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PLANT PROTECTION - Note

Yield responses of 12 okra cultivars to southern root-knot nematode (*Meloidogyne incognita*)

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ABSTRACT: *Meloidogyne incognita* is one of the most widespread and damaging plant-parasitic nematodes throughout the world and substantially affects growth and yield of okra (*Abelmoschus esculentus* L). In the present study, effects of *M. incognita* on yield parameters of 12 okra cultivars with varying levels of resistance or susceptibility were assessed. *M. incognita* caused significant reductions in yield parameters of okra plants of all the cultivars. Maximum reduction of 34.1% in yield was observed in highly susceptible (HS) cultivar Sharmeeli. The nematode caused 20 and 17.6% reductions in yields in susceptible (S) cultivars Okra Sindha and Anmol, respectively. Moderately susceptible (MS) cultivars suffered 5.9 to 12.9% reductions in yields. In case of moderately resistant (MR) cultivars (Sanam, Dikshah, Arka Anamika, Ikra-1 and Ikra-2), the reductions in yields were the minimum and ranged from 2.9 to 6.5%. The reductions in other yield parameters of okra cultivars were observed in the order HS > S > MS > MR. As the MR cultivars suffered less damage by the nematode, they are recommended for cultivation in fields heavily infested with *M. incognita*.

KEY WORDS: *Abelmoschus esculentus*, root-knot nematodes, growth variables, genotypes.

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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 (Mukhtar et al. 2013a). They attack different crop plants, including vegetables, causing severe growth retardation due to formation of typical galls. Okra (*Abelmoschus esculentus* L. Moench) is one of the most important vegetable crops of the world, being popular in many tropical and subtropical countries. It is mostly cultivated for human consumption and also for industrial use as fiber (Hussain et al. 2012). Pakistan is among the leading okra producing countries, and several cultivars are cultivated throughout the year on thousands of hectares. Okra yields are very variable, ranging from 1.7 to 19 $t \cdot ha^{-1}$ (Tiendrébéogo et al. 2010). Per hectare, the yield of okra in Pakistan (8.8 t) is very low as compared to Cyprus (17.8 t), Jordan (17.7 t), Egypt (14.1 t) and Barbados (11.1 t) (Anonymous 2006). Pests and diseases are the most damaging factors for okra production. In Pakistan, *Meloidogyne incognita* is the dominant species and found throughout the okra-producing regions where it substantially affects growth and yield (Mukhtar et al. 2013b). Sikora and Fernandez (2005) reported severe attack of root-knot disease caused by *Meloidogyne* spp. on okra, and yield losses up to 27%. Incidence and severity of wilt diseases caused by fungi and bacteria have been reported to increase in many crops by root-knot infections (Shahbaz et al. 2015; Tariq-Khan et al. 2016). The yield losses caused by root-knot nematodes are due to the build-up of inoculum of this pathogen (Kayani et al. 2013) and continuous growing of similar okra varieties in the same field year after year (Hussain et al. 2011).

The use of resistant cultivars and nematicides are the main strategies to abate yield losses caused by this nematode (Gomes et al. 2015; Silva et al. 2015). The application of nematicides, though very effective, is not attractive to farming community due to their high costs and hazardous effects (Mukhtar et al. 2013c). Contrariwise, the use of cultivars resistant to nematodes is an environmentally benign, secure, innocuous and economically feasible mean of controlling root-knot nematodes (Mukhtar et al. 2013d). The main criteria for successful and acceptable use of cultivars in cropping systems are their capability to yield profitably in the presence of nematode pathogen. However, there is no information on the effects of *M. incognita* on okra cultivars widely grown in the country for their suitability in cropping systems. Therefore, in the present study, the effects of *Meloidogyne incognita* were assessed on yield reductions of 12 okra cultivars with varying levels of resistance or susceptibility under controlled conditions.

Twelve okra cultivars (Table 1) with varying levels of resistance or susceptibility assessed on the basis of number of galls (Hussain et al. 2014; Mukhtar et al. 2014) were evaluated for yield attributes. Three seeds of each cultivar were sown in plastic pots (20-cm-day.) containing 3 kg formalin sterilized soil (sand: 60%; silt: 20%; clay: 19%; organic matter: 1%; pH 7.2). Ten days after emergence, 1 healthy seedling of each cultivar was maintained in each pot. The plants of each cultivar were then inoculated with 3,000 freshly hatched 2^{nd}-stage juveniles (J2s) of an indigenous population of *M. incognita*, which was maintained on tomato cv Money maker. The plants of each cultivar which were not inoculated with J2s served as control of that cultivar. Each cultivar was replicated 10 times. The pots were maintained in a completely randomized design in the glasshouse at 25 °C ± 2 for 90 d. The pots were watered as per requirement.

For assessment of yield losses, the fruits were harvested on weekly basis from the 40^{th} day after inoculation till the termination of the experiment. At each harvest, the data on total number of fruits per plant, individual fruit weight, fruit diameter, fruit length of healthy and inoculated plants of each cultivar were recorded, and their total fruit yields were calculated. Finally, the means of these variables were reckoned, and percent reductions were calculated over their controls (Iqbal et al. 2014).

The experiment was conducted twice. All the data were found normally distributed and did not require transformation. Firstly, the data of both experiments were analyzed to examine their interaction. As no significant interaction was observed, the 2 sets of data were combined (making 20 replications) for final analysis. The combined data were subjected to 2-way analysis of variance (ANOVA) using GenStat package 2009 (12^{th} edition), version 12.1.0.3278 (VSNi 2009). The differences among means were compared by Fisher's protected least significant difference test at $p \leq 0.05$.

Significant differences were observed amongst okra cultivars for different yield attributes. Moderately resistant (MR) cultivars differed from moderately susceptible (MS) ones regarding reduction in number of fruits per →

plant with few exceptions. Likewise, MS cultivars were different from susceptible (S) and highly susceptible (HS) cultivars (Table 1). MR and MS cultivars caused lesser reductions in number of fruits as compared to S and HS cultivars. MR cultivars were at par with each other in causing reductions in fruit number. A similar trend was observed in the reductions in fruit numbers among MS cultivars. The maximum reduction was observed in the HS cultivar followed by S cultivars (Table 1).

The cultivars also varied significantly apropos reduction in fruit diameters and lengths. Maximum reductions of 19.2 and 32.4% in these parameters were recorded in the HS cultivar, Sharmeeli. The reductions in S cultivars in these parameters were statistically less as compared to HS cultivar. Minimum reductions in these parameters were observed in MR cultivars, which were statistically different from the MS ones with few exceptions (Table 1).

The cultivars behaved differently regarding reductions in fruit weight and fruit yield per plant. Significant variations in the reduction of fruit weight and yield were observed among different categories of okra cultivars. Minimum reductions were recorded in MR cultivars. The reductions in these parameters were significantly higher in MS cultivars, except Sabz Pari, as compared to MR cultivars. MS cultivars also varied significantly from each other in these parameters. A maximum reduction of 34.1% in fruit yield was observed in the HS cultivar Sharmeeli. The reductions in S cultivars were statistically lesser than in HS cultivar (Table 1).

The reductions in yield parameters in S cultivars are attributable to root injury due to penetration and/or feeding by the nematodes, leading to impairment of the efficiency of root systems to absorb water. The induction of galls in the roots and giant cells in the stellar region by *Meloidogyne* spp. extensively disrupt xylem tissues and greatly retard absorption and upward movement of water and nutrients. The infection also greatly reduces permeability of roots to water. The infection in plant roots by *Meloidogyne* spp. induces the formation of nurse cells and regulates greater translocation of photosynthates towards infected root tissue while other parts (foliage) experience shortage (Wyss 2002; Di Vito et al. 2004). Due to the inadequate supply of water, nutrients, photosynthates and energy, growth and developments of leaf tissue and its constituents, especially chlorophyll pigments, are adversely affected (Khan and Khan 1997). The poor growth of foliage subsequently leads to decreased production (Hussain

Table 1. Effect of Meloidogyne incognita on reduction in different yield parameters of 12 okra cultivars .

Cultivar	Status	% reduction				
		Number of fruits/plant	Fruit diameter	Fruit length	Fruit weight	Fruit yield/plant
Sanam	MR	2.2 a	0.5 a	1.2 a	0.8 a	2.9 a
Dikshah	MR	2.3 a	3.2 b	2.5 b	1.4 abc	3.6 a
Arka Anamika	MR	2.6 ab	1.1 a	3.8 c	1.2 ab	3.8 a
Ikra-1	MR	2.9 abc	1.2 a	4.3 c	1.8 bc	4.7 ab
Ikra-2	MR	4.5 bcd	4.4 c	6.7 de	2.1 c	6.5 c
Sabz Pari	MS	3.2 abc	1.2 a	4.4 c	2.7 d	5.9 bc
Super Star	MS	3.6 abc	5.7 d	7.3 e	6.7 e	10.0 d
PMS-55	MS	5.6 d	4.2 bc	7.4 e	7.7 f	12.9 e
PMS Beauty	MS	4.8 cd	3.6 bc	6.0 d	7.6 f	12.0 e
Anmol	S	12.1 f	10.0 e	14.2 f	9.0 g	20.0 g
Okra Sindha	S	9.2 e	11.3 f	14.9 f	9.3 g	17.6 f
Sharmeeli	HS	19.2 g	19.2 g	32.5 g	18.5 h	34.1 h
ANOVA		F = 105.48 df = 11,239 p < 0.001	F = 183.24 df = 11,239 p < 0.001	F = 929.02 df = 11,239 p < 0.001	F = 511.16 df = 11,239 p < 0.001	F = 307.87 df = 11,239 p < 0.001
LSD value		1.40	1.15	0.78	0.64	1.47

Values are means of 20 replicates. Values sharing common letters do not differ significantly at $p \leq 0.05$ according to Fisher's protected least significant difference test. MR = Moderately resistant; MS = Moderately susceptible; S = susceptible; HS = Highly susceptible.

et al. 2016; Kayani et al. 2017). The giant cells are highly-specialized cellular adaptations induced and maintained by *Meloidogyne* females in susceptible plants (Castillo et al. 2001) and are essential for successful parasitism. In resistant or MR cultivars, the juveniles fail to induce formation of giant cells in the roots and they will either starve or migrate out; the host is not infected and yield is not affected.

It is concluded from the present study that okra cultivars showed significant differences for their yield responses to *M. incognita*. Five MR cultivars viz. Sanam, Dikshah, Arka Anamika, Ikra-1 and Ikra-2 suffered less damage by the nematode as compared to susceptible cultivars and are recommended for cultivation in fields heavily infested with *M. incognita*. Furthermore, these cultivars could be used in breeding programs to introduce new resistant cultivars to these nematodes.

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REFERENCES

Anonymous (2006). FAO Stat database (05/2006). Vegetables and melons outlook/VGS-317/October 19. Economic Research Service, USDA, Food and Agriculture Organization. New York: United Nations.

Castillo, P., Di Vito, M., Vovlas, N. and Jiménez-Díaz, R. M. (2001). Host-parasite relationships in root-knot disease of white mulberry. Plant Disease, 85, 277-281. http://dx.doi.org/10.1094/PDIS.2001.85.3.277.

Di Vito, M., Vovlas, N. and Castillo, P. (2004). Host-parasite relationships of *Meloidogyne incognita* on spinach. Plant Pathology, 53, 508-514. http://dx.doi.org/10.1111/j.1365-3059.2004.01053.x.

Gomes, J. A. A., Andrade Júnior, V. C., Oliveira, C. M., Azevedo, A. M., Maluf, W. R. and Gomes, L. A. A. (2015). Resistance of sweet potato clones to *Meloidogyne incognita* races 1 and 3. Bragantia, 74, 291-297. http://dx.doi.org/10.1590/1678-4499.0454.

Hussain, M. A., Mukhtar, T. and Kayani, M. Z. (2011). Assessment of the damage caused by *Meloidogyne incognita* on okra. Journal of Animal and Plant Sciences, 21, 857-861.

Hussain, M. A., Mukhtar, T. and Kayani, M. Z. (2014). Characterization of susceptibility and resistance responses to root-knot nematode (*Meloidogyne incognita*) infection in okra germplasm. Pakistan Journal of Agricultural Sciences, 51, 319-324.

Hussain, M. A., Mukhtar, T. and Kayani, M. Z. (2016). Reproduction of *Meloidogyne incognita* on resistant and susceptible okra cultivars. Pakistan Journal of Agricultural Sciences, 53, 371-375.

Hussain, M. A., Mukhtar, T., Kayani, M. Z., Aslam, M. N. and Haque, M. I. (2012). A survey of okra (*Abelmoschus esculentus*) in the Punjab province of Pakistan for the determination of prevalence, incidence and severity of root-knot disease caused by *Meloidogyne* spp. Pakistan Journal of Botany, 44, 2071-2075.

Iqbal, U., Mukhtar, T. and Iqbal, S. M. (2014). *In vitro* and *in vivo* evaluation of antifungal activities of some antagonistic plants against charcoal rot causing fungus, *Macrophomina phaseolina*. Pakistan Journal of Agricultural Sciences, 51, 689-694.

Kayani, M. Z., Mukhtar, T. and Hussain, M. A. (2017). Effects of southern root knot nematode population densities and plant age on growth and yield parameters of cucumber. Crop Protection, 92, 207-212. http://dx.doi.org/10.1016/j.cropro.2016.09.007.

Kayani, M. Z., Mukhtar, T., Hussain, M. A. and Haque, M. I. (2013). Infestation assessment of root-knot nematodes (*Meloidogyne* spp.) associated with cucumber in the Pothowar region of Pakistan. Crop Protection, 47, 49-54. http://dx.doi.org/10.1016/j.cropro.2013.01.005.

Khan, M. R. and Khan, M. W. (1997). Effects of root-knot nematode, *Meloidogyne incognita*, on the sensitivity of tomato to sulphur dioxide and ozone. Environmental and Experimental Botany, 38, 117-130. http://dx.doi.org/10.1016/S0098-8472(96)01060-X.

Mukhtar, T., Arshad, I., Kayani, M. Z., Hussain, M. A., Kayani, S. B., Rahoo, A. M. and Ashfaq, M. (2013b). Estimation of damage to okra (*Abelmoschus esculentus*) by root-knot disease incited by *Meloidogyne incognita*. Pakistan Journal of Botany, 45, 1023-1027.

Mukhtar, T., Hussain, M. A. and Kayani M. Z. (2013c). Biocontrol potential of *Pasteuria penetrans*, *Pochonia chlamydosporia*, *Paecilomyces lilacinus* and *Trichoderma harzianum* against *Meloidogyne incognita* in okra. Phytopathologia Mediterranea, 52, 66-76. *http://dx.doi.org/10.14601/Phytopathol_Mediterr-11305*.

Mukhtar, T., Hussain, M. A., Kayani, M. Z. and Aslam, M. N. (2014). Evaluation of resistance to root-knot nematode (*Meloidogyne incognita*) in okra cultivars. Crop Protection, 56, 25-30. http://dx.doi.org/10.1016/j.cropro.2013.10.019.

Mukhtar, T., Kayani, M. Z. and Hussain, M. A. (2013a). Nematicidal activities of *Cannabis sativa* L. and *Zanthoxylum alatum* Roxb. against *Meloidogyne incognita*. Industrial Crops and Products, 42, 447-453. http://dx.doi.org/10.1016/j.indcrop.2012.06.027.

Mukhtar, T., Kayani, M. Z. and Hussain, M. A. (2013d). Response of selected cucumber cultivars to *Meloidogyne incognita*. Crop Protection, 44, 13-17. http://dx.doi.org/10.1016/j.cropro.2012.10.015.

Shahbaz, M. U., Mukhtar, T., Haque, M. I. and Begum, N. (2015). Biochemical and serological characterization of *Ralstonia solanacearum* associated with chilli seeds from Pakistan. International Journal of Agriculture and Biology, 17, 31-40.

Sikora, R. A. and Fernandez, E. (2005). Nematode parasites of vegetables. In M. Luc, R. A. Sikora and J. Bridge (Eds.), Plant parasitic nematodes in subtropical and tropical agriculture (p. 319-392). London: CABI publishing.

Silva, R. V., Oliveira, R. D. L., Ferreira, P. S., Castro, D. B. and Rodrigues. F. A. (2015). Effects of silicon on the penetration and reproduction events of *Meloidogyne exigua* on coffee roots. Bragantia, 74, 196-199. http://dx.doi.org/10.1590/1678-4499.360.

Tariq-Khan, M., Munir, A., Mukhtar, T., Hallmann, J. and Heuer, H. (2016). Distribution of root-knot nematode species and their virulence on vegetables in northern temperate agro-ecosystems of the Pakistani-administered territories of Azad Jammu and Kashmir. Journal of Plant Diseases and Protection. http://dx.doi.org/10.1007/s41348-016-0045-9.

Tiendrébéogo, F., Edgar Traoré, V. S., Lett, J. M., Barro, N., Konaté, G., Traoré, A. S. and Traoré, O. (2010). Impact of okra leaf curl disease on morphology and yield of okra. Crop Protection, 29, 712-716. http://dx.doi.org/10.1016/j.cropro.2010.02.007.

VSNi (2009) Data analytics for bioscience; [accessed 2016 Oct 16]. www.vsni.co.uk

Wyss, U. (2002). Feeding behaviour of plant parasitic nematodes. In D. L. Lee (Ed.), The biology of nematodes (p. 233-260). London: Taylor and Francis.