reaction of two summer vegetables (okra and chillies) germplasm against root knot nematode (*Meloidogyne incognita*). Plant Protection, 1 (1): 23-27.

Mukhtar, T., I. Arshad, M. Z. Kayani, M. A. Hussain, S. B. Kayani, A. M. Rahoo & M. Ashfaq, 2013. Estimation of damage to okra (*Abelmoschus esculentus*) by root-knot disease incited by *Meloidogyne incognita*. Pakistan Journal of Botany, 45 (3): 1023-1027.

Odeyemi I. S., S. O. Afolami & F. T. Oguejiofor, 2016. Susceptibility of okra accessions to root knot nematode. International Journal of Vegetable Science, 22 (3): 289-294.

Özarslan, A. & İ. H. Elekcióğlu, 2010. Investigation on virulence of *Meloidogyne incognita* (Kofoid & White, 1919), *Meloidogyne arenaria* (Neal, 1889) and *Meloidogyne javanica* (Treub, 1885) (Tylenchida: Meloidogyridae) populations on resistant and susceptible tomato cultivars. Turkish Journal of Entomology, 34 (4): 495-502 (in Turkish with English abstract).
Resistance of local okra cultivars against *Meloidogyne incognita* (Kofoid & White, 1919) (Nematoda: Meloidogynidae), effects of nematode infestation on growth parameters and leaf macro- micronutrients

Pandey, R. K., S. Bhandari, K. Giri, P. Wangle & H. K. Manandhar, 2019. Influence of different fertilizers and nematicides on number of nematode galls and yield of okra in summer season in Chitwan, Nepal. Azarian Journal of Agriculture, 6 (2): 23-36.

Pandey, R. & A. Kalra, 2003. Root knot disease of ashwagandha *Withania somnifera* and its ecofriendly cost-effective management. Journal of Mycology and Plant Pathology, 33 (2): 240-245.

Pandey, R. K., D. K. Nayak & K. K. Rajesh, 2017. Effects of macronutrient contents of resistant and susceptible greengram cultivars as influenced by root-knot nematode, *Meloidogyne incognita*. International Journal of Current Research, 9 (4): 49166-49170.

Santana-Gomes, S. M., C. R. Dias-A, M. Roldi, T. S. Dadazio, P. M. Marini & D. A. O. Barizão, 2013. Mineral nutrition in the control of nematodes. African Journal of Agricultural Research, 8 (21): 2413-2420.

Sathish, D. & A. Eswar, 2013. A Review on: *Abelmoschus esculentus* (Okra). International Research Journal of Pharmaceutical and Applied Sciences, 3 (4): 129-132.

Sheela, M. S., Jiji, R. Malu & S. Shaiju, 2006. Screening of okra varieties for resistance against *Meloidogyne incognita*. Indian Journal Nematolojia, 36 (2): 292-293.

Sikora, R. A. & E. Fernandez, 2005. "Nematode Parasites of Vegetables, 319-392". In: Plant Parasitic Nematodes in Subtropical and Tropical Agriculture. CABI Publishing, 871 pp.