

# Sensitivity of Tomato Varieties Grown in Najaf Governorate for Root-Knot Nematodes (*Meloidogyne Javanica* and *M. Incognita*)

<sup>1</sup>Mukhtar Fadel, Wisam Adnan R. Aljuaifari<sup>2</sup>

<sup>1,2</sup>Plant Protection Department, Faculty of Agriculture, University of Kufa, Najaf, Iraq.

E-mail: [wisam.aljuaifari@uokufa.edu.iq](mailto:wisam.aljuaifari@uokufa.edu.iq)

## Abstract

This study was conducted in the greenhouse of Plant Protection Department at College of Agriculture, Kufa University to determine the effect of two types of root-knot nematodes (*Meloidogyne javanica* and *M. incognita*) on four varieties of tomato (Aswar, Mariana, Reem, and Kantor). The results of the statistical analysis showed that there were clear significant differences in the decrease of plant growth indicators compared to the other varieties of tomato by root-knot nematodes, especially with the Kantor variety, which had a more significant effect on reduced plant growth development of tomato. The parameters were: height (7.6 cm, 2.6 grams, 3, 7.66, 0.912 grams, 0.33 grams, 0.03 grams) respectively with *M. javanica* compared to untreated treatment (control) was 18.66 cm, 11.27 grams, 7.66, 14.33, 3.75 grams, 1.71 grams, 1.22 grams respectively for tomato plant growth parameters. Also, other varieties were affected by root-knot nematodes with different effects on plant growth development compared to untreated varieties with the pathogens. Aswar variety was the lowest variety affected by *M. javanica* and *M. incognita* compared to other varieties. Results of the study showed also different effects on root-knot nematode life stages development that included (number of juveniles per 500 cm<sup>3</sup> of soil, number of eggs, average of galls, number of juveniles per gram, number of eggs per gram, productive factor, and number of eggs-mass and juveniles inside the roots of tomato plants) with these different varieties of tomato; it was clear significant effect of these nematodes on tomato plants during infection with both nematodes *M. javanica* and *M. incognita* and it was clear the effect of number of juveniles and eggs compared to other varieties of tomato. Aswar variety was a lower variety in number of juveniles with *Meloidogyne incognita* compared to other varieties. In addition, there was significant effect on development of life stages of root-knot nematodes (*M. javanica*, *M. incognita*) with these varieties of tomato.

**Keywords:** *M. incognita*, *M. javanica*, Aswar, Mariana, Reem, and Kantor variety

## 1. Introduction

Tomato is one of the biggest and economically most important species, including important vegetables, spices and medicinal plants [1]. Tomato (*Lycopersicon esculantum* Mill.) belongs to the Solanaceae family, is one of the most important strategic vegetable crops in the world, because of its high nutritional value [2], [3]. It is rich in vitamins (especially A), C and mineral elements (Fe, P), which can also be used in many food industries. It can also be consumed as fresh vegetables [4, 5]. Due to its nutritional importance and economic benefit, tomato cultivation has expanded greatly in Iraq where tomato cultivation introduced to Iraq at the beginning of the twentieth century then it is spread to most areas of Iraq and succeeded in cultivating it in covered and open fields [6]. Tomato is grown in dry and temperate regions and it is believed that the starch of tomato is due to the small-fruited wild tomato variety, *L. Esculentum* var. *Cerasiform*, which grows in South America and was first cultivated in Mexico, then to the Philippines, then to Europe, then to North America, where it was cultivated for industrial purposes in the US state of Pennsylvania in 1874 A.D., where the statistics of the International Food and Agriculture Organization of the United Nations indicate that the area planted for tomatoes in the world for the year 2018 reached (4762457 hectares) and that the global production of tomatoes for that year amounted to (182256458 tons). In

Iraq, the cultivated area for the year reached 2018 (18,186 ha) and a production capacity of 266,294 tons [7]. This crop exposed to many pathogens cause great losses in the tomato plants, especially soils contaminated with root-knot nematode [8] where the tomato plant is infected with many pests that effect on quantity and quality of tomato production one of them is root-knot nematode is considered one of the most diseases caused by root-knot nematode (*Meloidogyne* spp.) [8] where the resulting damages amounted to about 80 billion dollars annually. In each year the yield damages from the tomato crop because of the nematode have been evaluated for the nematode could be sitting in the fields without seeing any symptoms clear on the plants on top of ground, the yield damages caused by this nematode are oftentimes undervalued. The yield damages can be different from year to the year that causes by this nematode and are affected by the variety of the tomato, the soil biotic factors and abiotic and climatological cases. The nematode can be more destroyed for the tomato if it is spread in the fields. As in another vegetable crops, okra production in Iraq is suffering from yield loss because of facing many biotic and abiotic factors. Yield loss by the plant parasitic nematodes is one of the most important issues [9].

Root-knot nematode *Meloidogyne* spp. is the most prevalent nematode associated with vegetable crops in Iraq [9] and chronic losses usually occur due to the frequent and high population of this nematode [10]. Root-knot nematodes are considered among the top 5 major

plant pathogens and the first among the 10 most important genera of plant parasitic nematodes in the world [11]. *Meloidogyne* spp. are one of the most widespread and damaging plant-parasitic nematodes throughout the world and substantially affects growth and yield of tomato. Root-knot nematode (*Meloidogyne* spp. includes over a hundred species, the four-wide distributed *Meloidogyne incognita*, *M. javanica*, *M. arenaria* and *M. hapla* are the most damaging on vegetables [12]. Root-knot: (*Meloidogyne incognita*) is microscopic roundworms is found in a wide range of homeland and agroeco systems. Those parasites infect gourd roots of plant, wherein they mash and full their life cycles. When left unlimited, those pathogens can be caused severe plant harm and yield lack to cucurbits and other popular vegetables in everywhere the Pacific. Two species of the nematodes hit gourd in all the world *Meloidogyne incognita* and *M. javanica*. *Meloidogyne* contains around 100 species. Some of these species are considered globally necessary and can be caused severe loss on economic crops. *Meloidogyne* is a sedentary endoparasite pathogen feeding into the root and tuber cells. The main objective of this study was to find out the best way to management the disease that causes by plant parasitic nematodes by using different varieties of tomato that grow in Najaf city was used to determine the effect on root-knot nematodes on different varieties of tomato.

## 2. Materials and Methods

This research was conducted over 60 days period that encompassed four specific varieties of tomato seeds that had been grown in the Najaf Province. The development of a potentially using different varieties in order to get idea about which one of these varieties of tomato can use as resistant to root-knot nematodes (*Meloidogyne incognita* and *M. javanica*) on tomato plants. Test including 12 treatments that including as flowing down:

- 1- Aswar F1 variety +*Meloidogyne javanica* (used 2000 eggs of *M. javanica* for each plant)
- 2- Aswar F1 variety +*Meloidogyne incognita* (used 2000 eggs of *M. incognita* for each plant)
- 3- (Untreated tomato plants -Aswar F1) Control
- 4- Mariana F1 variety + *Meloidogyne javanica* (used 2000 eggs of *M. javanica* for each plant)
- 5- Mariana F1 variety + *Meloidogyne incognita* (used 2000 eggs of *M. incognita* for each plant)
- 6- (Untreated tomato plants -Mariana F1) Control
- 7- Reem F1 variety + *Meloidogyne javanica* (used 2000 eggs of *M. javanica* for each plant)
- 8- Reem F1 variety + *Meloidogyne incognita* (used 2000 eggs of *M. incognita* for each plant)
- 9- (Untreated tomato plants - Reem F1) Control
- 10- Kantor F1 variety + *Meloidogyne javanica* (used 2000 eggs of *M. javanica* for each plant)
- 11- Kantor F1 variety + *Meloidogyne incognita* (used 2000 eggs of *M. incognita* for each plant)
- 12- (Untreated tomato plants- Kantor F1) Control

The research associated with two objectives was evaluated of *Meloidogyne incognita* and *M. javanica*, which was the one economically important nematode on tomato. In all tests tomato plants that ages were around

21 days were treated with *Meloidogyne incognita* and *M. javanica*, and untreated treatment for each variety as control. All varieties were evaluated on Root-knot nematode *Meloidogyne incognita* and *M. javanica*. Inoculum production of Root-knot nematode *Meloidogyne incognita* and *M. javanica*. Eggs, planted in a greenhouse and maintained on tomato plants were as inoculum in all tests [13, 14]. The soil was collected on a 325 um pore sieves then processed further by sucrose centrifugal flotation for 1 munit [15]. Root-knot nematode *Meloidogyne incognita* and *M. javanica* was maintained in the greenhouse on cotton. The eggs of Root-knot nematode *Meloidogyne incognita* and *M. javanica* were extracted from fresh roots by using NaOCl for 4 minutes with using 200 um pore sieves nested on 500 um pore sieves [14, 16]. Juveniles were extracted from the soil by sucrose centrifugal flotation [8, 15]. Methods for Greenhouse experimental in all varieties of tomato treated with Root-knot nematode *Meloidogyne incognita* and *M. javanica* were sown (one tomato plants /plastic bag (5 kilograms of sterile soil) in 20 cm diameter clay plastic bag filled with 3 kilograms of the sterilized soil-sand mixture (1:1, v/v). A suspension of 2000 eggs of Root-knot nematode *Meloidogyne incognita* and *M. javanica* were pipetted into the plastic bag at the time of planting. Two holes' depression (2.5 cm dia x 2.5 cm deep) were made around the tomato plants and 3ml of inoculum was pipetted onto the tomato plant. All experimental treatments were arranged in a RCBD with 5 replications and allowed to grow in the greenhouse maintained at approximately 28°C with artificial light of 12 hours/day. Plants were watered daily and received fertilizer weekly. At 8 weeks, the plants were harvest plant development and nematodes life stage development was recorded. Plant parameters and nematodes measurements, plants parameters measurements included height of plant/cm<sup>3</sup>, weight of plant/ grams, number of nodes, number of leaves/plants, weight of roots/ grams, weight of dry plant/ grams, weight of dry roots/ grams. Nematode population development was measured by the number of juveniles/ 500cm<sup>3</sup> recovered from the soil, and number of eggs from the roots of tomato plants, average of galls that was examined for galling and rated according to the following method. Each group of root plant materials for these treatments were laid on the lab counter top and observed for root knot galls. Root galling is recorded on a scale as follows: 0 = no galling, 1 = 25% galling, 2 = 50% galling, 3 = 75% and 4 =100% galling. Egg Masses Staining: Egg masses of *M. incognita* was stained by dipping the roots in 0.015% Phloxine B solution for 20 minutes as described by Hussey [17] and then washing the stained roots with tap water to remove the residual Phloxine B Aljaafri et al. [14]. In addition, number of juveniles and eggs per gram from divided by root weight. Also, in this experimental was counted productive factor by using the toral of (eggs+ juveniles + galls / 2000 eggs that used in the test) [13, 14].

### Statistical analysis

The data for plant measurements and nematode populations was analyzed using SAS Statistical Software

System version 9.4. Data was subjected to analysis of variance [18] using a randomized complete block design with 5 replications. Differences in treatments means were separate using Fisher's Protected Least Significant Difference Test for all the results [18].

### 3. Results and Discussion

Effect of Root-knot nematode *Meloidogyne incognita* and *M. javanica* on tomato plant growth development in the greenhouse at 60 days of planting.

The results of the statistical analysis showed in Table (1) that there were clear significant differences in the decrease of plant growth indicators compared to the control treatment that included height of plant/cm<sup>3</sup>, weight of plant/ grams, number of nodes, number of leaves/plants, weight of roots/ grams, weight of dry plant/ grams, weight of dry roots/ grams with Root-knot nematode *Meloidogyne incognita* and *M. javanica* especially with Kantor variety was more significant effect to reduced plant growth development of tomato which was 7.6, 2.6, 3, 7.66, 0.912, 0.33, 0.03 respectively with *M. javanica* compared to untreated treatment (control) was 18.66, 11.27, 7.66, 14.33, 3.75, 1.71, 1.22 respectively for tomato plant growth parameters. Also, the treatment with *Meloidogyne incognita* was significant differences in the decrease of plant growth indicators that reached to 8.5, 4.17, 3.66, 8.66, 1.44,

0.32, and 0.08 respectively for tomato plant growth parameters compared to control treatment. Otherwise, Assar variety was the best variety for both nematodes *Meloidogyne incognita* and *M. javanica* to increased plant growth development compared to others varieties. In addition, the others varieties also were significant effect by Root-knot nematodes *Meloidogyne incognita* and *M. javanica* compared to untreated treatments for both varieties for tomato plant growth development. That was related to species *Meloidogyne* spp. causes high levels of economic losses to many agricultural crops around the world, especially vegetable crops in tropical and subtropical regions [19]. That is be one of the important pathogens in Iraq, especially soils contaminated with root-knot nematode. Sasser [8] Where the tomato plant is infected with many pests that effect on quantity and quality of tomato production one of them is Root-knot nematode is considered one of the most diseases caused by Root-knot nematode (*Meloidogyne* spp.) where the resulting damages amounted to about 80 billion dollars annually [20]. The negative effect of root-knot nematode *Meloidogyne incognita* and *M. javanica* was evident on the plant, as the root-knot nematode penetrated the roots and fed on them, which negatively affected the total growth and length of the plant and the number of resulting nodes; this is consistent with what he found [21].

**Table (1) effect of Root-knot nematodes (*Meloidogyne incognita* and *M. javanica*) on different varieties of tomato that were grown in the greenhouse in Najaf Governance on plant growth development at 60 days of infection with Root-knot nematodes.**

Treatments	Height of plant/cm <sup>3</sup>	Weight of plant/ grams	Number of nodes	Number of leaves/ plants	Weight of roots/ grams	Weight of dry plant/ grams	Weight of dry roots/ grams
ASW++M. javanica	25.33	10.92	8.666	14	6.148	2.44	1.24
ASW+ M. incognita	17.66	5.6	4.333	16.33	3.519	2.87	1.23
ASW+ONLY	29.9	13.186	7.666	13.33	4.387	3.75	1.33
MAR+ M. javanica	9	4.426	4	14.66	0.950	0.74	0.03
MAR+ M. incognita	9.333	5.213	4	14	1.134	0.68	0.03
MAR+ONLY	10.16	5.693	4.666	15.66	0.674	0.7	0.13
REM+ M. javanica	8.5	4.026	3.666	12.33	2.116	0.4	0.13
REM+ M. incognita	9.666	3.08	3	10.33	1.410	0.4	0.03
REM+ONLY	10.83	7.266	4.333	14.66	0.774	0.89	0.2
KAN+ M. javanica	7.666	2.6	3	7.666	0.912	0.33	0.03
KAN+ M. incognita	8.5	4.173	3.666	8.66	1.449	0.32	0.08
KAN+ONLY	18.66	11.72	7.666	14.33	3.751	1.71	1.22
P-Value	0.0001	0.557	0.625	0.913	0.0001	0.033	0.425
LSD 0.05	5.946	6.917	1.798	10.584	1.713	0.898	0.290

Each number in the table represents the average of 5 replicates.

Results were compared using the arithmetic mean below the 0.05 significant level.

Effect of different varieties of tomato infected with Root-knot nematode *Meloidogyne incognita* and *M. javanica* on tomato nematodes life stages development in the greenhouse at 60 days of planting.

It was evident from the results (Figure 1) of the study that

the number of juveniles and eggs of Root-knot nematodes *Meloidogyne incognita* and *M. javanica* in the treatment of the different varieties of tomato, it was clear significant effect of these nematodes on tomato plants during infection with both nematodes *Meloidogyne incognita* and *M. javanica* and saw the effect of number of juveniles and eggs compared to control untreated. Aswar variety was a lower variety in number of juveniles with *Meloidogyne incognita* compared to other varieties.

Other varieties showed different effect by infection with Root-knot nematodes *Meloidogyne incognita* and *M. javanica* according to different number of juveniles and eggs of Root-knot nematodes *Meloidogyne incognita* and *M. javanica*. Root-knot nematodes that parasitize the tomato crop in Arab countries are *M. incognita*, *M. javanica*, *M. hapla*, *M. arenaria* and *M. ardenensis*. The species *M. incognita* are considered the most widespread and parasitizing the tomato crop in the world [22]. During previously study showed negative effect of life stages of Root-knot nematode including number of juveniles and eggs development on tomato plants that grow in the greenhouse and infected all the tomato plants.

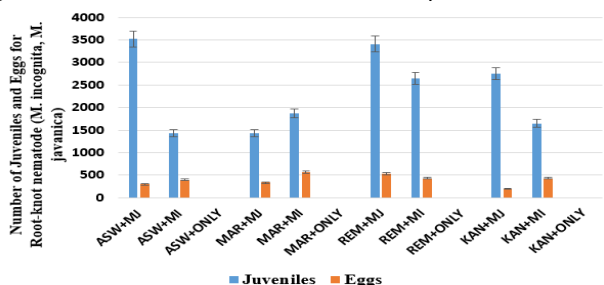


Figure (1) showed the effect of root-knot nematodes on number of juveniles in 500 grams of soil and eggs of root-knot nematodes (*Meloidogyne javanica* and *M. incognita*) on tomato plants in plastic bags 60 days after planting in the greenhouse

Each number in the table represents the average of 5 replicates.

Results were compared using the arithmetic mean below the 0.05 significant level.

P-Value juveniles = 0.0001, LSD 0.05 = 936.06

P-Value eggs = 0.0001, LSD 0.05 = 251.21

The results in (figure 2) showed different effect on average of galls of Root-knot nematodes *Meloidogyne incognita* and *M. javanica* with these four varieties of tomato (Aswar F1 variety, Mariana F1, Reem F1, Kantor F1) in the treatments of *M. incognita* and *M. javanica* with Aswar F1 variety and Mariana F1 reduced average of galls compared to other treatments. The best treatments were Kantor F1 that reducing average of galls for root-knot nematode *M. incognita* compared to other treatment. (Figure 2). The high results of both varieties in reducing the development of root-knot nematodes agree with *Meloidogyne* spp. attack different crop plants, including vegetables, causing severe growth retardation due to formation of typical galls [23].

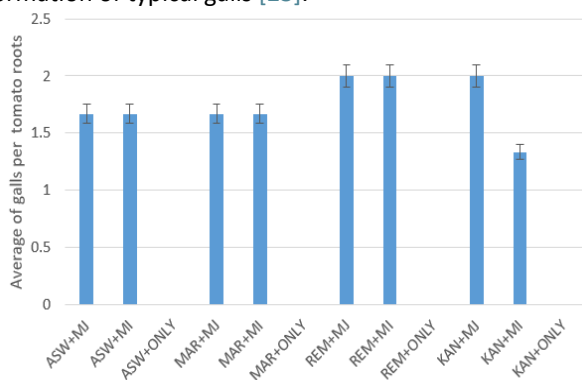


Figure (2) showed the effect of root-knot nematodes average of galls for root-knot nematodes (*Meloidogyne javanica* and *M. incognita*) on tomato plants in plastic bags 60 days after planting in the greenhouse

Each number in the table represents the average of 5 replicates.

Results were compared using the arithmetic mean below the 0.05 significant level.

P-Value Galls = 0.0005, LSD 0.05 = 1.158

It was evident from the results (Figure 3) of the test for number of juveniles per grams for Root-knot nematodes *Meloidogyne javanica*, *M. incognita* in the treatment of the different varieties of tomato, it was clear significant effect on number of juveniles per grams with treatment of aswar variety, it was clear significant effect to reduced number of juveniles per grams for both nematodes (*M. javanica*, *M. incognita*) which reached to 581.95 and 616.92 juveniles per grams respectively compared to 1872.93 and 1812.45 juveniles per grams in the Reem variety treatment for both nematodes (*M. javanica*, *M. incognita*) respectively. In addition, number of juveniles per grams for Root-knot nematodes *M. javanica* in the treatment kantor variety was reached to 3197.02 juveniles per grams. During previously study showed negative effect of life stages of Root-knot nematode including number of juveniles and eggs development on tomato plants that grow in the greenhouse and infected all the tomato plants.

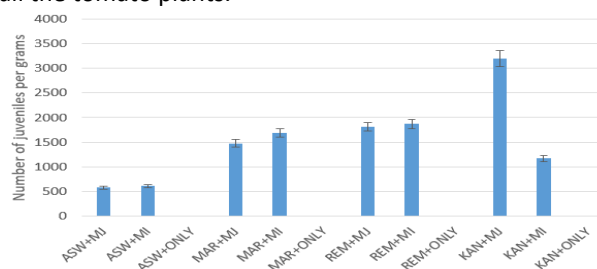


Figure (3) showed the effect of root-knot nematodes number of juveniles per grams for root-knot nematodes (*Meloidogyne javanica* and *M. incognita*) on tomato plants in plastic bags 60 days after planting in the greenhouse

Each number in the table represents the average of 5 replicates.

Results were compared using the arithmetic mean below the 0.05 significant level.

P-Value juveniles per grams = 0.0001, LSD 0.05 = 935.25

The results (Figure 4) of the test for number of eggs per grams for Root-knot nematodes *Meloidogyne javanica*, *M. incognita* in the treatment of the different varieties of tomato, it was clear significant effect on number of eggs per grams with treatment of aswar variety, it was clear significant effect to reduced number of eggs per grams for both nematodes (*M. javanica*, *M. incognita*) that reached to 50.05 and 134.48 eggs per grams respectively compared to 561.37 and 354.75 eggs per grams in the Mariana variety treatment for both nematodes (*M. javanica*, *M. incognita*) respectively. In addition, number of eggs per grams for Root-knot nematodes (*M. javanica*, *M. incognita*) in the treatments Reem and Kantor varieties were also significant effect to reduced number of eggs per grams compared to Mariana variety for eggs per grams. That was related to Root-knot nematode *Meloidogyne* spp. is the most prevalent nematode associated with vegetable crops in Iraq [9] and chronic losses usually occur due to the frequent and high population of this nematode [10].

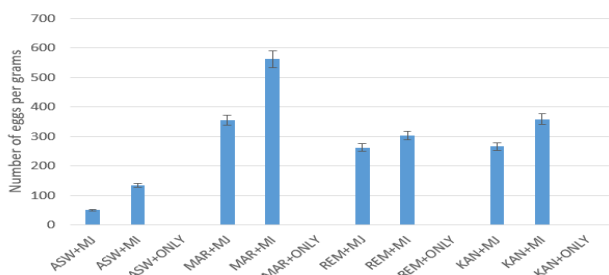


Figure (4) showed the effect of root-knot nematodes number of Eggs per grams for root-knot nematodes (*Meloidogyne javanica* and *M. incognita*) on tomato plants in plastic bags 60 days after planting in the greenhouse:

Each number in the table represents the average of 5 replicates.

Results were compared using the arithmetic mean below the 0.05 significant level.

P-Value Eggs per grams = 0.0016, LSD 0.05 = 266.16

The results in figure (5) showed effect the productive factor for Root-knot nematodes *Meloidogyne javanica*, *M. incognita* in with these varieties of tomato as it had seen there were significant on productive factor for root-knot nematodes with these varieties. In the treatment of aswar variety was clear significant effect on productive factor for Root-knot nematodes *M. incognita* that was 0.915 compared Reem variety with *M. incognita* was reached to 1.537. In addition, it was clear significant effect to reduced productive factor for both nematodes (*M. javanica*, *M. incognita*) with Marina variety that reached to 0.882 and 1.219 respectively compared other varieties. That was because *Meloidogyne* spp. is microscopic roundworms is found in a wide range of homeland and agroeco systems. Those parasites infect gourd roots of plant, wherein they mash and full their life cycles. When left unlimited, those pathogens can be caused severe plant harm and yield lack to cucurbits and other popular vegetables in everywhere the Pacific. Two species of the nematodes hit gourd in all the world *Meloidogyne incognita* and *M. javanica*.

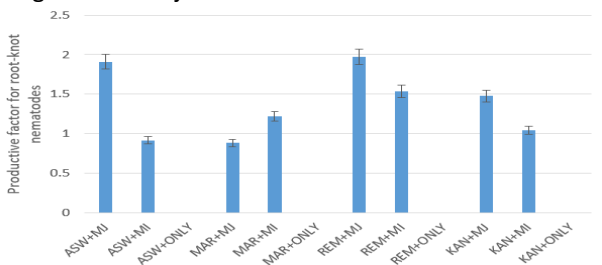


Figure (5) showed the Productive factor of root-knot nematodes (*Meloidogyne javanica* and *M. incognita*) on tomato plants in plastic bags 60 days after planting in the greenhouse

Each number in the table represents the average of 5 replicates.

Results were compared using the arithmetic mean below the 0.05 significant level.

P-Value Productive factor = 0.0001, LSD 0.05 = 0.5179

Root-knot Nematode life stages development of Root-knot nematodes *Meloidogyne javanica*, *M. incognita* was effect by different varieties of tomato plants that had grown in the greenhouse. Study had been shown a significant effect to reduce eggs mass of Root-knot

nematodes *Meloidogyne javanica*, *M. incognita* with Mariana and Reem varieties reduced egg mass which were 1 and 1.3 in *M. incognita* for both varieties compared to aswar variety was 4 / eggs mass per tomato roots. (Figure. 6) egg mass was clear on the roots by taken images. However, there was no significant effect on juveniles inside the roots between all of tomato varieties of Root-knot nematodes *Meloidogyne javanica*, *M. incognita*. That because of Root-knot nematode *Meloidogyne* spp. is the most prevalent nematode associated with vegetable crops in Iraq (Stephan et al., 1977). In addition, the egg mass is accoune outside the female body. Under appropriate conditions, eggs hatch to allow second phase juveniles (J2). J2s shift in search on the host plants to full their life cycle. Once the J2 reach the plant root, the J2 penetrate the closest root tips in the extension area [24]. The J2 establishes a nutrition site primary in bark /or relative parenchyma cells. Five to six cells serve as a nutrition site.

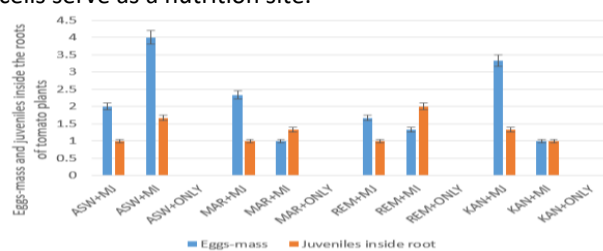


Figure (5) showed the Eggs-Mass of root-knot nematodes (*Meloidogyne javanica* and *M. incognita*) on tomato plants in plastic bags 60 days after planting in the greenhouse:

Each number in the table represents the average of 5 replicates.

Results were compared using the arithmetic mean below the 0.05 significant level.

P-Value Eggs-Mass= 0.0135, LSD 0.05 = 2.298

P-Value Juveniles insides roots= 0.249, LSD 0.05 = 1.754

#### 4. Conclusion

Currently study showed of the statistical analysis that there were clear significant differences in the decrease of plant growth indicators compared to the control treatment (without Root-knot nematodes *Meloidogyne javanica*, *M. incognita*) that included height of plant/cm<sup>3</sup>, weight of plant/ grams, number of nodes, number of leaves/plants, weight of roots/ grams, weight of dry plant/ grams, weight of dry roots/ grams with Root-knot nematode *Meloidogyne incognita* and *M. javanica* of four varieties of tomato plants that grown in the greenhouse including (Aswar, Mariana, Reem, and Kantor varieties). Results of the study showed also different effect on the number of juveniles and eggs of Root-knot nematodes *Meloidogyne incognita* and *M. javanica* in the treatment of the different varieties of tomato, it was clear significant effect of these nematodes on tomato plants during infection with both nematodes *Meloidogyne incognita* and *M. javanica* and saw the effect of number of juveniles and eggs compared to other varieties of tomato. Aswar variety was a lower variety in number of juveniles with *Meloidogyne incognita* compared to other varieties. In addition, there was significant effect on development of life stages of Root-knot nematodes (*M.*

javanica, *M. incognita*) with these varieties of tomato.

## References

- Al-Taey DK, Al-Naely IJ, Kshash BH. A study on effects of water quality, cultivars, organic and chemical fertilizers on potato (*Solanum tuberosum* L.) growth and yield to calculate the economic feasibility. *Bulgarian Journal of Agricultural Science*. 2019;25(6):1239-45.
- Mohit MK, Singh MK, Singh S, Naresh R. Effect of integrated use of organic and inorganic sources of nutrients on growth, yield quality and profitability of tomato (*Lycopersicon esculentum* mill.) Var. Pusa rohini. *Int J Agricult Stat Sci Vol*. 2019;15(1):57-66.
- Al-Abedy AN, Kadhim JH, Abdalmoohsin RG, Al-Taey DK. Genetic diversity of tomato yellow leaf curl virus isolates and the effect of virus on the hormones content of tomato (*Solanum lycopersicum*) plants. *Research on Crops*. 2021;22(2): 347-55. <https://doi.org/10.31830/2348-7542.2021.078>
- Al-Taey DK, Al-Dirbil KM, Al-Azawi SS, editors. Study The Effect of Water Quality, Bio Booster (Zytonic F) and Nano NPK fertilizer on Tomato Growth and Yield. IOP Conference Series: Earth and Environmental Science; 2021: IOP Publishing. <https://doi.org/10.1088/1755-1315/910/1/012063/meta>.
- Shihab K, Abood I. Genetic segregation of tomato trihybrid, double cross and detection of Mi1. 2, Mi-3 resistance genes against root-knot nematode (*Meloidogyne* spp.). *International Journal of Agricultural and Statistical Sciences*. 2019;15(1):153-62. Available from: <https://www.cabdirect.org/cabdirect/abstract/20203267732>
- Mohammed S, El Saedy MA, Enan MR, Ibrahim NE, Ghareeb A, Moustafa SA. Biocontrol efficiency of *Bacillus thuringiensis* toxins against root-knot nematode, *Meloidogyne incognita*. *J Cell Mol Biol*. 2008;7(1):57-66. Available from: <http://jcm.b.halic.edu.tr/>
- Nakai J. Food and Agriculture Organization of the United Nations and the sustainable development goals. *Sustainable Development*. 2018;22:1-450. Available from: <http://www.fao.org/faostat/en/#data>
- Sasser JN. Root-knot nematodes: a global menace to crop production. *Plant disease*. 1980;64(1):36-41. Available from: <https://www.cabdirect.org/cabdirect/abstract/19786728293>
- Stephan Z, Abu-Gharbieh W. Root-Knot Nematodes (*Meloidogyne* spp.) Damage, Losses and Control. *Plant nematodes in Arab Countries* (eds WA Abu-Gharbieh, AS Al-Hazmi, ZA Stephan, AA Dawabah) Darwael for Publishing, Arab Society of Plant Protection, Amman, Jordan. 2010:553-602.
- Stephan Z, Hassoon I, Antoon B. Use of biocontrol agents and nematicides in the control of *Meloidogyne javanica* root-knot nematode on tomato and eggplant. *Pakistan Journal of Nematology*. 1998;16:151-6.
- Mukhtar T, Kayani MZ, Hussain MA. Nematicidal activities of *Cannabis sativa* L. and *Zanthoxylum alatum* Roxb. against *Meloidogyne incognita*. *Industrial Crops and Products*. 2013;42:447-53. <https://doi.org/10.1016/j.indcrop.2012.06.027>
- Taylor AL, Sasser JN, Nelson L. Relationship of climate and soil characteristics to geographical distribution of *Meloidogyne* species in agricultural soils. North Carolina State University/AID, 1982. Available from: [https://pdf.usaid.gov/pdf\\_docs/pnaaq217.pdf](https://pdf.usaid.gov/pdf_docs/pnaaq217.pdf)
- Aljaafri WAR. Management of plant-parasitic nematodes using gene manipulation and biological nematicides. Mississippi State University, 2017. Available from: <https://www.proquest.com/openview/96253df6b04d3d82b8a3a712a1b8db30/1?pq-origsite=gscholar&cbl=18750>
- Aljaafri WA, Husain ER, Al-Fadhil FA. Examination of *Burkholderia renjensis*, *Streptomyces avermentilis*, and *Bacillus firmus* to management of *Meloidogyne incognita* on corn. *Journal of Pharmaceutical Sciences and Research*. 2019;11(3):942-7. Available from: <https://www.proquest.com/openview/38c609eeff083fbf2af38e72455e39ae/1?pq-origsite=gscholar&cbl=54977>
- Jenkins W. A rapid centrifugal-flotation technique for separating nematodes from soil. *Plant disease reporter*. 1964;48(9). Available from: <https://www.cabdirect.org/cabdirect/abstract/19650801105>
- McLean KS, Lawrence GW. Interrelationship of *Heterodera glycines* and *Fusarium solani* in Sudden Death Syndrome of Soybean. *J Nematol*. 1993;25(3):434-9.
- Hussey R. A comparison of methods of collecting inocula of *Meloidogyne* spp., including a new technique. *Plant Dis Rep*. 1973;57:1025-8. Available from: <https://cir.nii.ac.jp/crid/1573668924886064768>
- Inc SI. SAS® 9.3 system options: reference. SAS Institute Inc Cary, NC; 2011.
- Sikora RA, Fernandez E. Nematode parasites of vegetables. In: *Plant parasitic nematodes in subtropical and tropical agriculture*. CABI publishing Wallingford UK, 2005. p. 319-92. <https://doi.org/10.1079/9780851997278.0319>
- Nicol J, Turner S, Coyne DL, Nijs Ld, Hockland S, Maafi ZT. Current nematode threats to world agriculture. In: *Genomics and molecular genetics of plant-nematode interactions*. Springer, 2011. p. 21-43. [https://doi.org/10.1007/978-94-007-0434-3\\_2](https://doi.org/10.1007/978-94-007-0434-3_2)
- Kumar N, Bhatt J, Sharma RL. Interaction between *Meloidogyne incognita* with *Fusarium oxysporum* f. sp. *lycopersici* on Tomato. *International Journal of Current Microbiology and Applied Sciences*. 2017;6:1770-6. Available from: <http://www.thepharmajournal.com/>
- Bleve-Zacheo T, Melillo MT, Castagnone-Sereno P. The contribution of biotechnology to root-knot nematode control in tomato plants. *Pest Technology*. 2007;1(1):1-16. <https://doi.org/10.1.1.569.9363&rep=rep1&type=pdf>
- Hnoosh HJH, Aljuaifari WAR. Examination of biological seed treatments to management of root-knot nematode (*Meloidogyne* sp.) on okra (*Abelmoschus esculentus*). *Plant Archives*. 2020;20(1):1039-45. Available from:

[http://www.plantarchives.org/SPECIAL%20ISSUE%2020-1/1039-1045%20\(183\).pdf](http://www.plantarchives.org/SPECIAL%20ISSUE%202020-1/1039-1045%20(183).pdf)

24. Lohar DP, Bird DM. Lotus japonicus: a new model

to study root-parasitic nematodes. *Plant and Cell Physiology*. 2003;44(11):1176-84.

<https://doi.org/10.1093/pcp/pcg146>