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Evaluation of diverse okra germplasm for identification of source of resistance to root-knot nematode, *Meloidogyne incognita*

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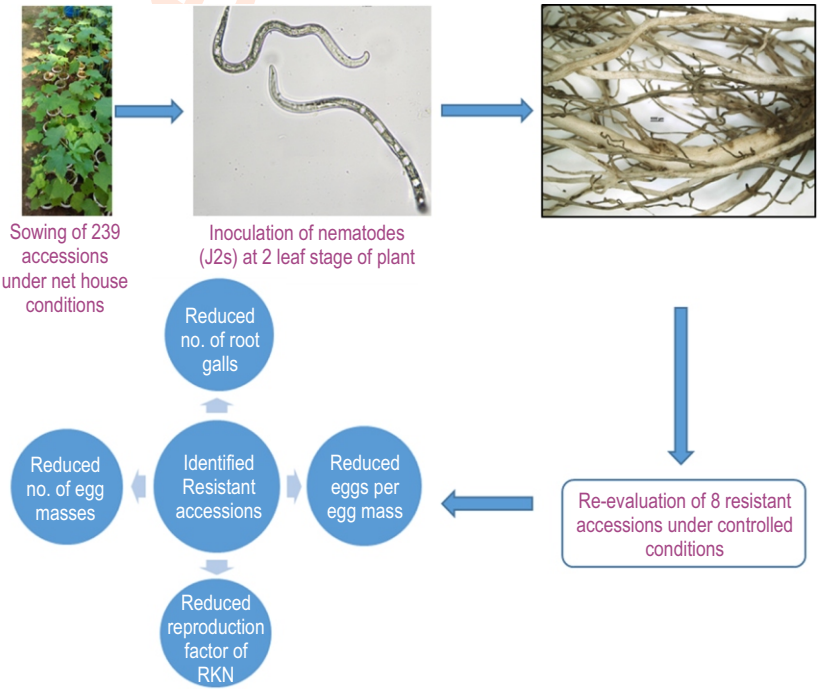
Abstract

Aim: The present study was carried out to identify the okra germplasm resistant to root-knot nematode for cost effective and environment friendly management of root-knot-nematode, *Meloidogyne incognita*.

Methodology: A total of 239 diverse accessions (acc.) of okra were evaluated under net house conditions. Experiments were conducted in 10 cm diameter pots filled with 500 g soil with challenge inoculation of 1000 second stage juveniles of root-knot nematodes. Resistance assessment was done after 42 days of inoculation based on the number of root galls developed. The resistant accessions were identified and re-evaluated under controlled conditions to validate the resistance.



Results: Based on root galling index, host response of 239 accessions (acc.) was observed as Immune (0 acc.), resistant (8 acc.), moderately resistant (19 acc.), moderately susceptible (28 acc.), susceptible (145 acc.) and highly susceptible (46 acc.). Repeated evaluation of 8 resistant accessions of okra (EC306737, EC305619, EC360672, EC360927, IC022232, IC117074, IC255758 and IC39140) showed consistent root-knot nematode resistance by these accessions. Final population and reproduction factor of root-knot nematode were found significantly low in identified resistant accessions.

Interpretation: These eight identified accessions are novel for root-knot nematode resistance and therefore, important for future use in crop breeding programmes for root-knot nematode resistance in okra.

Key words: *Abelmoschus esculentus*, Host plant resistance, Root-knot nematode

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Introduction

Okra, *Abelmoschus esculentus* (L.) Moench is a commonly grown vegetable crop in tropical and sub-tropical regions of the world. It belongs to the Malvaceae family and is also known as Lady's finger/Bhindi/Gumbo. The plant is originated from tropical and sub-tropical Africa, however, large number of related species with wide variability occur in South and South-east Asia. It is mainly grown for its edible green seed pods which are rich in minerals and vitamins. Along with nutritional benefits it also has nutraceutical and therapeutic properties due to presence of important bioactive compounds such as polyphenolic compounds, carotene, folic acid, thiamine, riboflavin, niacin, vitamin C, oxalic acid, and amino acids and their associated bioactivities (Gemede *et al.,* 2015; Elkhalifa *et al.,* 2021). Okra is an important vegetable crop grown in several Indian states and many cultivars have been commercially grown. India is a leading producer of okra where it is cultivated on 0.52 million ha land with a production of 6.35 million tonnes (Singh *et al.,* 2023). However, the productivity of okra is low owing to various biotic stresses such as yellow vein mosaic disease, powdery mildew, root-knot nematodes, wilt, aphids, white fly, red spider mites, etc.

The root-knot nematodes, *Meloidogyne* species are one of the major productivity constraints in the okra cultivation worldwide causing root galling and yield losses in okra (Odeyemi *et al.,* 2015; Salameh and Karajeh, 2015). It has been reported to cause yield loss up to 27% in okra (Sikora and Fernandez, 2005; Anwar and McKenry, 2012). In India, root-knot nematodes cause 19.5 percent average yield losses in okra that translates into losses of Rs. 2,480 million (Kumar *et al.,* 2020). Besides causing direct damage, root-knot nematodes are also known to interact with other soil microbes such as fungi and bacteria and form disease complexes, which aggravate the crop losses (Francl and Wheeler 1993; Son *et al.,* 2009; Begum *et al.,* 2012). They are also responsible for the breakdown of plant resistance to fungi and bacteria, and reduce the tolerance of okra plants to the environmental stresses (Taylor, 1979). In addition, root-knot nematodes reduce the nutritional quality of okra fruits as root galling hampers the nutrient uptake by plant roots (Nacar and Ozarslandan, 2021).

Management of root-knot nematodes is becoming difficult due to non-availability of effective nematicides. Moreover, chemical control methods are costly and responsible for environmental pollution (Mazrou *et al.,* 2020). Host plant resistance is the innate capacity of plants to limit or escape the damage caused by nematodes. It is a foremost component of integrated nematode management among other management methods for root-knot nematodes, which can be used in various combinations for effective nematode management (Khan *et al.,* 2018; Gawade *et al.,* 2022; Xie *et al.,* 2024). Resistant cultivars developed using this strategy can also be used as an alternative nematode management method, as it is cost effective and environment friendly (Gawade *et al.,* 2017; Fatima *et al.,* 2022). Identification of the source of the resistance against root-knot nematode is the prerequisite for the breeding / development of resistant varieties. Screening of germplasm is therefore an important but challenging activity due to the susceptibility of all commercial varieties of okra to root-knot nematode (Hussain *et al.,* 2016). Worldwide, the efforts have been made to identify the root-knot nematode resistant cultivars in okra, however, all the studied cultivars were found susceptible to root-knot nematode (Hussain *et al.,* 2016; Kumar *et al.,* 2020, Rekha and Gowda, 2000; Mohanta and Mohanty, 2012). Evaluation of diverse and large number of accessions / genotypes of cultivated crops and their wild relatives is useful in identification of sources of resistance to root-knot nematodes. National Genebank (NGB) situated at ICAR-National Bureau of Plant Genetic Resources (ICAR-NBPGR), New Delhi, India is world's second largest Seed Genebank harboring more than 4.5 lakh plant germplasm accessions of native and exotic origin. Utilizing this rich diversity, continuous efforts are being made to identify the root-knot nematode resistant accessions. During last ten years, more than 6,000 accessions of various crops have been evaluated by our team to identify the root-knot nematode resistant accessions and it has led to successful identification of sources of resistance in crops such as cowpea (Khan *et al.,* 2018), lentil (Khan *et al.,* 2017), eggplant (Gawade *et al.,* 2022) etc. There are 3,493 accessions of okra conserved at NGB and in lieu of this; the present study was aimed at utilization of the conserved germplasm of okra for identification of root-knot nematode, *Meloidogyne incognita* resistant accessions. In this study, two hundred thirty-nine (239) diverse accessions of okra, which contained commercial cultivars and wild relatives of okra were evaluated to identify the *M. incognita* resistant accessions for future crop improvement programmes in okra crop.

Materials and Methods

Experimental material and conditions: Seeds of 239 diverse accessions of okra were procured from National Genebank (NGB), ICAR-National Bureau of Plant Genetic Resources (NBPGR), New Delhi, India. The accessions included were indigenous collections (IC) as well as exotic collections (EC) of cultivated and wild okra conserved in NGB. Experiments were conducted under net house conditions at ICAR-NBPGR, New Delhi (28°37'48" N, 77°09'06" E) in pots filled with soil, sand and Farm Yard Manure (FYM) mixture. Experiments on evaluation of all 239 accessions was conducted during rainy / kharif seasons of year 2021 and 2022 during which average temperature and relative humidity ranged between 28° to 30.0°C and 74-82%, respectively. The validation / confirmatory evaluation of resistant accessions was conducted during rainy seasons of 2022 and 2023 under controlled conditions (average temperature= 28.0 to 30.0°C and relative humidity= 75.0%) at same location.

Nematode inoculum: Root-knot nematode species *M. incognita* used in present study was confirmed using morphological and molecular methods in our previous studies (Gawade *et al.,* 2022). Population of *M. incognita* was morphologically characterized by studying the perineal pattern of nematode females (Southey,

1986). Perineal area of studied matured females showed high dorsal arch, which is characteristic feature of *M. incognita.* Molecular confirmation of species was also done by DNA extraction from second stage juveniles of root-knot nematode, PCR amplification and sequencing of the Internal Transcribed Region (ITS) of nrDNA and D2-D3 sequence of 28S rRNA as mentioned in Gawade *et al.* (2022) wherein both the sequences were found highly similar with *M. incognita*. The pure culture of characterized population was maintained at ICAR-NBPGR and nematodes were isolated from it for inoculation in experimental plants. Population of *M. incognita* was raised from single egg mass and multiplied regularly on susceptible cultivars of tomato (Pusa Ruby) and eggplant (Pusa Purple Long). Second stage juveniles (J2s) hatched from single egg mass were inoculated on three-week-old seedlings and regularly watered to maintain moisture at field capacity level. After forty-five days of inoculation, the plants were gently taken out from the pots and washed with tap water to remove adhering soil. The egg masses of *M. incognita* were handpicked with the help of a fine forceps and incubated at 28°C for 2-4 days to allow J2s to hatch out. Freshly hatched J2s were used further for screening experiments (Gawade *et al.,* 2022).

Screening of okra germplasm: During this experiment, a total of 239 genotypes of okra were screened for *M. incognita* resistance under a net-house conditions (Table 1). Three to four seeds of

Table 1: Categorization of okra accessions based on host reaction to *M. incognita* infection

Host reaction	No. of accessions	Accessions	[a]Galling index
Resistant (1-10 galls per plant)	8	EC306737, EC305619, EC360672, EC360927, IC022232, IC117074, IC255758, IC39140	1-2
Moderately resistant (11-30 galls per plant)	19	Arka Abhay, EC169361, EC169396, EC169430, EC169462, EC169481, EC19432, EC306724, EC360787, EC360819, EC550848, Hisar Naveen, Hisar Unnat, IC090184, IC18973, IC23624, IC469550, IC93746, NJ/15-070	3
Moderately susceptible (31-50 galls per plant)	28	EC169464, EC169506, EC305664, EC305741, EC360820, IC013664, IC018544, IC090185, IC111499, IC111517, IC111527, IC111537, IC117021, IC117089, IC117237, IC117281, IC117350, IC128090, IC12934-A, IC18532, IC332458, IC34124-A, IC52273, IC89871, IC90174, IC90180, Parbhani Kranti, Pusa-4	4
Susceptible (51-100 galls per plant)	138	Arka Anamika, Azad Bhindi-3, EC169334, EC169348, EC169380, EC169409, EC169441, EC169442, EC169446, EC169448, EC169468, EC169490, EC169522, EC177900, EC305622, EC305654, EC305659, EC305743, EC306713-A, EC316089, EC329359, EC360798, Phule Utkarsh, IC011533, IC018536, IC033345, IC039133, IC042490-A, IC043741, IC090272, IC10574, IC111319, IC111377, IC111472, IC111474-A, IC111481, IC111492, IC111495, IC111497, IC111521, IC111550, IC112495, IC112497, IC113912, IC11492, IC11533, IC11547, IC116962, IC117019, IC117070, IC117086, IC117108, IC117110, IC117122, IC117136, IC117138, IC117223, IC117224, IC117224-A, IC117251, IC117256, IC117269, IC117272, IC117276, IC117298, IC117308, IC118150, IC13917, IC140949, IC140969, IC140990, IC141026, IC169482, IC18537, IC26375, IC282296, IC29117-A, IC32855-B, IC3301, IC331217, IC332457, IC33405, IC39141-A, IC39702, IC412972, IC415749, IC433628, IC433638, IC433639, IC437532, IC45802, IC45815, IC45887, IC46018, IC467699, IC469655, IC47343, IC48736, IC49749-B, IC548494, IC550642, IC550654, IC550657, IC550662, IC550685, IC550765, IC588197, IC89936, IC90107, IC90224, IC90324, IC90363, IC9388, IC93884, IC948448, IC94848, JMP-14-7, JP-31, Kashi Pragati, Kashi Satdhari, Kashi Vibhuti, ND/DC-08, NJ/15-004, NJ/15-018, NJ/15-021, NJ/15-026, NJ/15-027, NJ/15-042, NJ/15-062, PTP/DC/AMP-53, Pusa Sawani, RCM/LKB/18, RCM/LKB/23, RCM/LKB/31, RCM/LKB/32, RCM/LKB/42, RCM/LKB/44, RCM/LKB/47,	
Highly Susceptible (>100 galls per plant)	46	EC169332, EC169363, EC169369, EC169388, EC169407, EC169413, EC169420, EC169435, EC169452, EC169453, EC169483, EC305646, IC117214, IC003307, IC043736, IC083768, IC093768, IC093882, IC111483, IC111500, IC111514, IC111523, IC112481, IC112490, IC113904, IC117076, IC117130, IC117252, IC16566, IC18073-A, IC18973-A, IC18975, IC22283, IC23594, IC24906, IC305645, IC34190-C, IC410138, IC433673, IC43736, IC45750, IC58705-A, IC62738, IC90276, IC99743, Utkal Gourav	5

[a]Galling index: No. of galls per root system were divided on the scale of 0-5 as per Taylor and Sasser, 1978, Scale: 0= No galls, 1= 1-2, 2= 3-10; 3=11-30, 4=31-100, 5= >100 galls per root system

each genotype were sown in 10 cm diameter plastic pots filled with 500 g soil mixed with FYM and sand. There were five replications of each accession and pots were arranged in a complete randomized design. Two weeks after germination, the plants were thinned to maintain single plant per pot. Each plant was then artificially inoculated with freshly hatched 1000 J2s of *M. incognita.* Soil around roots were slightly removed to expose roots and J2 suspension was dispensed in 5 ml water around the root zone with a pipette, thereafter the exposed roots were covered with soil and the pots were lightly watered. Planted pots were watered as needed to maintain the soil moisture at field capacity level. Six weeks after *M. incognita* inoculation, the plants were carefully taken out from the pots. The roots were washed with tap water and processed for gall counting for host status designation. Gall index (GI) of 0-5 was assigned where: 0=no galls, 1 = 1-2, 2 = 3-10, 3 = 11-30, 4 = 31-100, 5 = >100 galls per root system (Taylor and Sasser, 1978). Host designation was assigned to accessions as per Gaur *et al.* (2001) with slight modifications (Gawade *et al.,* 2022) wherein, 0 galls /plant= Highly resistant/ immune; 1–10 galls/ plant= Resistant; 11–30 galls/ plant= Moderately resistant; 31–50 galls/ plant= Moderately susceptible, 51–100 galls/ plant= Susceptible, and >101 galls/ plant= Highly susceptible.

Validation of accessions: Repeat experiment was conducted for the okra accessions, which showed <10 root galls/ plant root system under the same set of experimental conditions and method used during preliminary evaluation, except use of steam sterilized soil to avoid infection by other pathogens and to get correct validation data. The number of galls/ plant and number of egg masses/ plant were counted to confirm the resistance consistency. Photographs of root galls and egg masses were taken under stereozoom microscope with Nikon Imaging software. After counting root galls and egg masses, the eggs were extracted from the roots of each plant by the sodium hypochlorite method (Hussey and Barker, 1973). For estimation of soil population, 200 g soil from each pot was washed using sieving and decantation technique and juveniles were recovered. Eggs and juveniles were counted under a microscope using square counting dish, and the numbers were used for calculating the reproduction factors (RF) following the method given by Southey (1986). Final population was calculated by adding the number of eggs per plant root system with the juvenile population extracted from soil.

Statistical analyses: All the data on root galls per plant, number of egg masses per plant, number of eggs per egg mass, average eggs per plant root system, average soil population were subjected to ANOVA and the means were calculated and separated by Duncan's Multiple Range Test (DMRT) at the significance level $P < 0.05$ using software, SPSS for Windows, Version 17.0. Chicago, SPSS Inc.

Results and Discussion

The total of 239 accessions of okra (cultivated and wild related species of okra) were evaluated to study their host reaction to the root-knot nematode, *M. incognita* infection. All these genotypes showed varied response to the *M. incognita* infection (Table 1). Based on the number of root galls induced by *M. incognita,* significant variation was observed among the accessions studied. Out of the 239 accessions evaluated against *M. incognita,* 8 were resistant, 19 were moderately resistant, 28 were moderately susceptible, 145 were susceptible, 46 were highly susceptible, while none of the accession was immune or highly resistant to it (Table 1). The susceptible tomato cv. Pusa Ruby developed numerous galls (GI= 5) at the same inoculum density, it was confirmed that the J2s were viable and in sufficient quantities to initiate the infection. Thus, we believed that the environmental conditions were conducive for critical evaluation of host status of these okra accessions as experiments were conducted during okra growing season. The susceptibility of large number of okra genotypes (Hussain *et al.,* 2016; Kumar *et al.,* 2020, Rekha and Gowda, 2000; Mohanta and Mohanty, 2012) can be due to genetic components of accessions. It might also be attributed to wide adaptability of *M. incognita* to feed on large number of host plants.

Accessions within each host designation varied also according to source of germplasm (Exotic versus indigenous). Out of the 51 exotic accessions evaluated, 4 were resistant (7.8%), 10 were moderately resistant (19.6%), 5 were moderately susceptible (9.8%), 20 were susceptible (39.0%), while 12 were highly susceptible (23.5%). Out of the 188 indigenous accessions, 4 were resistant (2.1%), 9 were moderately resistant (4.8%), 23 were moderately susceptible (12.2%), 118 were susceptible (62.8%), while 34 were highly susceptible (18.1%) (Fig. 1). Ratio of exotic and indigenous accessions in each host response category showed that the exotic accessions were less susceptible as compared to the indigenous accessions. This might be due to type location of exotic accession and genetic components. Among the eight resistant accessions, five accessions were of cultivated okra, *A. esculentus,* while 3

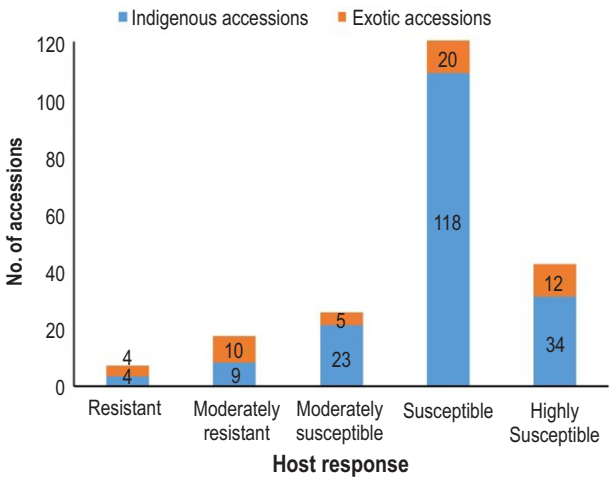

Fig. 1: Comparative host response of indigenous and exotic origin accessions of okra to root-knot nematode infection.

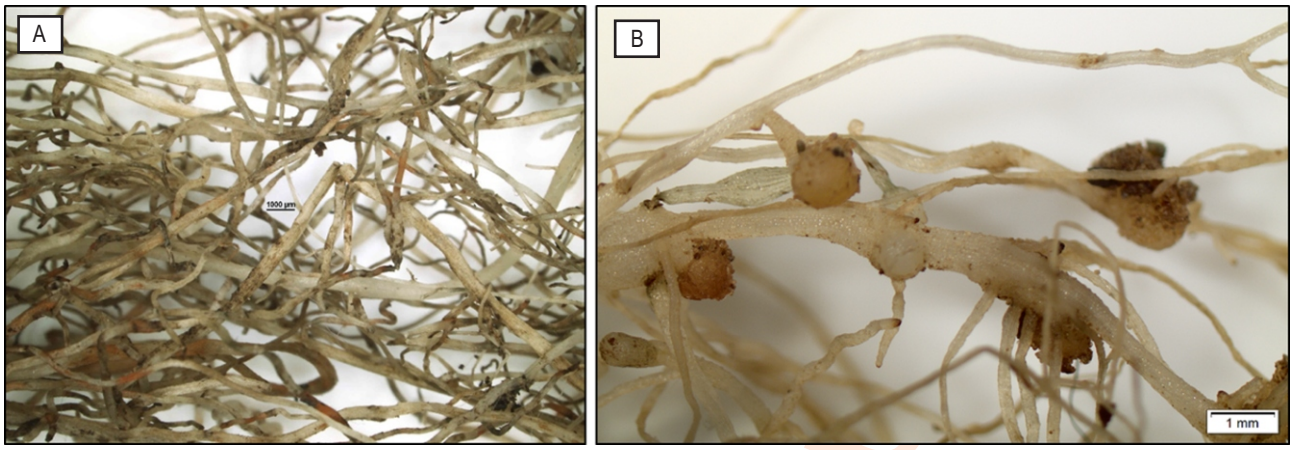

Fig. 2: Microphotographs of okra roots infected by root-knot nematode, *Meloidogyne incognita:* A: Resistant accession (EC306737) with few and small sized root galls. B: Susceptible accession IC111523 showing large size galls with well developed egg masses.

Table 2: Validation of resistant accessions of okra against *M. incognita*

Accession number	Number of galls per root system (mean±SE)*	Gall index#	Percent reduction over check@	Host status$
EC306737	3.4±0.60[a]	2	97.4	R
EC305619	6.2±0.48[ab]	2	95.3	R
EC360672	7.2±0.66[ab]	2	94.2	R
EC360927	7.8±0.66[ab]	2	94.5	R
IC022232	7.2±0.58[ab]	2	94.5	R
IC117074	7.4±0.51[ab]	2	94.4	R
IC255758	8.6±0.60[ab]	2	93.5	R
IC39140	6.6±0.51[ab]	2	95.0	R
IC111523 (Control check)	133.2±3.86[c]	5	0	HS

*Mean±standard error (n=5), Means followed by different letters in the same column are statistically different according to Duncan's Multiple Range Test ($P<0.05$); #Galling index: No. of galls per root system categorized using scale of 0-5 as per Taylor and Sasser, 1978, Scale: 0= No galls, 1= 1-2, 2= 3-10; 3=11-30, 4=31-100, 5= >100 galls per root. @percent reduction of gall formation in resistant accessions as compared to susceptible check accession. $Host status- R= Resistant, HS= Highly susceptible

accessions were of wild species of okra *viz., Abelmoschus manihot* spp. *manihot* (1) and *Abelmoschus moschatus* (2). The wild related species of cultivated crops are important sources of resistance to root-knot nematode in okra (Kumar and Jain, 2011) as well as other vegetable crops (Gawade *et al.,* 2022). The resistant okra accessions identified during preliminary evaluation studies were selected for the validation or confirmatory evaluation under controlled conditions to verify their resistance consistency (Table 2). There was significant variation in the number (Table 2) and size of galls (visual observation) between resistant and susceptible accessions of okra (Fig. 2). Fewer root galls were formed with galling index (GI) < 2.0 in eight validated accessions of okra. The average number of gall formation varied from 3.4 to 8.6 in different resistant accessions (Table 2). Among resistant accessions, the lowest number of root galls (3.4±0.60) formation was observed in accession- EC306737 whereas the highest number (8.6±0.60) was observed in accession- IC255758. The reduction of gall formation in resistant accessions were noted as 93.5-97.4% as compared to the susceptible control- IC111523 (Table 2). The number of egg masses were also significantly low in resistant accessions (0.4 to 2.6) as compared to the control accession IC111523 (108 egg masses per plant). The variation in the number of root galls and egg masses among accessions might be due host-nematode interaction and food preference (Rashwan, 2011; Ye *et al.,* 2017).

Average eggs per plant root system and the final soil population was also significantly reduced in the resistant accessions as compared to the susceptible control accession. Consequently, the reproduction factor was reduced and varied between 0.09 to 0.47 in the resistant accessions as compared to the susceptible control- IC111523 (RF=30.66) (Table 3). Reproduction factors were less on resistant accessions as compared to susceptible control accession and these differences

Table 3: Host response of resistant accessions of okra on multiplication and reproduction of *M. incognita*

Accession no.	Number of egg masses per plant	Number of eggs per egg masses	Average eggs per plant root system	Final soil population	Average reproduction factor
EC306737	0.4±0.24[a]	24.4±15.34[a]	24.4±15.34[a]	65.00±41.53[a]	0.09
EC305619	2.6±0.24[a]	122±12.90[c]	323±50.98[a]	106.0±12.21[a]	0.43
EC360672	1.4±0.51[a]	66.2±18.03[ab]	106±31.87[a]	87.20±23.42[a]	0.19
EC360927	2.2±0.66[a]	103±28.26[b]	277±80.58[a]	129.80±33.65[a]	0.47
IC022232	1.4±0.51[a]	58±21.92[ab]	121.6±69.92[a]	88.60±25.46[a]	0.21
IC117074	0.6±0.24[a]	40.6±17.28[a]	40.6±17.28[a]	47.60±20.69[a]	0.09
IC255758	1.0±0.32[a]	56.4±7.70[ab]	49.2±13.45[a]	57.60±17.71[a]	0.17
IC39140	2.4±0.60[a]	47.8±7.44[ab]	107.2±24.82[a]	89.20±5.98[a]	0.20
IC111523 (Control check)	108.2±4.48[b]	263.8±19.14[d]	28466.2±2118.93[b]	2199.8±305.31[b]	30.66

Values are Mean±standard error (n=5), Means followed by different letters in the same column are statistically different according to Duncan's Multiple Range Test ($P<0.05$).

could be due to genetic factor in the host which confers susceptibility or resistance as well as genetic differences between nematode populations (Castagnone-Sereno, 2006; Hussain *et al.,* 2016).

In conclusion, significant reduction in number of root galls, egg-mass formation and reproductive potential of root-knot nematode, *M. incognita* on resistant accessions suggest that the disease resistance may be due to host genetic component, which can be pre-infectional and post-infectional. Detailed studies need to conducted to understand the biochemical and genetic basis of resistance in these accessions. These resistant accessions can be further useful in okra pre-breeding and breeding programmes for crop improvement.

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Authors' contribution: B.H. Gawade: Conceptualization of research, execution of experiments, data collection, manuscript writing, data analysis; **Z. Khan:** Designing of the experiments, conceptualization of research, data interpretation, manuscript writing; **K.K. Gangopadhyay:** Contribution of experimental materials; **C.D. Pandey:** Contribution of experimental materials; **V. C. Chalam:** Manuscript preparation, data interpretation.

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References

Anwar, S.A. and M.V. McKenry: Incidence and population density of plant parasitic nematodes infecting vegetable crops and associated yield losses. *Pak. J. Zool.,* **44**, 327-333 (2012).

Begum, N., M.I. Haque, T. Mukhtar, S. M. Naqvi and J. F. Wang: Status of bacterial wilt caused by *Ralstonia solanacearum* in Pakistan. *Pak. J. Phytopath.,* **24**, 11-20 (2012).

Castagnone-Sereno, P.: Genetic variability and adaptive evolution in parthenogenetic root-knot nematodes. *Heredity,* **96**, 282–289 (2006).

Elkhalifa, A.E.O., E. Alshammari, M. Adnan, J.C. Alcantara, A.M. Awadelkareem, N. E. Eltoum, K. Mehmood, B. P. Panda and S.A. Ashraf: Okra (*Abelmoschus esculentus*) as a potential dietary medicine with nutraceutical importance for sustainable health applications. *Molecules,* **26**, 696 (2021).

Fatima, S., M. Asif, T. Ansari, F. Khan, M. Shariq, A. Khan, M. Ikram and M.A. Siddiqui: Evaluation for resistance of some spinach (*Spinacia oleracea* L.) cultivars against root-knot nematode, *Meloidogyne javanica. J. Environ. Biol.,* **43**, 801-809 (2022).

Francl, L.J. and T.A. Wheeler: Interaction of plant parasitic nematodes with the wilt inducing fungi. In: Nematode Interactions India (Ed.: M.W. Khan) Chapman and Hall, India, pp. 1–18 (1993).

Gaur, H.S., R.V. Singh, S. Kumar, V. Kumar and J.V. Singh: Search for nematode resistance in crops. In: AICRP on Nematodes, Division of Nematology, IARI, New Delhi Publication, 4 pages (2001).

Gawade, B.H., A. Sirohi, A.K. Ganguly, R. Kansal, D. Chaudhary and R. Koulagi: Effect of chickpea proteinase inhibitor on survival and parasitism of root-knot nematode, *Meloidogyne incognita. J. Environ. Biol.,* **38**, 347-352 (2017).

Gawade, B.H., S. Chaturvedi, Z. Khan, C.D. Pandey, K.K. Gangopadhyay, S.C. Dubey and V.C. Chalam: Evaluation of brinjal germplasm against root-knot nematode, *Meloidogyne incognita. Indian Phytopath.,* **75**, 449-456 (2022).

Online Copy

Gemede, H.F., G.D. Haki, F. Beyene, A.Z. Woldegiorgis and S.K. Rakshit: Proximate, mineral, and antinutrient compositions of indigenous okra (*Abelmoschus esculentus*) pod accessions: Implications for mineral bioavailability. *Food Sci. Nutr.,* **4**, 223-233 (2015).

Hussain, M., K. Singh, M. Zouhar, P. Rysanek, S. Anwar and M. Kamran: Response of selected okra cultivars to *Meloidogyne incognita. Crop Prot.,* **82**, 1-6 (2016).

Hussey, R.S. and K.R. Barker: A comparison of methods of collecting inocula of *Meloidogyne* spp., including a new technique. *Plant Dis. Rep.,* **57**, 1025-1028 (1973).

Khan, Z., N.K Gautam, B.H. Gawade and S.C. Dubey: Screening of lentil (*Lens culinaris* Medik.) germplasm for resistance to root-knot nematode, *Meloidogyne incognita. Indian J. Genet. Plant Breed.,* **77**, 408-413 (2017).

Khan, Z., N.K Gautam, B.H. Gawade and S.C. Dubey: Evaluation of cowpea (*Vigna unguiculata* L.) germplasm for resistance to root-knot nematode, *Meloidogyne incognita. Nematropica,* **48**, 27-33 (2018).

Kumar, V. and R.K. Jain: Reaction of wild type genotypes of okra against root-knot nematode, *Meloidogyne incognita* Race-1. *Indian J. Nematol.,* **41**, 217-218 (2011).

Kumar, V, M.R. Khan and R.K. Walia: Crop loss estimations due to plant-parasitic nematodes in major crops in India. *Natl. Acad. Sci. Lett.,* **43**, 409–412 (2020).

Kumar, V, A. Kumar, S.K. Dhankhar and S.S. Mann: Screening of okra (*Abelmoschus esculentus*) cultivars for resistant against root-knot nematode, *Meloidogyne incognita*. *Int. J. Agril. Sci.,* **16**, 203-207 (2020).

Mazrou, A.H. Makhlouf, M.M. Hassan, A. Baazeem and M.M. Hassan: Microbial induction of resistance in tomato against root-knot nematode *Meloidogyne javanica* with biocontrol agents. *J. Environ. Biol.,* **41**, 1054-1060 (2020).

Mohanta, S. and K.C. Mohanty: Screening of okra germplasms/varieties for resistance against *Meloidogyne incognita. J. Pl. Prot. Environ.,* **9**, 66-68 (2012).

Nacar, C. and A. Ozarslandan: Resistance of local okra cultivars against *Meloidogyne incognita* (Kofoid & White, 1919) (Nematoda: Meloidogynidae), effects of nematode infestation on growth parameters and leaf macro- micronutrients. *Turk. J. Entomol.,* **45**, 193-206 (2021).

Odeyemi, S., S. Afolami and F. Oguejiofor: Susceptibility of okra accessions to root knot nematode. *Int. J. Veg. Sci.,* **22**, 289-294 (2015).

Rashwan, A.M.A.: Study of genotypic and phenotypic correlation for some agro-economic traits in okra (*Abelmoschus esculents* (L.) Moench). *Asian J. Crop Sci.,* **3**, 85-91 (2011).

Rekha, A.R. and G.N. Gowda: Screening of okra germplasm and varieties for resistance against *Meloidogyne incognita. Indian J. Nematol.,* **30**, 249 (2000).

Salameh, N. and M. Karajeh: Evaluation of okra landraces and accessions response to the root-knot nematode, *Meloidogyne javanica. Jordan J. Agricul. Sci.,* **11**, 735-745 (2015).

Sikora, R.A. and E. Fernandez: Nematode parasites of vegetables. In: Plant Parasitic Nematodes in Subtropical and Tropical Agriculture (Eds.: M. Luc, R.A. Sikora and J. Bridge). CABI Publishing, London, U.K., pp. 319-392 (2005).

Singh, B., P. Karmakar, P. Singh, B.K. Maurya, H. Singh, V. Sagar, G.P. Mishra and S.K. Sanwal: Okra: Breeding and Genomics. *Veg. Sci.,* **50**, 261-273 (2023).

Son, S.H., Z. Khan, S.G. Kim and T.H. Kim: Plant growth-promoting rhizobacteria, *Paenibacillus polymyxa* and *P. lentimorbus* suppress disease complex caused by root-knot nematode and fusarium wilt fungus. *J. Appl. Microbiol.,* **107**, 524–532 (2009).

Southey, J.F.: Laboratory methods for work with plant and soil nematodes. Ministry of Agriculture Fisheries and Food, HMSO, London, U.K., 202 pages (1986).

SPSS for Windows, Version 17.0. Chicago, SPSS Inc.

Taylor, C.E.: *Meloidogyne* interrelationships with micro-organisms. In: Root-knot Nematodes (*Meloidogyne* species) (Eds: F. Lamberti and C.E. Taylor, Academic Press, London, New York, pp. 375-398 (1979).

Taylor, A.L. and J.N. Sasser: Biology, identification and control of root-knot nematodes (*Meloidogyne* spp.). North Carolina State University and United States Agency for International Development, Graphics, 111 pages (1978).

Trudgill, D.L.: Resistance to and tolerance of plant parasitic nematodes in plants. *Ann. Rev. Phytopathol.,* **29**, 167-192 (1991).

Xie X., J. Ling, J. Lu, Z. Mao, J. Zhao, S. Zheng, Q. Yang, Y. Li, G.F. Richard, Y.B. Visser and B. Xie: Genetic dissection of *Meloidogyne incognita* resistance genes based on VIGS functional analysis in *Cucumis metuliferus*. *BMC Plant Biol.,* **24**, 964 (2024).

Ye, D. Y., Y.H. Qi, S.F. Cao, B.Q. Wei and H.S. Zhang: Histopathology combined with transcriptome analyses reveals the mechanism of resistance to *Meloidogyne incognita* in *Cucumis metuliferus. J. Plant Physiol.,* **212**, 115-124 (2017).

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