RESPONSE OF WHEAT, BARLEY AND OAT CULTIVARS AND ACCESSIONS TO *MELOIDOGYNE JAVANICA*

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Summary. A screening was undertaken to assess the reaction of three gramineous crops to *Meloidogyne javanica*. Fourteen cultivars of barley, seven cultivars of durum wheat and four accessions of oat recently introduced in Jordan, were evaluated by inoculating the test pots with 1000 second stage juveniles (J_2) of the nematode or filling them with field soil containing 520 eggs and J_2/250 g. Inoculation of J_2 showed that two cultivars of barley (Morocco 9-75 and WI2291), one of wheat (Cham 5) and three accessions of oat (O22, O23, O24) appeared to be immune to the nematode, while the other tested cultivars were ranked resistant to *M. javanica* infection. Using field soil, all of the tested cultivars and accessions were ranked resistant except two cultivars of barley (Rum and Acsad 176) that were susceptible, and one of wheat (Khayar Tunis) that was tolerant.

Keywords: Cereals, host reaction, root-knot nematodes.

The genus *Meloidogyne* comprises widely distributed species of plant-parasitic nematodes commonly known as root-knot nematodes (RKNs). These nematodes attack a wide range of crop plant species, including field and vegetable crops and fruit trees. In Jordan, Abu-Gharbieh (1994) estimated an average annual yield loss of irrigated vegetable crops in the Jordan Valley due to root-knot nematodes of about 15%.

In a survey (Karajeh, 2004) of most of the irrigated agricultural areas of Jordan, three species of *Meloidogyne* [*M. javanica* (Treub) Chitw., *M. incognita* (Kofoid *et* White) Chitw. races 1 and 2, and *M. arenaria* (Neal) Chitw. race 2], with predominance of the Javanese root-knot nematode *M. javanica*, were reported.

Since there is an escalating reliance on environmentally friendly means for the management of plant diseases, non-chemical strategies of control are likely to involve genotypic interactions between the nematode and its host (Hayman and Wipple, 1996). Plant resistance is currently the most effective and environmentally safe method to control root-knot nematodes (Faske and Starr, 2009).

Cereal crops can be used in a crop rotation programme for controlling the root-knot nematodes. Therefore, comprehensive information is needed on the response of the various field crops to the nematodes, especially the predominant species (*M. javanica*). Therefore, the objective of this study was to evaluate the response (degree of resistance or susceptibility) to *M. javanica* of cultivars of barley (*Hordeum vulgare* L.) and durum wheat (*Triticum durum* Desf.) and accessions of common oat (*Avena sativa* L.) recently introduced in Jordan, using artificial inoculation or naturally infested field soil.

The material evaluated was of different origin (Table I) and was composed of fourteen cultivars and accessions of barley, seven cultivars of durum wheat, and four common oat accessions.

The nematode population used for the artificial inoculation had been previously collected from an eggplant field at Ein-Sarah site, in Karak province of Jordan, and raised as a pure culture in the laboratory. The pure isolate was identified by means of nematode morphology, host preference using the North Carolina differential host test (Hartman and Sasser, 1985) and SCAR-PCR tests. The identity of the root-knot nematodes from the infested field soil was confirmed by morphological observation and SCAR-PCR test (Karajeh, 2004).

For the artificial inoculation experiment, three seeds of each cultivar or accession were sown in each of the 10 cm-diameter plastic pots filled with 250 cm^3 of a sterile mixture of peat and perlite (1:1, v/v). The cucumber cultivar Hayel, previously rated as highly susceptible to the nematode, was used as a positive control. The pots were transferred to a controlled growth room (25 ± 3 °C air temperature and 16 h daylight). There were five replicates of each cultivar and accession. Nematode eggs were obtained from infected tomato (cultivar GS12) plants maintained in a growth room. The tomato roots were immersed in a 0.5% NaOCl solution and macerated in a food blender for 30 seconds. The suspension of macerated roots was sieved through a 74 µm sieve, to remove root debris, and the dispersed eggs were collected on a 25 µm sieve (Hussey and Barker, 1973). Infective second stage juveniles were obtained by immersing the eggs in water and 72-hour-old juveniles were used as inoculum. One week after seed germination, each pot was inoculated with 1000 second-stage juveniles by pouring 10 ml of a suspension containing

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Table I. Species, cultivar or accession and origin of the cereals used in this study.

Plant species	Cultivar or accession	Source
Barley (*Hordeum vulgare* L.)	Rum	NCARE*, Jordan
	Acsad 176	NCARE, Jordan
	Athroh	NCARE, Jordan
	Yarmouk	NCARE, Jordan
	Muta'a	NCARE, Jordan
	Tadmor	ICARDA**, Syria
	Arta	ICARDA, Syria
	Morocco 9-75	ICARDA, Syria
	WI2291	ICARDA, Syria
	Zanbaka	ICARDA, Syria
	Harmel	ICARDA, Syria
	Furat2	ICARDA, Syria
	ER/Apm	ICARDA, Syria
	Landrace	Local farmers, Jordan
Wheat (*Triticum durum* Desf.)	Om Qais	NCARE, Jordan
	Khayar Tunis	NCARE, Jordan
	Hourani Nawawi	NCARE, Jordan
	Deir Alla 6	NCARE, Jordan
	Cham1	NCARE, Jordan
	Cham 3	NCARE, Jordan
	Cham 5	NCARE, Jordan
Oat (*Avena sativa* L.)	FL 49198-D22-E3 (O22)	Canada
	FL 93418-G1-A2B1-C5 (O23)	Canada
	FL 99084-D4 (O24)	Canada
	FL 99162-E1 (O25)	Canada

*NCARE = National Center of Agricultural Research and Extension,.
** ICARDA = International Center for Agricultural Research in the Dry Areas, Aleppo, Syria.

100 juveniles/ml into two holes made in the soil surface. All pots were arranged according to a completely randomized design (CRD). The experiment was discontinued five weeks after inoculation.

In the second experiment, soil infested with *M. javanica* was collected from the same field at the end of the eggplant growing season in December 2009. The soil was mixed thoroughly in the laboratory and distributed into 0.5 dm^3 plastic pots. The population density of the root-knot nematode was 510 second-stage juveniles/250 g soil as determined by extracting the nematodes with a modified Baermann tray method (Schindler, 1961). The pots were then sown with three seeds of each cultivar/accession. The pots were transferred to a controlled growth room (25 ± 3 °C air temperature and 16 h daylight). All pots were arranged according to a CRD. The experiment lasted five weeks from the date of sowing.

At the end of each experiment, plants were removed from the pots and their roots were gently washed. Each root was indexed for root galling (GI) depending on the number of visible galls on the entire root system according to Abu-Gharbieh *et al.* (1978), where 0 = no gall; 1 = 1-9 galls/plant; 2 = 10-19 galls/plant; 3 = 20-29 galls/plant; 4 = 30-39 galls/plant; and 5 = more than 40 galls/plant. The eggs were extracted from the roots by blending in a 0.5% NaOCl solution for 30 seconds and counted under a compound microscope at a 10× magnification. The reproduction factor (RF) was then arbitrarily calculated as the number of eggs on the roots per pot (Pf) divided by the initial second stage juvenile inoculum (Pi). For each cultivar-nematode combination in which GI = 0 and RF = 0, the reaction was considered immune, GI ≤2 and RF ≤1 resistant, GI ≤2 and RF >1 tolerant, GI >2 and RF ≤1 hyper-susceptible and GI >2 and RF >1 susceptible (Khan and Khan, 1991).

Data were analyzed using the GLM procedure of SAS for Windows System Version 6.12 (SAS Institute, Cary, NC, USA). The values of GI and RF were compared by Tukey's test at the 5% probability level.

In the artificial inoculation experiment, among the cultivars of barley, Morocco 9-75 and WI2291 were rated immune, with RF = 0 and no galls on the roots (GI = 0). The other barley cultivars were scored as resistant to *M. javanica*, with GI of 0.2-1.5 and RF of 0.1-0.7 (Table II). The GI and RF values were significantly (P = 0.05) higher for Rum and Acsad 176 than for the other cultivars. All durum wheat cultivars were resistant, having low GI (0-1.8) and low RF (0-0.8) except for Cham 5, which appeared immune to *M. javanica* infection. Of the oat accessions, all were immune to the root-knot nematode infection except O25, which was resistant with significant differences from other oat accessions in both GI and RF. Cucumber (cultivar Hayel), the standard host, was susceptible to the nematode as shown by its maximum value of GI (5.0) and

Table II. Reaction responses of some cultivars of barley and wheat and accessions of oat to the root-knot nematode, *Meloidogyne javanica*, compared with that of the susceptible cucumber cultivar Hayel.

Plant cultivar or accession	Artificial inoculation experiment			Infested soil experiment		
	Galling index (0-5) [a]	Reproduction factor [b]	Reaction degree [c]	Galling index (0-5)	Reproduction factor	Reaction degree
Barley (*Hordeum vulgare* L.)						
Rum	1.5 [d] h[e]	0.6 ef	R	2.8 i	1.5 g	S
Acsad 176	1.2 g	0.7 fg	R	2.4 h	1.2 f	S
Athroh	0.8 ef	0.2 bc	R	1.4 fg	0.3 bcd	R
Yarmouk	0.3 bc	0.3 c	R	1.6 g	0.6 d	R
Muta'a	0.2 ab	0.2 bc	R	0.6 bc	0.1 a	R
Tadmor	0.5 cd	0.1 ab	R	0.8 cd	0.3 bc	R
Arta	1.0 fg	0.2 bc	R	0.4 ab	0.3 bc	R
Morocco 9-75	0 a	0 a	I	0.4 ab	0.1 a	R
WI2291	0 a	0 a	I	0.8 cd	0.2 ab	R
Zanabaka	0.2 a	0.2 bc	R	0.6 bc	0.3 bc	R
Harmel	1.0 f	0.3 c	R	1.0 de	0.6 d	R
Furat 2	0.5 cd	0.2 bc	R	0.4 ab	0.3 bc	R
ER/Apm	0.7 de	0.3 c	R	1.2 ef	0.9 e	R
Landrace	1.0 f	0.5 de	R	1.2 ef	0.6 d	R
Wheat (*Triticum durum* Desf.)						
Om Qais	0.7 de	0.2 bc	R	1.0 de	0.5 cd	R
Khayar Tunis	1.8 i	0.8 g	R	2.0 a	1.1 ef	T
Hourani Nawawi	0.2 a	0 a	R	0.6 bc	0.2 ab	R
Cham1	0.5 c	0.2 bc	R	1.2 ef	0.9 e	R
Cham 3	0.7 de	0.3 c	R	1.0 de	0.6 d	R
Cham 5	0 a	0 a	I	0.8 cd	0.3 bc	R
Deir Alla 6	0.2 a	0 a	R	0.8 cd	0.6 d	R
Oat (*Avena sativa* L.)						
O22	0 a	0 a	I	0.4 ab	0 a	R
O23	0 a	0 a	I	0.2 a	0 a	R
O24	0 a	0 a	I	0.2 a	0 a	R
O25	0.5 cd	0.2 bc	R	0.8 cd	0.3 bc	R
Cucumber (*Cucumis sativus* L.)						
Hayel	5.0 j	5.7 h	S	5.0 j	6.4 h	S

[a] Root galling index (GI): 0 = no galling; 1= 1-9 galls/ plant; 2 = 10-19 galls/ plant; 3 = 20-29 galls/ plant; 4 = 30-39 galls/ plant; and 5 = more than 40 galls/ plant.
[b] Reproduction factor (RF) = final nematode population density/ initial population density.
[c] Reaction degree: I; immune; R: resistant, T: tolerant; and S: susceptible.
[d] Average of five pots (3 plants/pot)/ treatment.
[e] Means followed by the same letter within columns are not significantly different according to Tukey's test at 5% probability.

nematode reproduction (RF) greater than 5 (Table II).

In the infested soil experiment, the tested cultivars of barley were resistant (but with significant differences in GI and RF) except for Rum and Acsad 176, which were found susceptible to the root-knot nematode, having a GI more than 2 and a RF more than 1, both significantly larger than those of the other cultivars (Table II). All cultivars of wheat were resistant (RF 0.2-0.9; GI 0.6-1.2) except for Khayar Tunis, which was tolerant to the root-knot nematode. All accessions of oat were also resistant to the nematode, but GI and RF values for accession O25 were significantly larger than those for the other accessions. Cucumber (cv. Hayel) confirmed its susceptibility to the nematode as shown by its maximum GI (5) value and the largest RF value of 6.4 (Table II).

Plant resistance to root-knot nematodes has been widely investigated (Hartman and Sasser, 1985; Karajeh *et al*., 2005; Abu-Gharbieh and Karajeh, 2006). These studies showed that the cultivars of various crops show different levels of resistance/susceptibility to *M. javanica*.

Our study reports information on the reactions of three gramineous crops (barley, wheat and oat) cultivars and accessions to *M. javanica* under artificial nematode inoculation and infested soil conditions. Generally, these cereals were ranked from resistant to immune to *M. javanica*, thus agreeing with earlier findings that indicated that barley, wheat and oat are poor hosts or non-host for *M. javanica* (Roberts *et al*., 1981; Kaloshian *et al*., 1989; Ibrahim *et al*., 1991).

Both galling index and reproduction factor of the nematode were greater in infested field soil than under artificial inoculation conditions, e.g. barley cultivars Morocco 9-75 and WI2291 were immune to *M. javanica* under artificial inoculation conditions but resistant under infested field soil conditions, possibly due to the larger initial nematode population in the infested field soil.

Crop rotation with non-host or poor host crop plant species could be used to reduce populations of root-knot nematodes (Johnson, 1985). Rotation with either of the two susceptible barley cultivars (Rum and Acsad 176) would lead to a build-up rather than to a decrease in the nematode population in the infested soil, while rotation with the other tested cultivars (WI2291, Morocco 9-75, Athroh, Yarmouk, Muta'a, Tadmor, Arta, Zanabaka, Harmel, Furat 2 and ER/Apm) would decrease the nematode population.

Meloidogyne javanica infected cultivars of durum wheat and produced egg masses on their roots, especially in pots containing soil from the infested field. A previous study (Roberts *et al*., 1981) had shown that *M. incognita* can infect and reproduce on bread wheat under field conditions in southern California, where the nematode developed one generation during the winter growing season. Most of the wheat cultivars tested by us were resistant or moderately resistant under artificial inoculation conditions and moderately resistant under infested field soil conditions. Therefore, they can be included in a crop rotation programme. In a sweet corn-soybean-wheat-soybean-spinach cropping system, the wheat cultivar Oasis did not result in a considerable increase in the population density of *M. incognita* or *M. hapla* Chitw. (Johnson, 1985).

The oat accessions used in this study were recently introduced for research purposes into Jordan from Canada. They were more resistant than barley or wheat to *M. javanica*. This finding agrees with Johnston and Motsinger (1989), who found that the oat cultivars Brooks and Florida 501 were more resistant than barley and wheat cultivars to *M. javanica*.

However, further studies are suggested to investigate the role of gramineous crops in suppressing populations of other species and races of *Meloidogyne* under field conditions for the management of root-knot nematodes in Jordan.

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