Journal of Horticultural Research 2016, vol. 24(1): 73-78
DOI: 10.1515/johr-2016-0009

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ROOT-KNOT NEMATODE (*MELOIDOGYNE JAVANICA*) – DEFICIT IRRIGATION INTERACTIONS ON EGGPLANT CROPPED UNDER OPEN FIELD CONDITIONS

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Received: March 2016; Accepted: June 2016

Abstract

To investigate the influence of deficit irrigation on the root-knot nematode, *Meloidogyne javanica*, and its interaction with the eggplant crop, field experiments were conducted at two drip-irrigated agricultural areas in Jordan. Effects of limiting irrigation levels to 80, 60, 40 and 20% of the field capacity (FC) were compared with full irrigation (100%) treatment. Growth of eggplant plants was greatly reduced at irrigation levels of 40 and 20% FC at one field location, suggesting that the influence of deficit irrigation is field-dependant. Fruit yield was similar at all irrigation levels, except at 20% level, where a lower yield was noticed compared to 100% irrigation. Root galling of eggplant caused by the nematode was significantly lower at irrigation levels of 20 and 40% than 80 and 100% of FC, but was field-dependant at 60% of FC. The final nematode population was obviously lower at irrigation levels of 20, 40 and 60% than 80 and 100%. Thus, deficit irrigation to levels of 40 or 60% of FC can be utilised for the management of *M. javanica* infection in eggplant under field conditions.

Key words: eggplant roots, population *M. javanica*, water deficit

INTRODUCTION

Plant-parasitic nematodes are important plant pests (Sasser & Freckman 1987). They develop on the extensive root systems of both annual and perennial crops, damage the root system severely and cause economic losses of more than 12% annually worldwide (Sasser 1987); about 5% of the crop losses are caused by a widely distributed group of plant-parasitic nematodes that are usually known as the root-knot nematodes (Sasser et al. 1983; Sasser & Freckman 1987; Siddiqui et al. 2003). Plants infected by root-knot nematodes show stunted growth accompanied by symptoms of severe deficiency of some nutritional elements, substantially reduced nutrient and water uptake, and yield amount and quality (Khyami-Horani & Al-Banna 2006; Strajnar et al. 2012).

Soil moisture is an important factor affecting nematode development and infection (Wallace 1963; Duncan et al. 1998; Hunter 2000). Increasing water stress decreases the water potential from −1 to −10 bars around the root-knot nematode, *Meloidogyne javanica* (Treub 1885; Chitwood 1949), which reduces the percentage of eggs hatching and increases the percentage of second-stage juvenile mortality (Mohwesh & Karajeh 2013). Therefore, water stress ensures that nematodes remain confined to the irrigated and highly rained agricultural areas worldwide (Sasser et al. 1983), such as the irrigated agricultural regions of Jordan (Abu-Gharbieh et al. 2005; Karajeh & Al-Ameiri 2010). For coping with water shortage and scarce supplies, deficit irrigation, defined as application of water below the full requirement of the crop, is an important tool that achieves the goal of reducing the amount

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of water required for irrigation (Fereres & Soriano 2007). Deficit irrigation has been widely investigated as a valuable and sustainable production strategy in dry regions (Geerts & Raes 2009). Although deficit irrigation has been effectively used in fruit tree orchards (Zegbe et al. 2004; Shin 2005; Kriedemann & Goodwin 2009; Mahadeen et al. 2011), there is potential for improving water productivity in many field crops, and there is sufficient information available for devising the best deficit irrigation strategy in many situations (Fereres & Soriano 2007). Also, deficit irrigation could have the ability to control soil moisture-sensitive plant pests and diseases (Shin 2005; Mohwesh & Karajeh 2013). Deficit irrigation used at a rate of 80 and 60% of full irrigation had controlled the root-knot nematode, *M. javanica*, in tomato and eggplant (*Solanum melongena* L.) under controlled environmental conditions (Mohwesh & Karajeh 2013). Thus, deficit irrigation can be utilised to control some plant pests and diseases, especially those that are affected by irrigation regimes and are moisture-dependant, as an extra benefit (Shin 2005).

Therefore, the main objectives of this study are to compare the effects of deficit irrigation regimes [20, 40, 60 and 80% of field capacity (FC)] with those of full irrigation (100% of FC) on some parameters of eggplant growth and population of *M. javanica* under open field conditions.

MATERIALS AND METHODS

Two field experiments were conducted in two different drip-irrigated agricultural areas: Ghor es-Safi region (receives about 80 mm of annual rainfall and has silty loam soil; situated 418 m below sea level) of southern Ghors; and Karak Valley region (receives about 200 mm of annual rainfall and has clay loam soil; situated about 200 m above sea level) of semi-Ghor area in Karak province of Jordan. Field experiments were conducted during the eggplant growing seasons, from mid-September 2012 to mid-March 2013 in Ghor es-Safi, and from mid-February to mid-July 2013 in Karak Valley. Average minimum and maximum regional air temperatures at Ghor es-Safi and Karak Valley during the course of the experiments ranged between 12 and 32 °C and 10 and 28 °C, respectively. Two field populations of root-knot nematodes were identified as *M. javanica* by observing the perineal pattern of females and measuring the length of second-stage juveniles (Barker et al. 1985), and confirmed by *Meloidogyne* species-specific sequence characterised amplified region-polymerase chain reaction-based test (Karajeh 2004).

Eggplant cv. ‘Classic’, a susceptible cultivar to *M. javanica*, was selected for cropping in both field experiments. Three-week-old seedlings (averaging 7 cm in height) were transplanted 80 cm apart into black plastic mulch-covered rows, with inter-row spacing of 150 cm. When the plants were 4 weeks old, the following treatments were applied in a randomised complete block design. Each treatment involved 25 plants per plot (row), replicated three times (three blocks). Irrigation was done using the drip irrigation system when 50% of total water available for full irrigation (100%) was depleted (readily available water = 50% of available water). The irrigation regimes gave irrigation 80, 60, 40 and 20% of FC to the amount of treatment based on the full irrigation treatment.

At the end of the experiment (after 15 weeks from the date of transplanting), all the plants (about 25 plants per plot) were dug out from the fields. Dry weights of shoots and roots (after air-drying of the samples on an electrical oven at 70 °C for 5 days), and fruit yield were assessed. Root galling index was evaluated on a scale of 0-5 as follows: 0 no galling; 1. 1-2 galls; 2. 3-10 galls; 3. 11-30 galls; 4. 31-100 galls; and 5. over 100 galls (Taylor & Sasser 1978). Representative rhizospheric soils [five random samples (500 g per sample) per plot] were collected from each treatment for nematode extraction using Baermann’s method (Whitehead & Hemming 1965; Hussey & Barker 1973) to estimate the final nematode population (Pf) density rather than determining the reproductive factor of the nematode, since the initial nematode population was very small to be detected despite extensive sampling at the beginning of the experiment.

Data were analysed statistically using the general linear model procedure (SPSS 11.5 software; SPSS Inc., Chicago, IL, USA). Duncan's multiple range test was used for separation of means at a probability level of 0.05. Significance of main factors and interactions were tested at a probability level of 0.05.

RESULTS

There was reduction in shoot and root dry weights when irrigation levels of 20 and 40% were used, but irrigation at 60 and 80% levels did not significantly change ($p \leq 0.05$) the shoot and root dry weights when compared with the full (100%) irrigation level in the field conditions of Ghor es-Safi (Table 1). However, no significant differences were found in shoot and root dry weights between the different irrigation levels in the field conditions of Karak Valley. Eggplant fruit yield was obviously similar for all irrigation levels, except the 20% level, where yield lower than that of 100% level was noticed (Table 1).

Root galling index of eggplant was significantly ($p \leq 0.05$) lower for plants irrigated at 20, 40 and 60% levels than plants irrigated at 80 and 100% levels in the field conditions of Ghor es-Safi, but plants irrigated at 60% levels did not differ in their root galling index from those irrigated at 80 and 100% levels (Fig. 1A). The final nematode population at the end of the eggplant growing season was lower in the rhizospheric soil taken from fields irrigated at 20, 40 and 60% levels than fields irrigated at 80 and 100% of FC under the two field conditions (Fig. 1B).

Table 1. Shoot and root dry weight and fruit yield of eggplant cropped under two field conditions (Field 1 – Ghor es-Safi region, Field 2 – Karak Valley of Jordan)

Irrigation regimes	Shoot dry weight (g/plant)		Root dry weight (g/plant)		Fruit Yield (kg/plant)	
	Field 1	Field 2	Field 1	Field 2	Field 1	Field 2
20%	111.8[2] b[3]	22.9 a	50.1 b	38.1 a	0.80 b	0.30 b
40%	142.9 b	21.1 a	62.3 b	31.6 a	0.96 ab	0.39 ab
60%	166.1 a	20.4 a	70.1 ab	30.2 a	1.00 ab	0.48 ab
80%	157.3 a	25.5 a	75.7 a	23.5 a	1.04 ab	0.65 ab
100%	162.3 a	29.7 a	67.1 ab	36.4 a	1.11 a	0.88 a

The means within columns followed by the same letters are not significantly different at 0.05 probability level using DMRT test.

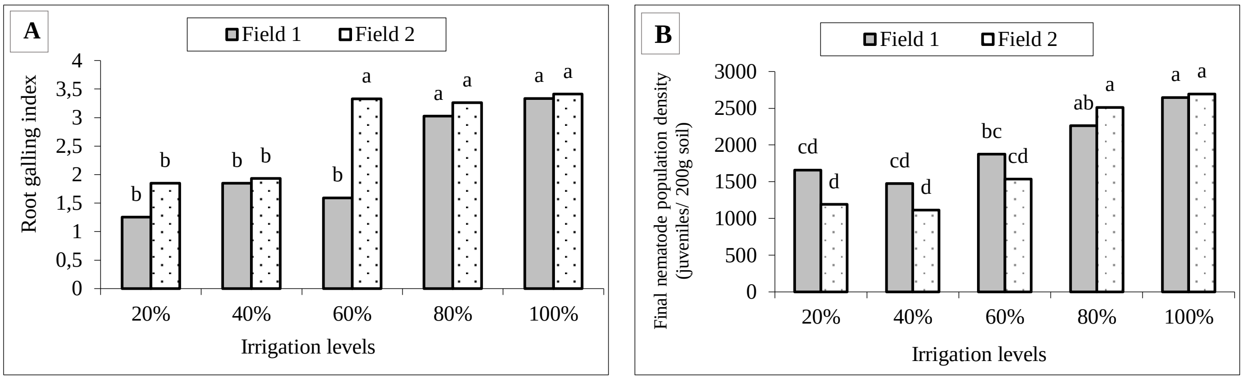

Fig. 1. Effects of different irrigation levels (20, 40, 60, 80 and 100% of field capacity) on root galling (A) and final population density of *Meloidogyne javanica* in eggplant cultivation. Field 1 – Ghor es-Safi region, Field 2 – Karak Valley of Jordan. The means with the same letters on bars are not significantly different at 0.05 probability level using DMRT test

Table 2. Main and interaction effects (probability values) of *Meloidogyne javanica* – infested fields (Ghor es-Safi or Karak Valley), and irrigation levels (20, 40, 60, 80 and 100% of field capacity) on plant and nematode measured parameters

Source	Shoot dry weight	Root dry weight	Fruit yield	Root galling index	Final nematode number
Field	0.023* 301488.0 1	0.000*** 43565.3 1	0.000*** 67527.1 1	0.802ns 11145.8 1	0.343ns 34672.0 1
Irrigation	0.001** 40547.0 4	0.403ns 78584.1 4	0.000*** 78521.1 4	0.000*** 33386.0 4	0.046* 10286.7 4
Field X irrigation	0.363ns 678.8 4	0.089ns 5687.0 4	0.108ns 1112.6 4	0.243ns 3465.9 4	0.875ns 3339.4 4
Blocks	0.002** 87601.8 2	0.035* 47821.5 2	0.045* 58326.4 2	0.011* 33364.0 2	0.048* 87526.0 2

Means, mean squares and degrees of freedom are shown per each cell.
*, ** and *** are significant at 0.05, 0.01 and 0.001 probability levels.

Field as a main factor significantly ($p \leq 0.05$) affected shoot and root dry weights, and fruit yield of eggplant due to differences in soil properties and climatic conditions between the two fields studied, but did not affect root galling caused by the nematode or the final nematode population at the end of the eggplant growing season. However, irrigation as a main factor affected all the plant and nematode parameters, yet the interaction between the type of field and irrigation level was not significant (Table 2).

DISCUSSION

Today, irrigation/farm water delivery systems are the single largest consumer of water on the planet, but competition for water from other sectors will force agricultural production to use irrigation methods suited to operate under conditions of water scarcity, thus leading to adoption of deficit irrigation technique. By reducing water used for irrigation, farmers can cope with situations where water supply is restricted (Sharp et al. 1996; Fereres & Soriano 2007). Greater reduction in plant growth occurred at deficit irrigation levels of 40 and 20% of FC than at 60 and 80%, where root growth of eggplant was not greatly reduced under controlled environmental conditions (Mohawesh & Karajeh 2014). Under open field conditions, growth of eggplant plants was greatly affected at irrigation levels of 40 and 20% of FC in one field location, but not at the other field location, which indicates that the influence of deficit irrigation is field-dependant, as there are some differences in soil properties and climatic conditions even when using the same irrigation level. Eggplant fruit yield was similar at all irrigation levels, except at 20% level, where a lower yield was noticed than the 100% level. By affecting plant growth, development, and carbon assimilation, water deficit may reduce the yield (Hsiao 1973). The reduction in yield at irrigation level of 20% of FC is caused by a decrease in biomass production (Kirnak et al. 2001). Furthermore, water productivity, which is the yield or net income per unit of water used in evapotranspiration (Kijne et al. 2003), is expected to increase under deficit irrigation relative to its value under full irrigation, as revealed experimentally for many crops (Tüzel et al. 1994a, b; Zwart & Bastiaanssen 2004; Fan et al. 2005; Fereres & Soriano 2007).

Water is a potential factor that affects the growth, development, and survival of nematodes (Prot 1979; Towson & Apt 1983). In the present study, irrigation as the main factor affected nematode parameters, including eggplant infection in terms of root galling caused by the root-knot nematode *M. javanica*, and its reproduction. Root galling index of eggplant was much lower for plants irrigated at 20, 40 and 60% levels than those at 80 and 100% levels under one field condition, but plants irrigated at 60% level did not differ in the extent of root infection from plants irrigated at 80 and 100% levels in the other field conditions. Field as the main factor did not affect root galling caused by the nematode or the final nematode population at the end of the eggplant growing season. The final population of *M. javanica* was obviously lower in the rhizospheric soil of fields irrigated at 20, 40 and 60% levels than that of fields irrigated at 80 and 100% levels under the two field conditions. Thus, deficit irrigation levels of 40 and 60% of FC can be used for the management of *M. javanica* without any negative impact on eggplant growth and yield under field conditions.

Acknowledgement

This work is a part of the research project financially supported by the Scientific Research Support Fund of the Ministry of Higher Education and Scientific Research of Jordan.

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