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Original article (Orijinal araştırma)

Distribution and prevalence of root-knot nematode species in greenhouse vegetables in northern Iraq[1]

Kuzey Irak'taki sera sebzelerinde kök-ur nematodu türlerinin dağılımı ve yaygınlığı

Hoshang HAMAD[2,3] **Gökhan AYDINLI[4*]** **Sevilhan MENNAN[3]**

Abstract

The objective of the study was to determine the distribution and prevalence of root-knot nematodes (*Meloidogyne* spp.) in greenhouse vegetables in Sulaymaniyah, Erbil and Duhok Provinces of northern Iraq. One hundred and eighty-seven greenhouses were surveyed during November and December 2018. *Meloidogyne* spp. were identified by perineal patterns and esterase phenotype. *Meloidogyne* were detected in 37% of the greenhouses surveyed and the prevalence were 40% in Sulaymaniyah, 38% in Duhok and 34% in Erbil. *Meloidogyne javanica* Treub, 1885 and *Meloidogyne incognita* Kofoid & White, 1919 (Tylenchida: Meloidogynidae), were found in 64 and 36% of the greenhouses infested with *Meloidogyne*, respectively. By province surveyed, *M. incognita* and *M. javanica* were detected in 23 and 15% of greenhouses in Duhok, 12 and 22% of greenhouses in Erbil, 10 and 30% of surveyed greenhouses in Sulaymaniyah, respectively. *Meloidogyne* spp. were found in arugula, cauliflower, cucumber, eggplant, lettuce, tomato and zucchini. The highest prevalence of *Meloidogyne* spp. were in cucumber (58%) and tomato (33%), which are the most commonly grown vegetables in greenhouses in the study area.

Keywords: Esterase, greenhouse, identification, Iraq, *Meloidogyne*

Öz

Bu çalışmanın amacı, Kuzey Irak'ın Süleymaniye, Erbil ve Duhok illerindeki sera sebzelerinde kök-ur nematodlarının (*Meloidogyne* spp.) dağılımının ve yaygınlığının belirlenmesidir. Yüz seksen yedi serada 2018 yılı Kasım ve Aralık aylarında sürvey yapılmıştır. *Meloidogyne* spp., perineal patternler ve esteraz fenotipi kullanılarak teşhis edilmiştir. Sürvey yapılan seraların %37'sinde *Meloidogyne* varlığı tespit edilmiş ve yaygınlık Süleymaniye'de %40, Duhok'da %38 ve Erbil'de %34'dür. *Meloidogyne* ile bulaşık seraların %64'ünde *Meloidogyne javanica* (Treub, 1885) ve %36'sında *Meloidogyne incognita* (Kofoid & White, 1919) (Tylenchida: Meloidogynidae) bulunmuştur. Sürvey yapılan ile göre, *M. incognita* ve *M. javanica*, sırasıyla Duhok'da seraların %23 ve %15'de, Erbil'de seraların %12 ve %22'de, Süleymaniye'de seraların %10 ve %30'da tespit edilmiştir. *Meloidogyne* spp., roka, karnabahar, hıyar, patlıcan, marul, domates ve kabakta bulunmuştur. *Meloidogyne* spp.'nin en yüksek yaygınlığı, çalışma alanındaki seralarda en yoğun yetiştirilen sebzeler olan hıyar (%58) ve domates (%33)'de tespit edilmiştir.

Anahtar sözcükler: Esteraz, sera, teşhis, Irak, *Meloidogyne*

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[2] Salahaddin University, College of Agricultural Engineering Sciences, 44001, Erbil, Iraq
[3] Ondokuz Mayıs University, Faculty of Agriculture, Department of Plant Protection, 55139, Atakum, Samsun, Türkiye
[4] Ondokuz Mayıs University, Bafra Vocational High School, 55400, Bafra, Samsun, Türkiye
* Corresponding author (Sorumlu yazar) e-mail: gokhanay@omu.edu.tr
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Introduction

Agricultural production has made significant progress in Iraq over the past few years (Hilal et al., 2022). Especially, northern Iraq has shifted from being a smallholder-based, food-producing region that met its basic needs to being significant food importer (Jongerden et al., 2019). Greenhouses, which can increase productivity and profitability and extend crop production season, contribute valuable to agricultural production (Omer, 2016; Hilal et al., 2022). This vegetable production system is expanding in northern Iraq and total area of the greenhouses in 2021 reached ~112 ha in this region, where Sulaymaniyah is the leader province with 71%, followed with Erbil 18% and Dohuk 10% (MoAWR, 2022). However, one of the main obstacles to the continued expansion of greenhouse production of vegetables is the greater need for plant protection practices, since greenhouses have suitable conditions for the development of pests and diseases. In contrast to open fields, populations of plant-parasitic nematodes in greenhouse soil rapidly develop in the root zone due to stable microclimate, continuous plant cultivation, and the use of nematode-infested planting material by uniformed growers (Phani et al., 2021).

Root-knot nematodes (RKNs), *Meloidogyne* Göldi, 1887 (Tylenchida: Meloidogynidae), are considered to be some of the most harmful groups of plant-parasitic nematodes, and a limiting factor in the yield of greenhouse vegetable production globally (Sikora & Fernández, 2005). These obligate endoparasites feed within plant roots and induce root galls, which is the primary symptom of RKN infection on many plants. Due to the damaged root system, the capacity of the plant to absorb nutrients and water from the soil is reduced. In addition, nematode feeding sites, called giant cells, disrupt the plant metabolism and photosynthesis products are directed to these differentiated cells that provide nutrients for the nematode (Carneiro et al., 1999; Williamson & Gleason, 2003). As a result, the growth of infested plants is retarded and a reduction in crop yield and product quality occurs. In heavy nematode infestations, especially the seedlings, rapidly wilt and usually die (Sikora & Fernández, 2005).

Of more than 100 RKN species so far described (Ghaderi & Karssen, 2020), five have been found in Iraq (Hasan et al., 2020). Four of these species (*Meloidogyne arenaria* Neal, 1889, *Meloidogyne hapla* Chitwood, 1949, *Meloidogyne incognita* Kofoid & White, 1919 and *Meloidogyne javanica* Treub, 1885) have been present in this country for many years (Katcho, 1972; Katcho et al., 1976; Stephen et al., 1977, 1985; Al-Saaedy & Stephan, 1986; Stephan, 1997) whereas *Meloidogyne cruciani* Garcia-Martinez, Taylor & Smart, 1982 was only recently recorded as a new species for Iraq (Hasan et al., 2020). These species have been reported to infest vegetable crops in various regions of Iraq (Al-Saaedy & Stephan, 1986; Al-Sabie & Ami, 1990; Stephan, 1997; Al-Kubaicy & Al-Sabe'a, 2014; Ami et al., 2018; Kandouh et al., 2018; Hasan et al., 2020). Of these studies, only one was conducted in greenhouses (Ami et al., 2018), while other studies were in open fields. Consequently, there is a lack of information on the distribution and identification of RKNs in the greenhouses in Iraq. In most of these studies, which were conducted to detect *Meloidogyne* spp. in Iraq, species identification was only made by microscopic examination of perineal patterns of the females (Al-Saaedy & Stephan, 1986; Al-Sabie & Ami, 1990; Ali et al., 2014; Al-Kubaicy & Al-Sabe'a, 2014; Ami et al., 2018; Kandouh et al., 2018; Aljuboori & Al-Hakeem, 2020). More recently, a few reports indicated that molecular methods were used for species identification combined with the perineal patterns (Hasan & Abood, 2018; Hanoon et al., 2018; Hasan et al., 2020). However, no studies have used biochemical methods (isozyme analysis) for the identification of RKNs.

The objective of the study was to determine the prevalence of RKNs in the greenhouses of Sulaymaniyah, Erbil and Dohuk Provinces of northern Iraq, and to identify *Meloidogyne* species collected from infested greenhouses in this region using morphological (perineal pattern morphology) and biochemical (esterase phenotype) methods.

Materials and Methods

Survey and sample analyses

The survey was conducted during November and December 2018 in greenhouse vegetables in Sulaymaniyah, Erbil and Duhok Provinces of northern Iraq (Figure 1). A total of 187 greenhouses arbitrarily selected from 30 districts were surveyed at the end of the season, whenever plants were at least 3 months old post planting. In each greenhouse, 5 to 8 plants with the aboveground symptoms of RKN (yellowing, wilting and stunting) were sampled. Root zone soil and root samples were taken and combined to obtain a composite sample for each greenhouse. These samples were placed into plastic bags, labeled and taken to the laboratory for assessment where the samples were kept at 4°C and processed within 3 days.

In composite samples, the roots were washed with water, and rated on a scale of 0 to 5: 0, no galling; 1, trace infestation with some minor galls; 2, <25% galled roots; 3, 25-50% of galled roots; 4, 51-75%; and 5, >75% of galled roots (Hussey & Janssen, 2002). The RKN severity in each greenhouse was determined based on the roots with highest gall rating in each composite sample. The prevalence of RKN for each province was calculated as the number of greenhouses with RKN divided by total number of greenhouses surveyed × 100 (Carrillo-Fasio et al., 2021).

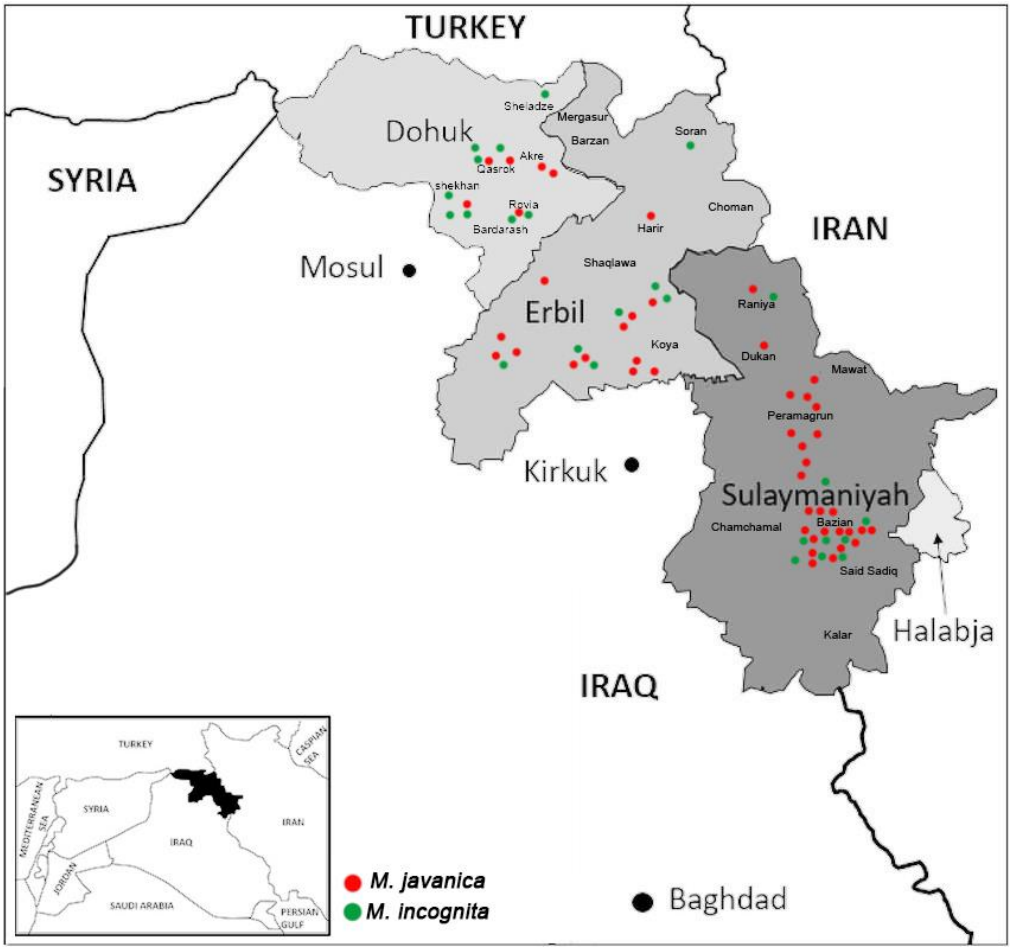

Figure 1. Distribution map of *Meloidogyne* spp. in vegetable greenhouses in northern Iraq. Each dot represents a single population.

Nematode extraction and identification

RKN populations were obtained by planting tomato (*Solanum lycopersicum* L.) cv. Falcon as individual seedlings into pots filled with 450 cm^3 of composite soil samples from each greenhouse (Aydınlı, 2018). Pots were maintained at 25 ± 2°C in the greenhouses and plants were uprooted after 60 days. Females were randomly picked from roots and used for morphological (perineal pattern) and biochemical (esterase phenotype) identification. Ten mature females from each population were arbitrarily selected for morphological identification. Females were transferred into 45% lactic acid and their perineal areas were cut and cleaned, then mounted in glycerine on glass slides (Hartman & Sasser, 1985). Perineal patterns were examined with a light microscope. Twenty-one young females from each population were used for biochemical identification. A single female was transferred to a bottom-sealed microhematocrit tube with 5 µL of extraction solution (20% sucrose with 1% Triton X-100) and crushed with a pestle. The specimens were stored at –20°C. Electrophoresis was performed according to Aydınlı & Mennan (2016). The polyacrylamide gels were stained for esterase activity with the substrate α-naphthyl acetate in the dark at 37°C for 20-30 min. Protein of females obtained from pure laboratory cultures of *M. javanica* was included in each gel as reference samples.

Results

RKNs was found in the three provinces surveyed (Figure 1). Of the 187 greenhouses, 70 (37%) were infested with RKN. The occurrence of RKN was greater in Sulaymaniyah (40%) than Duhok (38%) and Erbil (34%) Provinces (Table 1).

Eighty-eight greenhouses from 11 districts in Sulaymaniyah Province were surveyed and RKN was detected in eight districts. RKNs were not found in Tasluja, Tainal and Takia districts. The highest number of surveyed greenhouses was located to the Allai district (20 greenhouses) with RKN found in 55% (11 greenhouses), so in combination about one-third of greenhouses were infested with RKNs in this province. The prevalence of RKN in other districts varied from 25 to 50% (Table 1).

In Erbil Province, which ranks second in terms of greenhouse area after Sulaymaniyah in northern Iraq, the survey included 59 greenhouses from 11 districts. *Meloidogyne* was not detected in greenhouses in Choman, Gomaspan, Mamajalka and Grdarasha districts, while 20 to 63% of greenhouses in other districts of Erbil were found to be infested with RKNs (Table 1).

In Duhok Province, 40 greenhouses in eight districts were surveyed. RKNs were not found in Ble and Bardarash districts, but in the other districts the prevalence of RKN varied from 20 to 66.7% (Table 1).

When the perineal patterns of the females in 70 populations multiplied on tomatoes were examined, the morphology of perineal patterns was very similar to those of the original descriptions of *M. incognita* or *M. javanica*. Perineal patterns of females of 45 populations showed a district lateral field apparently separated from striae by parallel lines similar to that of *M. javanica* (Figure 2). Additionally, the patterns of these females were oval-shaped or rounded with a low dorsal arch. When the individual females of these populations were analyzed for their esterase phenotypes, *M. javanica* specific esterase phenotype (J3) was only detected (Figure 3). Perineal patterns of females in the remaining 25 populations had a high and squarish dorsal arch without lateral lines, representing *M. incognita* (Figure 2). The esterase phenotypes I1 and I2 observed in these populations confirmed the occurrence of *M. incognita* (Figure 3). In contrast to the phenotype I2 detected as the most common esterase phenotypes in these populations, phenotype I1 was only found in three populations from Erbil (ER6 and ER13) and Duhok (DU7) Provinces.

Table 1. Distribution and prevalence of root-knot nematodes (*Meloidogyne* spp.) in greenhouse vegetables in northern Iraq

Province	District	Greenhouses surveyed	Prevalence (%)*	Population code	Host plant	GI (0-5)**	Species
Duhok	Qasrok	6	50.0	DU1	Tomato	5	*M. incognita*
				DU2	Cucumber	2	*M. incognita*
				DU3	Cucumber	1	*M. javanica*
	Chammah	3	66.7	DU4	Lettuce	1	*M. javanica*
				DU5	Cucumber	3	*M. incognita*
	Shifazan	7	42.9	DU6	Tomato	5	*M. javanica*
				DU7	Tomato	4	*M. incognita*
				DU8	Cucumber	3	*M. incognita*
	Bjil	5	40.0	DU9	Cucumber	4	*M. javanica*
				DU10	Cucumber	4	*M. javanica*
	Shiladz	5	20.0	DU11	Zucchini	2	*M. incognita*
	Spimar	7	57.1	DU12	Cucumber	2	*M. incognita*
				DU13	Cucumber	1	*M. javanica*
				DU14	Tomato	2	*M. incognita*
				DU15	Tomato	5	*M. incognita*
	Ble	3	0	-	-	-	-
	Bardarash	4	0	-	-	-	-
Erbil	Soran	5	20.0	ER1	Cucumber	1	*M. incognita*
	Harir	3	33.3	ER2	Cucumber	2	*M. javanica*
	Qaryatakh	8	37.5	ER3	Cucumber	1	*M. incognita*
				ER4	Cucumber	5	*M. javanica*
				ER5	Tomato	1	*M. javanica*
	Bnberz	6	50.0	ER6	Tomato	3	*M. incognita*
				ER7	Lettuce	2	*M. incognita*
				ER8	Lettuce	3	*M. javanica*
	Mastawa	8	62.5	ER9	Cucumber	3	*M. javanica*
				ER10	Tomato	3	*M. javanica*
				ER11	Cucumber	5	*M. javanica*
				ER12	Cucumber	2	*M. javanica*
				ER13	Zucchini	3	*M. incognita*
	Qushtapa	7	57.1	ER14	Cucumber	1	*M. javanica*
				ER15	Lettuce	1	*M. javanica*
				ER16	Cucumber	4	*M. javanica*
				ER17	Cucumber	5	*M. incognita*
	Pirdawd	5	60.0	ER18	Cucumber	2	*M. incognita*
				ER19	Cucumber	2	*M. javanica*
				ER20	Cucumber	3	*M. javanica*
	Mamajalka	4	0	-	-	-	-
	Gomaspan	5	0	-	-	-	-
	Grdarasha	4	0	-	-	-	-
	Choman	4	0	-	-	-	-

Table 1. Continued

Province	District	Greenhouses surveyed	Prevalence (%)*	Population code	Host plant	GI (0-5)**	Species
Sulaymaniyah	Allai	20	55.0	SU1	Tomato	3	*M. javanica*
				SU2	Tomato	4	*M. incognita*
				SU3	Cucumber	5	*M. incognita*
				SU4	Cucumber	3	*M. javanica*
				SU5	Cucumber	4	*M. incognita*
				SU6	Zucchini	4	*M. javanica*
				SU7	Cucumber	2	*M. javanica*
				SU8	Cucumber	1	*M. javanica*
				SU9	Cucumber	2	*M. javanica*
				SU10	Cucumber	5	*M. incognita*
				SU11	Cucumber	4	*M. incognita*
	Mahmudia	8	37.5	SU12	Eggplant	2	*M. javanica*
				SU13	Cucumber	3	*M. incognita*
				SU14	Cucumber	4	*M. javanica*
	Qushqaya	10	50.0	SU15	Cucumber	5	*M. javanica*
				SU16	Tomato	4	*M. javanica*
				SU17	Cucumber	1	*M. javanica*
				SU18	Tomato	2	*M. incognita*
				SU19	Cucumber	1	*M. javanica*
	Halai	9	44.4	SU20	Cucumber	3	*M. javanica*
				SU21	Arugula	1	*M. javanica*
				SU22	Eggplant	5	*M. javanica*
				SU23	Cucumber	1	*M. javanica*
	Bazian	10	50.0	SU24	Cucumber	4	*M. javanica*
				SU25	Zucchini	5	*M. javanica*
				SU26	Cauliflower	5	*M. javanica*
				SU27	Cucumber	1	*M. incognita*
				SU28	Tomato	1	*M. javanica*
	Piramagron	9	44.4	SU29	Cucumber	5	*M. javanica*
				SU30	Cucumber	3	*M. javanica*
				SU31	Arugula	1	*M. javanica*
				SU32	Cucumber	5	*M. javanica*
	Dokan	4	25.0	SU33	Cucumber	1	*M. javanica*
	Rania	5	40.0	SU34	Tomato	5	*M. incognita*
				SU35	Tomato	3	*M. javanica*
	Tasluja	5	0	-	-	-	-
	Tainal	4	0	-	-	-	-
	Takia	4	0	-	-	-	-

* Number of greenhouses with *Meloidogyne* spp. divided by total number of greenhouses surveyed × 100. **Gall index: 0, no galling; 1, trace infestation with some minor galls; 2, <25% galled roots; 3, 25-50% of galled roots; 4, 51-75%; and 5, >75% of galled roots (Hussey & Janssen, 2002).

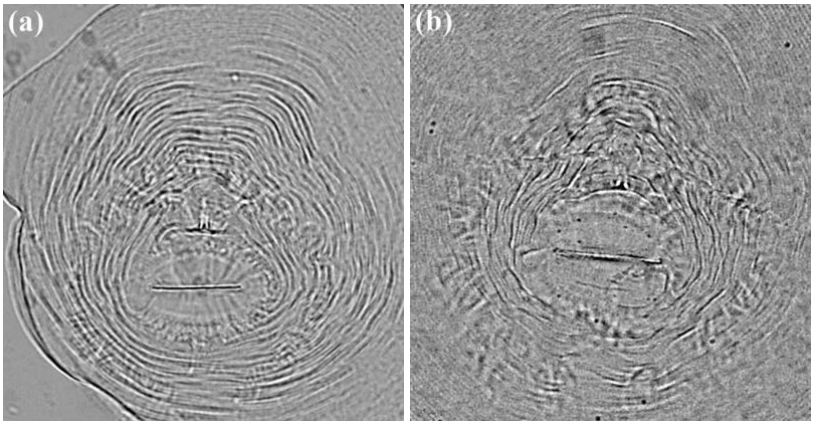

Figure 2. Perineal patterns of *Meloidogyne incognita* (a) and *Meloidogyne javanica* (b) from greenhouses in northern Iraq.

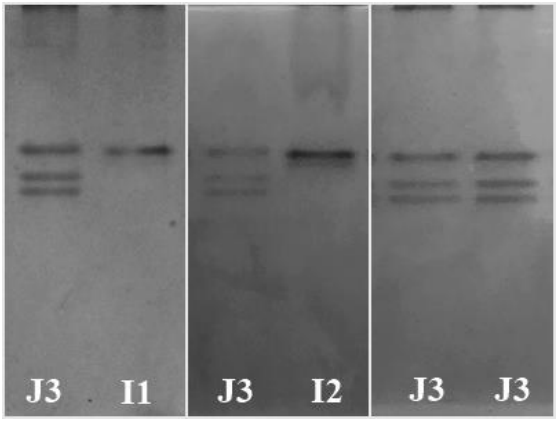

Figure 3. Esterase phenotypes of *Meloidogyne incognita* (I1 and I2) and *Meloidogyne javanica* (J3) from greenhouses in northern Iraq.

Based on the identification results obtained perineal pattern and esterase phenotypes of females, *M. javanica* and *M. incognita* were detected in 64 and 36% of the greenhouses infested with RKN, respectively. Considering the distribution of RKN species, both RKN species were found in the three provinces surveyed in northern Iraq (Table 1). In Duhok, *M. incognita* and *M. javanica* were detected in 23 and 15% of surveyed greenhouses, respectively. Both species occurred in all districts infested with RKN of this province, except in Bjil and Shiladz (Figure 1). In Erbil, *M. javanica* was the most common RKN species detected in 22% of the surveyed greenhouses, but *M. incognita* was found in 12% of the greenhouses. Both species were found in most districts infested with RKN in Erbil, except in Soran and Harir districts. In Sulaymaniyah, *M. javanica* was found in 30% of greenhouses surveyed and in all districts with RKNs. *Meloidogyne incognita* was found in 10% of surveyed greenhouses and was not detected in Halai, Piramagron and Dokan districts, where *M. javanica* occurred.

Eight vegetable species including cucumber (72 greenhouses), tomato (45 greenhouses), lettuce (20 greenhouses), zucchini (19 greenhouses), arugula (10 greenhouses), eggplant (8 greenhouses), cauliflower (7 greenhouses), broccoli (6 greenhouses) were sampled in the greenhouses surveyed and RKNs were found in all these vegetable species, except broccoli. The highest prevalence of RKNs was in cucumber (58%), which was cultivated in 39% of the greenhouses surveyed. The prevalence of *M. javanica* and *M. incognita* in cucumber were 39 and 19%, respectively. The prevalence in tomato was the second highest at 33%, of which 18 and 16% were *M. incognita* and *M. javanica*, respectively. RKN prevalence was 25% in eggplant, 20% in arugula and 14% in cauliflower with only *M. javanica* found in these species. *Meloidogyne javanica* and *M. incognita* were found in 15 and 5% on lettuces surveyed respectively, and both at 11% in zucchini.

Discussion

This study constitutes a comprehensive survey of RKN on vegetables in greenhouses in northern Iraq. Except for the study of Ami et al. (2018), the previous RKN surveys of vegetables in Iraq were conducted in open fields (Al-Saaedy & Stephan, 1986; Al-Sabie & Ami, 1990; Al-Kubaicy & Al-Sabe'a, 2014; Kandouh et al., 2018). Ami et al. (2018) reported the occurrence of *M. javanica* in cucumber in 16 greenhouses from four locations in Semel district of Duhok Province. RKN survey in open fields in various locations in northern Iraq found *M. javanica* and *M. incognita* in tomato in Duhok, *M. javanica* in eggplant in Erbil (Al-Sabie & Ami, 1990). In our study, *M. incognita* occurred more frequently than *M. javanica* in the greenhouses surveyed in Duhok Province than in Erbil and Sulaymaniyah. *Meloidogyne javanica* was the most common species found (24%) across all greenhouses surveyed, but *M. incognita* was found in 13% of greenhouses surveyed. Our results confirm earlier reports on the occurrence of RKN in several parts of Iraq (Al-Saaedy & Stephan, 1986; Al-Sabie & Ami, 1990; Al-Kubaicy & Al-Sabe'a, 2014; Kandouh et al., 2018). *Meloidogyne javanica*, which was detected in 80% of the eggplant fields surveyed in 17 provinces in Iraq, was the most abundant species, followed by *M. incognita* (Al-Saaedy & Stephan, 1986). Al-Kubaicy & Al-Sabe'a (2014) reported similar results on the occurrence and prevalence of both species in eggplant fields in Nineveh Province in northern Iraq. In these surveys of eggplant fields, *M. arenaria* was detected only in a few locations (Al-Saaedy & Stephan, 1986) or mixed with *M. javanica* (Al-Kubaicy & Al-Sabe'a, 2014). A similar pattern for these two species was also observed in okra fields of Najaf Province in southern Iraq, with 69% *M. javanica* and 31% *M. incognita* (Kandouh et al., 2018).

Globally, *M. arenaria, M. incognita* and *M. javanica*, with particularly wide host ranges, are the most prevalent RKN species. These species are mainly found in tropical and subtropical regions as well as in glasshouses in temperate regions (Zijlstra et al., 2000). According to the International *Meloidogyne* Project, which provides an overview of the global distribution of RKN species, *M. incognita* and *M. javanica* are more prevalent species than *M. arenaria* despite possessing similar temperature requirements (Van Gundy, 1985). Earlier reports, which indicate a rare occurrence of *M. arenaria* in Iraq, are in agreement with this global trend, and this species was only found in crops in open field (Katcho, 1972; Al-Saaedy & Stephan, 1986; Al-Sabie & Ami, 1990; Al-Kubaicy & Al-Sabe'a, 2014), so this is consistent with *M. arenaria* not being detected in the present study.

In the present study, RKNs were found in seven economically-important vegetable species (cucumber, tomato, lettuce, zucchini, arugula, eggplant and cauliflower), with prevalence was particularly high in cucumber and tomato, the most commonly grown vegetables in the study area. These results indicate that RKNs are a potential threat to greenhouse vegetable production in Iraq, and suitable control techniques should be developed and applied. Accordingly, accurate identification of RKNs is required to determine the most appropriate control methods (Coyne et al., 2009). In the past, perineal patterns have been frequently used for the identification of RKN in Iraq (Katcho, 1972; Al-Saaedy & Stephan, 1986; Al-Sabie & Ami, 1990; Al-Kubaicy & Al-Sabe'a, 2014; Ali et al., 2014; Ami et al., 2018; Kandouh et al., 2018; Aljuboori & Al-Hakeem, 2020). Although the identification of *Meloidogyne* spp. has relied on this morphology for many years, the value of this has decreased with the increasing number of RKN species described (Hunt & Handoo, 2009). Also, species-level identification is difficult due to variation in perineal patterns within and between populations (Garcia & Sanchez-Puerta, 2012). In our study, the perineal patterns of *M. javanica* had clear lateral lines separating the pattern into ventral and dorsal areas, this characteristic allowed for confident species determinations (Janati et al., 2018). The remaining populations had the typical perineal pattern of *M. incognita*. However, this does not provide reliable species-level identification because *incognita*-type perineal patterns have been observed in a considerable number of species, with some of them consequently being misidentified as *M. incognita* (Hunt & Handoo, 2009). The isozyme analyses, especially esterase phenotypes, have been widely used over many years as a reliable diagnostic technique for distinguishing RKN species from diverse geographical areas worldwide (Dickson et al., 1970; Esbenshade

& Triantaphyllou, 1985; Pais & Abrantes, 1989; Carneiro et al., 2000; Cofcewicz et al., 2004; Brito et al., 2008; Kolombia et al., 2017). In the present study, esterase enzyme phenotypes of females were also used for the diagnosis of *Meloidogyne* spp. Combining perineal pattern morphology and esterase phenotypes allowed for more reliable identification. Three esterase phenotypes, J3, I1 and I2, were obtained. The phenotype J3 is species-specific for *M. javanica*, and I1 and I2 for *M. incognita*. These phenotypes have consistently been associated with populations of these species from other parts of the world (Esbenshade & Triantaphyllou, 1985; Pais & Abrantes, 1989; Carneiro et al., 2001; Brito et al., 2008; Aydınlı & Mennan, 2016; Kolombia et al., 2017). To our knowledge, this exploration is the first study on esterase phenotypes of *Meloidogyne* populations from Iraq.

The occurrence of *M. javanica* and *M. incognita* has been commonly reported in studies conducted in open vegetable fields in Iraq (Al-Saaedy & Stephan, 1986; Al-Sabie & Ami, 1990; Al-Kubaicy & Al-Sabe'a, 2014; Kandouh et al., 2018). The prevalence of both RKN species in greenhouse vegetable production in northern Iraq confirms that these species are currently the dominant species of RKN in Iraq. This study provides evidence that these species are a significant threat in Iraq, with the potential considerable losses in both quality and quantity of vegetables. Consequently, further studies should focus on management approaches that will be needed to reduce this threat and the potential damage.

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