Pathogenicity of *Heterodera daverti*, *H. zeae*, and *Meloidogyne incognita* on Rice

I. K. A. Ibrahim*, M. A. El-Saedy*, S. F. A. Awd-Allah, Zafar A. Handoo*** and Asmaa A. Mokbel******

***Department of Plant Pathology, Faculty of Agriculture, Alexandria University, Alexandria, Egypt,**
****Department of Nematology, Agriculture Research Center, Ministry of Agriculture, Alexandria, Egypt,**
*****Nematology Laboratory, USDA, ARS, Beltsville Agricultural Research Center, Beltsville, MD 20705.**
******Biology Department, Faculty of Science, Jazan University, Kingdom of Saudi Arabia.**
E-mail: Zafar.Handoo@ars.usda.gov

Abstract. The reactions of five rice cultivars to the cyst nematodes *Heterodera daverti* and *H. zeae* and the root-knot nematode *Meloidogyne incognita* were determined in the greenhouse. The results showed that both *H. daverti* and *H. zeae* infected and reproduced successfully on some of the tested rice cultivars. Rice cultivars Giza 177 and Giza 178 were moderately susceptible and susceptible to *H. daverti*, respectively, while the other tested cultivars (Giza 171, Sakha 101, and Sakha 102) were resistant. Also, rice cultivars Giza 178 and Sakha 101 were susceptible to *H. zeae* and cultivars Giza 177 and Sakha 102 were moderately susceptible, whereas cv. Giza 171 was moderately resistant. In contrast, the tested rice cultivars were either susceptible or highly susceptible to *M. incognita*.

Keywords. *Heterodera daverti, Heterodera zeae, Meloidogyne incognita*, pathogenicity, resistant, rice cultivar, susceptible.

INTRODUCTION

In Egypt, plant-parasitic nematodes constitute one of the most important pest groups of many economic crop plants (Ibrahim and Handoo, 2007, Ibrahim *et al.*, 1976, 1986, 2000, 2010). Previous studies have shown the presence of large numbers of genera and species of phytoparasitic nematodes associated with rice crops in different locations in Egypt (Ibrahim *et al.,* 1976, 2010, Tarjan, 1964). Many of these phytoparasitic nematodes such as *Aphelenchoides besseyi, Helicotylenchus* spp., *Heterodera* spp., *Hirschmanniella gracilis, H. oryzae, Hoplolaimus* sp., *Longidorus* spp., *Meloidogyne incognita, Mesocriconema* sp., *Pratylenchus brachyurus, P. goodeyi, P. minyus, P. pratensis, P. thornei, P. zeae, Trichodorus* sp., *Tylenchorhynchus clarus, T. annulatus*, and *Xiphinema* spp. may be considered a limiting factor in rice production in Egypt and other parts of the world (Bridge, 1988, Ibrahim *et al.,* 1972, 2010; Davide, 1988; Hollis and Keoboonrueng, 1984; Rezk and Ibrahim, 1978; Villanueva *et al.,* 1992).

The root-knot nematode *M. incognita* has widespread occurrence and adversely affects the production of rice and other field crops in Egypt (Ibrahim *et al.,* 1972, 1973, 1986, 2010). Also, the cyst nematodes *Heterodera daverti* and *H. zeae* were found associated with rice and other field crops (Ibrahim and Handoo, 2007; Ibrahim *et al.*, 2010). Rice has been shown to be a host of *H. zeae* in India and the United states (Srivastava and Jaiswal, 2011; Ringer *et al.,* 1987). However, the pathogenicity of *H. daverti* and *H. zeae* on rice cultivars in Egypt is not known.

The objective of this study was to determine the reactions of five rice cultivars to *H. daverti, H. zeae,* and *M. incognita*.

MATERIALS AND METHODS

Isolates of *Heterodera daverti* and *H. zeae* were obtained from infected rice and corn roots and reared on rice (*Oryza sativa* cv. Giza 178) and corn (*Zea mays* cv. Pioneer 3062), respectively, in the greenhouse for 8 weeks. Mature cysts were collected and picked by hand from infected roots (Ayoub, 1980). Nematode eggs for experimental inoculations were obtained by crushing mature cysts.

Inoculum of *Meloidogyne incognita* race 1 was obtained from infected roots of tomato (*Solanum lycopersicum* cv. Rutgers) grown in the greenhouse. Viable eggs of this nematode were extracted from infected tomato roots by using sodium hypochlorite (NaOCl) solution (Hussey and

Table 1. Reaction of five rice cultivars to the cyst nematode *Heterodera daverti.*

Cultivar	Treatment	No. of cysts/pot	Rf[x]	Host reaction	Shoot Dry Weight (g)	Root Dry Weight (g)
Giza 171	*H. daverti*	0[wy]	0	R[z]	2.89a	1.86ab
	Control	-	-	-	2.82a	1.89a
Giza 177	*H. daverti*	49b	0.75b	MS	1.99c	1.51bc
	Control	-	-	-	2.27bc	1.79ab
Giza 178	*H. daverti*	95a	1.46a	S	1.89c	1.53bc
	Control	-	-	-	2.24bc	1.78ab
Sakha 101	*H. daverti*	0	0	R	2.32bc	1.77ab
	Control	-	-	-	2.66b	1.86ab
Sakha 102	*H. daverti*	0	0	R	2.09c	1.52bc
	Control	-	-	-	2.16c	1.58bc

[w]Means are average of 5 replicates.
[x]Rf = Final population (Pf)/ initial population (Pi). Pi = 65 cysts/pot.
[y]Means with the same letter in each column are not significantly different at P = 0.05.
[z]R = Resistant, MS = Moderately susceptible, S = Susceptible.

Table 2. Reaction of five rice cultivars to the cyst nematode *Heterodera zeae*.

Cultivar	Treatment	No. of cysts/pot	Rf[x]	Host reaction	Shoot Dry Weight (g)	Root Dry Weight (g)
Giza 171	*H. zeae*	17d[wy]	0.34d	MR[z]	2.59a	1.88a
	Control	-	-	-	2.77a	1.79a
Giza 177	*H. zeae*	39c	0.78c	MS	2.05b	1.73a
	Control	-	-	-	2.04b	1.83a
Giza 178	*H. zeae*	57b	1.14b	S	2.08b	1.77a
	Control	-	-	-	2.25ab	1.79a
Sakha 101	*H. zeae*	103a	2.06a	S	1.92b	1.96a
	Control	-	-	-	2.36ab	1.99a
Sakha 102	*H. zeae*	45c	0.90c	MS	2.31ab	1.91a
	Control	-	-	-	2.24ab	1.72a

[w]Means are average of 5 replicates.
[x]Rf = Final population (Pf)/ initial population (Pi). Pi = 50 cysts/pot.
[y]Means with the same letter in each column are not significantly different at P = 0.05.
[z]MR = Moderately resistant, MS = Moderately susceptible, S = Susceptible.

Table 3. Reaction of five rice cultivars to the root-knot nematode *Meloidogyne incognita.*

Cultivar	Treatment	No. of galls/plant	No. of egg masses/plant	Host reaction	Shoot Dry Weight (g)	Root Dry Weight (g)
Giza 171	*M. incognita*	230b[w y]	158a	HS[z]	2.09bc	1.37cd
	Control	-	-	-	2.48a	1.62ab
Giza 177	*M. incognita*	122e	78d	S	1.89d	1.20d
	Control	-	-	-	2.07bc	1.75ab
Giza 178	*M. incognita*	151d	96c	S	1.65e	1.25d
	Control	-	-	-	1.89d	1.53bc
Sakha 101	*M. incognita*	248a	170a	HS	1.75e	1.29d
	Control	-	-	-	2.45a	1.79a
Sakha 102	*M. incognita*	193c	125b	HS	2.00c	1.37cd
	Control	-	-	-	2.21b	1.84a

[w]Data are average of 5 replicates.
[y]Means with the same letter in each column are not significantly different at P = 0.05.
[z]S = Susceptible, HS = Highly susceptible.

Barker, 1973).

The reactions of five rice (*Oryza sativa* L.) cultivars to *H. daverti, H. zeae,* and *M. incognita* were determined in three greenhouse tests as one test for each nematode species. Seeds were sown in 12-cm-diameter plastic pots (0.75 liter) filled with a mixture of equal volumes of steam sterilized sand and clay soil. After emergence, seedlings were thinned to 5 per pot. Two weeks after emergence, soil of treated pots was infested by creating holes near the plant roots and then adding an initial population (Pi) of 75 crushed nematode cysts/pot or 5,000 eggs of *M. incognita*/pot. Non-treated pots served as controls. Treatments and controls were replicated five times. Pots were arranged in a randomized complete block design in a greenhouse at 20-26°C.

Experiments were terminated 90 days after soil infestation. Roots were washed free of soil. In cyst nematode tests, numbers of mature intact nematode cysts on roots and in soil (final population, Pf) were counted. The tested plant cultivars were rated on a scale of 0-5 according to the nematode reproduction factor (Rf), Rf = Pf/Pi. Plants with Rf =0 were considered resistant, Rf=0.1-0.5 moderately resistant, Rf = 0.6-1.0 moderately susceptible, Rf = 1.1-5.0 susceptible and Rf>5 highly susceptible (Golden *et al.*, 1970; Ibrahim *et al.*, 2012). Roots infected with *M. incognita* were immersed in an aqueous solution of phloxine B (0.15g/L water) for 15 minutes to stain the nematode egg masses (Taylor and Sasser, 1978). The numbers of *M. incognita* root galls and egg masses were determined. Plants were rated on a 0-5 scale according to the numbers of egg masses. Plants with 0-2 egg masses/plant were considered resistant; 3-10 egg masses/plant, moderately resistant; 11-30 egg masses/ plant, moderately susceptible; 31-100 egg masses/plant, susceptible; and >100 egg masses/plant, highly susceptible (Taylor and Sasser, 1978). Harvested plants were dried in an electric oven at 60°C for 48 hours, and the dry weights of the shoot and root systems were determined.

Analysis of variance (ANOVA) was carried out with SAS version 7 (SAS institute, 1988) on the final population (Pf) of *H. daverti,* and *H. zeae*, the reproduction factor (Rf), the number of root galls and egg masses of *M. incognita*, and the dry weights of the shoot and root systems of the tested rice plants.

RESULTS AND DISCUSSION

The reactions of the tested rice cultivars to *H. daverti, H. zeae* and *M. incognita* are presented in Tables 1-3. The results show that rice cv. Giza 178 was susceptible to *H. daverti* with Rf=1.46 while rice cv. Giza 177 was moderately susceptible with Rf = 0.75. On the other hand, rice cultivars Giza 171, Sakha 101 and Sakha 102 were resistant to *H. daverti*, as no nematode cysts were observed on their roots. Nematode infection did not induce significant changes in the dry weights of the shoots and roots of the tested rice cultivars (Table 1).

Data presented in Table 2 show that rice cultivars Giza 178 and Saka 101 were susceptible to *H. zeae* with Rf = 1.14 and 2.06, respectively, while rice cultivars Giza 177 and Sakha 102 were moderately susceptible with Rf = 0.78 and 0.90, respectively. On the other hand, rice cv. Giza 171 was moderately resistant with Rf = 0.34. Nematode infection resulted in no significant reductions in the shoot and root dry weights of the tested rice cultivars.

Rice cultivars Giza 171, Sakha 101 and Sakha 102 were highly susceptible to *M. incognita*, as great numbers of root galls and egg masses (193 and248 galls and 125 and 170 egg masses, respectively) developed on infected rice roots (Table 3). On the other hand, rice cultivars Giza 177 and Giza 178 were susceptible to *M. incognita*, with 122 and151 root galls and 78 and 96 egg masses observed on the infected roots. All the tested rice cultivars showed significant reductions in shoot and root dry weights in response to nematode infection (Table 3.)

It is evident that some of the tested rice cultivars were good hosts for *H. daverti* and *H. zeae* as these nematodes reproduced successfully on their roots. These results may be considered a first record on the pathogenicity of *H. daverti* and *H. zeae* on rice plants in Egypt. Previous studies revealed that rice plants in Africa and Asia were supported reproduction of other species of the cyst nematodes, for example, *Heterodera oryzae* in Côte d'Ivoire (Luc and Brizuela, 1961), *H. oryzicola* in India (Rao and Jayaprakash, 1978), *H. sacchari* in Côte d'Ivoire (Babatola, 1983) and in Liberia (Vovlas *et al.*, 1986), and *H. elachista* in Japan (Shimizu, 1976).

The results show that all tested rice cultivars were either susceptible or highly susceptible to *M. incognita* (Table 3). Cultivars Giza 171, Sakha 101 and Sakha 102 were highly susceptible with 125-170 nematode egg masses/plant, while cultivars Giza 177 and Giza 178 were susceptible with 78 and 96 egg masses/plant. All the tested cultivars exhibited significant reductions in the shoot and root dry weights with nematode infection (Table 3). These results agree with other reports indicating that *M. incognita* is a good pathogen on rice plants (Babatola, 1980; Fademi, 1986; Ibrahim *et al.*, 1972, 1973; Salawn, 1978).

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LITERATURE CITED

Ayoub, S. M. 1980. *Plant nematology. An agricultural training aid.* Sacramento, California, USA: NemaAid Publications, 195 pp.

Babatola, J. O. 1980. Reaction of some rice cultivars to the root-knot nematode *Meloidogyne incognita*. *Nema tropica* **10,** 5-9.

Babatola, J. O. 1983. Pathogenicity of *Heterodera sacchari* on rice. *Nematologia Mediterranea* **11,** 21-25.

Bridge, J. 1988. Plant parasitic nematodes in the Pacific Islands. *Journal of Nematology* **20,** 173-183.

Davide, R. G. 1988. Nematode problems affecting agriculture in Philippines. *Journal of Nematology* **20,** 214-218.

Fademi, O. A. 1986. Reaction of some selected rice cultivars to a root-knot nematode, *Meloidogyne incognita* (Kofoid and White) Chitwood. *Pakistan Journal of Nematology* **4,** 15-18.

Golden, A. M., J. M. Epps, R. D. Riggs, L. A. Duclos, J. A. Fox and R. L. Bernard 1970. Terminology and identity of interspecific forms of soybean cyst nematode (*Heterodera glycines*). *Plant Disease Reporter* **54,** 544-546.

Hollis, J. P. and S. Keoboonrueng 1984. Nematode parasites of rice. Pp. 95-146. In: *Plant and insect nematodes*, W. R. Nickle (ed.). New York. USA: Marcel Dekker.

Hussey, R. S. and K. R. Barker 1973. A comparison of methods of collecting inocula of *Meloidogyne* spp. including a new technique. *Plant Disease Reporter* **57,** 1025-1028.

Ibrahim, I. K. A. and Z. A. Handoo 2007. A survey of cyst nematodes (*Heterodera* spp.) in northern Egypt. *Pakistan Journal of Nematology* **25,** 335-337.

Ibrahim, I. K. A., I. A. Ibrahim and M. A. Rezk 1972. Pathogenicity of certain parasitic nematodes on rice. *Alexandria Journal of Agricultural Research* **20,** 175-181.

Ibrahim, I. A., I. K. A. Ibrahim and M. A. Rezk 1973. Host parasite relationship of *Meloidogyne incognita* (Kofoidet White) Chit. on rice. *Nematologia Mediterranea* **1,** 7-14.

Ibrahim, I. K. A., M. A. Rezk and M. A. El-Saedy 1976. Occurrence and distribution of plant parasitic nematodes in Northern Egypt. *Alexandria Journal of Agricultural Research* **24,** 93-101.

Ibrahim, I. K. A., M. A. Rezk and A. A. M. Ibrahim 1986. Plant parasitic nematodes associated with gramineous plants in northern Egypt. *Pakistan Journal of Nematology* **6,** 31-37.

Ibrahim, I. K. A., Z. A. Handoo and A. A. El-Sherbiny 2000. A survey of phytoparasitic nematodes on cultivated and non-cultivated plants in north-western Egypt. *Supplement to the Journal of Nematology* **32,** 478-485.

Ibrahim, I. K. A., A. A. Mokbel and Z. A. Handoo 2010. Current status of phytoparasitic nematodes and their host plants in Egypt. *Nematropica* **40,** 239-262.

Ibrahim, I. K. A., S. F. A. Awd-Allah and Z. A. Handoo 2012. Host sustainability of some poaceous crop cultivators for *Heterodera goldeni*. *Nematropica* **42,** 324-327.

Luc, M. and R. B. Brizuela 1961. *Heterodera oryzae* n. sp. (Nematoda: Tylenchoidea) parasite du riz en Côte d'Ivoire. *Nematologica* **6,** 272-279.

Rao, Y. S. and A. Jayaprakash 1978. *Heterodera oryzicola* n. sp. (Nematoda: Heteroderidae) a cyst nematode on rice (*Oryza sativa* L.) from Kerala State, India. *Nematologica* **24,** 341-346.

Rezk, M. A. and I. K. A. Ibrahim 1978. Survey study on plant-parasitic nematodes associated with corn and rice in Egypt. *Alexandria Journal of Agricultural Research* **26,** 215-222.

Ringer, C. E., S. Sardanelli, and L. R. Krusberg 1987. Investigations of the host range of the corn cyst nematode, *Heterodera zeae*, from Maryland. *Annals of Applied Nematology* (*Journal of Nematology* 19, *Supplement*) **1,** 97-106 .

Salawn, E. O. 1978. Effect of *Meloidogyne incognita* and *Heterodera sacchari* singly and combined on growth of rice. *Niger Journal of Plant Protection* **4,** 78-81.

SAS Institute. 1988. *SAS/ STAT User's Guide, 6th Edition*. Cary, North Carolina, USA: SAS Institute Inc., 1028 pp.

Shimizu, K. 1976. Influence of the upland rice cyst nematode, *Heterodera elachista*, on the yield of the upland-cultured paddy rice. *Japanese Journal of Nematology* **6,** 1-6.

Srivastava, A. N. and R. K. Jaiswal 2011. Host and non-host status of plant species for the maize cyst nematode, *Heterodera zeae*, in India. *Nematologia Mediterranea* **39,** 203-206.

Tarjan, A. C. 1964. Plant parasitic nematodes in the United Arab Republic. *FAO Plant Protection Bulletin* **12,** 49-56.

Taylor, A. L. and J. N. Sasser 1978. *Biology, identification, and control of root-knot nematodes* (Meloidogyne *spp.*). Raleigh, N.C., USA: North Carolina State University Graphics.

Villanueva, L. M., J. C. Prot and D. M. Matias 1992. Plant parasitic nematodes associated with upland rice in Philippines. *Journal of Plant Protection in the Tropics* **9,** 143-149.

Vovlas, N., F. Lamberti and D. K. Tuopay 1986. Observations on the morphology and histopathology of *Heterodera sacchari* attacking rice in Liberia. *FAO Plant Protection Bulletin* **34,** 153-156.