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Identification and Distribution of Root-knot Nematode Species Associated with Eggplant Crop in District Aligarh, Uttar Pradesh, India

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A B S T R A C T

A study was managed to determine the distribution, incidence and intensity of nematode disease of eggplant in ten (10) localities of Aligarh (U.P.) India. It was observed that the crop of eggplant was affected with root-knot nematodes in all of these localities. Hundred percent (100%) frequency was observed in Dhanipur, Atrauli and Bhakraula. It was maximum frequency. Our investigation was under taken to determine infestation, distribution and identification of *Meloidogyne* species associative eggplant. The disease incidence in all locations was being represented higher by our results. All root-samples of eggplant observed in all 10 localities were found infected with root-knot nematodes. However, wide variations were found with regard to disease intensity in all the observed root samples. The range of gall index and egg mass index were reported from two to five and two to five (2 to 5 and 2 to 5) respectively. *Meloidogyne arenaria*, *M. incognita* and *M. javanica* were identified from all infested areas associated with eggplant. All three species were observed either individually or in aggregated populations. *Meloidogyne incognita* showed off the best frequency (86.36%) and was the dominant species in the studied areas. *Meloidogyne javanica* (79.09%) was the second most common species. Finally, *M. arenaria (44.54%)* was also a common species.

***Key words*:** *Meloidogyne spp.,* Root-knot nematodes, Eggplant, Distribution, Frequency, Incidence, Population

Eggplant (*Solanum melongena* L.) is a well-known and most valuable vegetable crop. It's widely grown-up in tropical and subtropical regions of throughout the world, be associated with solanaceae family [1] especially in Asia, Europe, Africa and America [2]. Prominently, the second largest producer country of eggplant throughout the world is India and after that China. Its production in India is 13557.8 MT from an area of 711.3 ha [3]. In spite of, ranks of India for eggplant production in whole world is second after China, until now its production in per unit area is comparatively low [4]. Eggplant fruits have a substantial nutritional value by cause of its composition such as dietary fibers and minerals like iron, calcium, sodium, potassium [5-8]. Besides this, a rich source of ascorbic acid and phenolics are reported in eggplant fruits [9]. Total soluble sugars are prominently occurred in oblong-fruited varieties of eggplant, although greater concentration of phenols, amide proteins, anthocyanins, free reducing sugars and glycoalkaloids are present in the long-fruited varieties [10]. The white eggplant is reported to be good for diabetic patients [11]. It has the highest antioxidant capacity among the top ten vegetables [12]. Eggplant is also valuable for its medicinal properties and has got decholesterolizing properties, primarily due to the presence of 65.1% linoic and linolenic poly-unsaturated fatty acids present in seeds and flesh of fruits. Magnesium and potassium salts in fruits also have impact decholesterolizing action [13].

Several pathogens, including root knot nematodes, are major pest for vegetables all over the world; they invade on eggplants and cause significant yield losses in several regions of the world [14-16]. There are many species and races of these animals infect eggplants, but four species are widely distributed in whole world namely *Meloidogyne arenaria*, *M. javanica*, *M. incognita* and *M. hapla* [17] from which former three species are most common in warm regions [18-20] particularly. The annual considered crop losses by cause of major plant parasitic nematodes were estimated to the sum of Rs. 242.1 billion in India. An average annual loss may occur from 19.6% to 60% [21].

Being of polyphagous nature, root knot nematodes have a serious impact on growth and yield of plants. They develop galls on the roots (Fig 1) by way of hyperplasia and hypertrophy [22-24]. So, they disturbed various metabolic activities like water and nutrient uptake which leads to

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stunted growth of plants [Fig 2] and subsequently the drastic reduction in size of leaves, flowers, fruit and quality of fruits. Similar adverse impact goes on to vigor and yield also [25]. The disease severity like nematode incidence and intensity depends on so many factors like the species and races, soil type, moisture availability along with some other physico-chemical properties [26-27]. So, this is an important aspect to report and assess the distribution and identification of the root-knot nematode surveyed from all localities. Earlier in 2014, Gautam *et al.* [28] reported the status of root knot nematode in some districts of Chhattisgarh state of India. Apart from this, in the considered study, efforts have also been conferred to explore incidence and intensity of root-knot nematodes from Aligarh (U.P.), India.

Fig 1 Below ground symptoms knotted roots on an eggplant caused by root-knot nematode

Fig 2 Above ground symptoms "stunting growth" on leaves of an eggplant caused by root knot nematode

MATERIALS AND METHODS

Field observation

An examination was attended in several locations of nearby Aligarh and its city area to evaluate the incidence of nematode disease of eggplant. Several samples of infected host plants from all localities were collected randomly in the time of observation of the eggplant crop and put up them into polythene bags with proper labeling. These samples were brought to the laboratory of the department of Botany D.S. College, Aligarh for critical thorough examination of the existence of galls as standard procedure.

Root sampling

The infected roots were free from soil and washed in tap water very gently. After then these were dried and computed and then fully soaked up with an aqueous solution of phloxine-B 0.15 gram per liter to 15 minutes. Again, the roots were rinsed with tap water for staining of egg masses. After that, these visibly totaled for galls and egg masses. And subsequently gall index and egg mass index was also calculated by scale [29].

Scales	Galls	Reaction
0	0	Immune or extremely resistant
1	1to2	Resistant
2	3to10	Moderate resistant
3	11 to30	Moderate susceptible
4	31 to100	Susceptible
5	>100	Highly susceptible

The frequency and incidence evaluation

The occurrence of frequency (%) and incidence (%) of the root-knot nematode on each eggplant surveyed from all localities were calculated analyzed with the help of the following formulas:

$$\text{Percentage of frequency (\%)} = \frac{\text{No. of infected fields with root-knot nematode}}{\text{Total No. of observed fields}} \times 100$$

$$\text{Percentage of frequency (\%)} = \frac{\text{No. of infected roots with root-knot nematode}}{\text{Total No. of observed plants}} \times 100$$

Maintaining the inoculum

Some isolated inoculum from each location of selected fields was maintained on eggplant var. Pusa Kranti in a greenhouse of D.S. College, Aligarh. Two weeks old seedlings were inoculated with inoculum in clay pots containing autoclaved soil and collected chopped infected roots from the field. Further, the inoculum was cultured and sub cultured to procure pure form of root-knot nematode. In order to make pure culture of the root-knot nematode populations, fresh grown seedlings of single egg mass were picked out by hand then inoculation was made onto the eggplant. Further, new eggplant seedlings were inoculated with cultured and sub cultured inoculum with about 20 egg masses, and each obtained from pure culture in furtherance of keeping up the enough inoculum for doing more experimental analysis.

Identification of Meloidogyne species

The collected *Meloidogyne* species from each location were identified with the help of applying the perineal pattern method [30]. And also was maintained in the greenhouse. Mature females were cut up from larger galls present on the roots of eggplants. There were 10-12 slides of perineal pattern prepared from each sample or location and investigated under binocular microscope to study of their morphological characteristics, hence identified the species on the basis of perineal pattern characteristics [30].

RESULTS AND DISCUSSION

Incidence of disease on eggplant

A survey governed to estimates the frequency, incidence and intensity of the root-knot nematode disease on eggplant in terms of GI/EMI for 10 localities in and around the district of Aligarh are given in (Table 1). There were 10 localities in and around Aligarh, where the eggplant crop was found infected with the root-knot nematode. A total of 150 fields selected for the study, out of them 124 fields were found infested with root-knot nematodes. Therefore, the overall reported frequency of occurrence of the disease was 82.6%. Frequency of occurrence was diverse at different individual fields. The frequency of occurrence was found maximum i.e. (100%) from Dhanipur, Atrauli and Bhakraula followed by 93.3% in Gangiri and Khair respectively. In the fields of the other studied areas, as Gopi and Bijauli, the frequency of occurrence of the disease was 73.3% and 86.6% independently. It was followed by 66.6% and 60.0% in Gonda and Mohrauni. There was a minimum frequency of occurrence of the disease observed in Tappal i.e., 53.3%. So, the fields surveyed in all the studied areas showed 82.6% on an average (Table 1).

Table 1 Frequency distributions of root-knot nematodes in different localities in and around Aligarh

Locations	Occurrence			Incidence			Intensity
	No. of fields		Frequency	No. of samples of root		Frequency	GI/EMI
	Surveyed	Infested		Collected	Infected		
Dhanipur	15	15	100.0	120	110	91.6	5-5/5-5
Atrauli	15	15	100.0	120	108	90.0	5-5/5-5
Bijauli	15	13	86.6	120	90	75.0	4-5/4-5
Gangiri	15	14	93.3	120	95	79.1	3-5/3-5
Gopi	15	11	73.3	120	80	66.6	2-5/2-5
Tappal	15	8	53.3	120	72	60.0	2-4/2-4
Khair	15	14	93.3	120	91	75.3	4-5/4-5
Bhakraula	15	15	100.0	120	109	90.8	5-5/5-5
Mohrauni	15	9	60.0	120	105	87.5	4-5/4-5
Gonda	15	10	66.6	120	88	73.3	4-4/4-4

Incidence frequency of root-knot nematodes on eggplant

Different localities showed varied incidence frequency on eggplant surveyed. The highest frequency of incidence was recorded from Atrauli, Bhakraula and Dhanipur on the basis of collected samples of the roots. It was 90.0%, 90.8% and 91.6% in all the three localities respectively followed by Mohrauni (87.5%) and Gangiri (79.1%). There was 73.3%, 75% and 75.3% frequency of incidence recorded from Gonda, Bijauli and Khair respectively. The observed frequency from Gopi was 66.6% and lowest was being recorded from Tappal (60%). The Overall, frequency of incidence of nematode disease was 82.6% which itself reveals that the eggplant is an excellent susceptible host to root-knot nematode species. The intensity of nematode disease on eggplant at several surveyed locations of Aligarh set upon average gall and egg mass index was commonly higher (Table 1). Furthermore, variations were also found in case of intensity as per field. Both galls and egg mass index varied from 2 to 5. Top most intensity of disease in terms of average galls and egg mass index was observed at Dhanipur (5/5) Atrauli (5/5) and Mohrauni (5/5) where it was highest. The gall and egg mass indices were found 4-5 in fields of Bijauli, Khair and Mohrauni areas. It was assessed 4-4 from Gonda and 3-5 from Gangiri. Least possible average gall and egg mass index (2-4) was observed from Tappal followed by Gopi (2-5), so minimum incidence was observed from Gopi. As a result, the intensity of the disease was top most in Dhanipur (5/5), Atrauli (5/5) and Mohrauni (5/5) and lowest in Tappal (Table 1).

All the three root-knot nematode species were found associated with eggplant with variations of their frequencies. Frequently, *M. incognita* was greater than *M. javanica* and *M. arenaria* on eggplant. However, frequency of *M. arenaria* was lesser than the other two species on eggplant, where its frequency in Tappal (20.8%) was lower than *M. javanica* (66.6%) and *M. incognita* (77.77%) respectively. However, the highest frequency of *M. arenaria* occurred in the Dhanipur area (44.5%) (Table 2). All the three species of root-knot nematodes (*M. arenaria M. javanica* and *M. incognita*) were present in single or mixed forms in all localities on eggplants. Population of *M. arenaria* was reported singly from Dhanipur, Bhakraula and Atrauli areas. Frequency of *M. incognita* (86.3%), was better than *M. javanica* (79.0%) and *M. arenaria* (44.5%) (Table 2). Seven combinations of species were reported from the area in mixed states. *M. incognita* mixed with *M. javanica* or *M. arenaria* was present in all surveyed localities of different studies areas. Three combinations of species i.e., *M. incognita*, *M. javanica* and *M. arenaria also* occurred in mixed populations as recorded from Gopi, Tappal, Khair, Bijauli, Gangiri, Mohrauni and Gonda (Table 2).

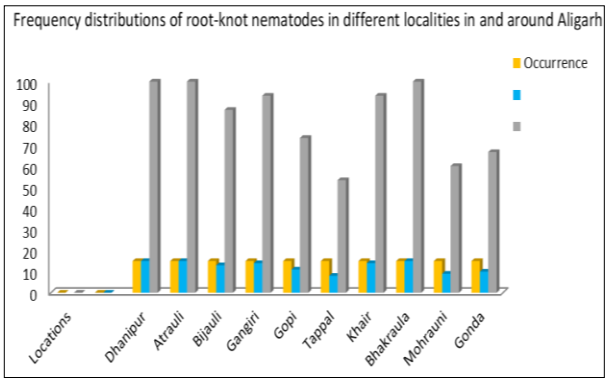
Identification of the species

On the basis of perineal pattern characteristics, all the three species of root-knot nematodes i.e., *M. incognita*, *M. javanica* and *M. arenaria* were identified from eggplant infected roots of different areas. The species were found either singly or in mixed populations. Out of the three, *M. incognita* was more frequent compared to the rest of both species however; *M. arenaria* was found less at surveyed

areas. Their frequency also varied in the areas of occurrence. *M. incognita*, *M. javanica* and *M. arenaria* were commonly present in all studied areas. Among the studied areas, highest frequency of *M. incognita* was found in Dhanipur 86.3% followed by Bhakraula 85.7%, Atrauli 83.3%, Mohrauni 82.8%, Gangiri 81.0%, Khair 80.2%, Gonda 79.5%, Bijauli 78.8%, Gopi 78.7%, and lowest in Tappal areas 77.7%. However, Frequency of *M. javanica* was also highest in Dhanipur 79.0% followed by Bhakraula 78.8%, Atrauli 76.8%, Gangiri 74.7%, Mohrauni 71.4%, Khair 70.3%, Bijauli 70.0%, Gonda 69.3%, Gopi 68.7%, and lowest in fields of Tappal 66.6%. *M. arenaria* was also more frequently found in Dhanipur 44.5% as compared to Bhakraula 42.2% Atrauli 39.8% Mohrauni 36.1% Gangiri 34.7% Bijauli 32.2% Khair 31.8% Gonda 29.54% Gopi, 26.2% and Tappal 20.8% respectively (Table 2).

Table2 Species frequency distributions of root-knot nematodes in different localities in and around Aligarh

Locations	Number of infected root samples	Infected root samples with single or mix population			Percent frequency of species in total infected root samples		
		M. arenaria	*M. javanica*	*M. incognita*	*M. arenaria*	*M. javanica*	*M. incognita*
Dhanipur	110	49	87	95	44.54	79.09	86.36
Atrauli	108	43	83	90	39.81	76.85	83.33
Bijauli	90	29	63	71	32.22	70.00	78.88
Gangiri	95	33	71	77	34.73	74.73	81.05
Gopi	80	21	55	63	26.25	68.75	78.75
Tappal	72	15	48	56	20.83	66.66	77.77
Khair	91	31	64	73	31.86	70.32	80.21
Bhakraula	109	46	82	90	42.20	78.89	85.71
Mohraini	105	38	75	87	36.19	71.42	82.85
Gonda	88	26	61	70	29.54	69.31	79.54



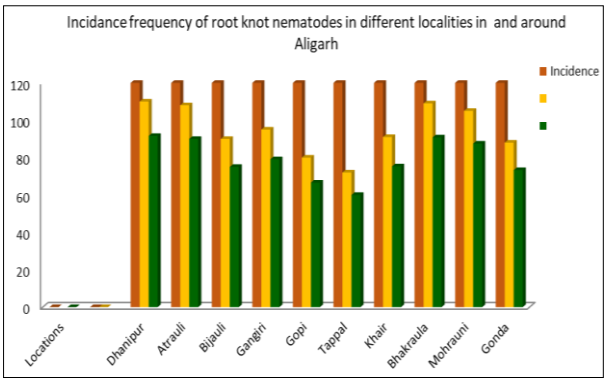


Fig 1 Below ground symptoms knotted roots on an eggplant caused by root-knot nematode

The results of the present study display the current position of incidence and occurrence of the root-knot nematodes (*Meloidogyne* species) in some areas of Aligarh district. During the study, it was observed that the growth of eggplant was exceedingly varied due to the presence of galls on roots with relevant root systems. This investigation contributes the evaluation of distribution, occurrence of frequency, identification, incidence and intensity of nematodes associated with the eggplant crop of these locations. Earlier reports are also available with regard to their (*Meloidogyne incognita*, *M. javanica* and *M. arenaria*) close association with causing widespread damage to the crop in the developing countries [31]. It is challenging to control these pests through management practices like rotation of crop and resistant cultivars due to their wide spread host range and concomitant occurrence of virulent species and races [32-34]. Ehwaeti *et al*. advocated as the reason behind such rapid nematode multiplication on good hosts [35]. It helps to increase the difficulty to prevent the crop damage particularly in the growing season. *Meloidogyne incognita* is the topmost prevalent among their other species on vegetable crops throughout the world where they live endoparasitically in roots and produce galls on roots causing critical damage [36-39]. Highest average nematode frequency has also been observed on eggplant surveyed in different areas. The curious occurrence of this species on eggplant grown in Aligarh district clearly encountered severe damage to this crop. Our presented work corroborates with the reports of so many researchers [27], [40-42] on the upper most accurate and relative frequency of *Meloidogyne incognita* with high notable value of *M. javanica* among root-knot nematodes from Aligarh district. Results of the incidence, distribution identification and population assessed the *Meloidogyne* species. Probably, it appears to be the most important species accompanying harm to eggplant yield production in the district and may be considered to be the most important parasite for the crops under regional conditions. Three species of *Meloidogyne* were reported viz. *M incognita*, *M. javanica* and *M. arenaria*. All occurred either separately or collectively in all localities of the district. Likewise, [43] have been observed similar results of *Meloidogyne incognita* and *M. arenaria* from Aligarh district. Similar results were reported by [40-41] where *Meloidogyne incognita* and *M. arenaria* demonstrated a high percentage of occurrences. *M. incognita* has been documented as the upper most frequent and extensive species of root-knot nematode from locations and establishes an enormous part of the root-knot nematode population in Aligarh district. The rank of *Meloidogyne arenaria* is third for frequency. It is relatively less common

in these areas. In this manner, *Meloidogyne incognita* and *M. arenaria* are also together frequent and conceivably detrimental species of the area. Additionally, *Meloidogyne javanica* is also obtained in the area with lesser frequency than *Meloidogyne incognita* but higher as compared to *Meloidogyne arenaria*. All obtained species are the usual for these areas therefore; management of these species must be efficient [44]. The incidence of *Meloidogyne* species on eggplant crops has been increased significantly as the holding allotted to this crop has grown. Results of our work are in conformity with investigations made by Sasser [45] who noted a study of significant genera of plant nematodes including the genus *Meloidogyne* and obtained its noteworthy representation in various regions of the developed and developing countries in the whole world. Our findings also clearly determine that *Meloidogyne incognita M. javanica* and *M. arenaria* are widely distributed across Aligarh district and associate a wide host range. The present study demonstrated a high incidence, intensity of disease and level of infestations. It would certainly be reflecting in the productivity of the eggplant grown in the region. It should be taken into account in the management strategies of disease.

CONCLUSION

According to the survey done, Aligarh district was found to be at high risk of root knot-nematode disease of eggplants due to its geographic location and climatic conditions. As a result, adequate precautions should be taken to manage the disease below the economic threshold level. Crop rotation of solanaceous crops with non-solanaceous crops and organic amendments is strongly required to minimize disease occurrence and severity.

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Conflict of interests

The authors declare that they do not have any established competing financial interest or personal relationship that may seem to have affected the work discussed in this research paper.

LITERATURE CITED

1. Roychowdhury R, Tah J. 2011. Differential response by different parts of *Solanum melongena* L. for heavy metal accumulation. *Plant Sci. Fed*. 1(6): 80-83.
2. Demir K, Bakir M, Sarıkamis G, Acunalp S. 2010. Genetic diversity of eggplant (*Solanum melongena*) germplasm from Turkey assessed by SSR and RAPD markers. *Genet. Mol. Research* 9(3): 1568-1576.
3. Anonymous. 2014. Indian Horticulture Database. Data on area, production and productivity on brinjal in India. National Horticulture Board, New Delhi.
4. Jayaramaiah KM, Mahadevakumar, Chairth Raj AP, Janardhana GR. 2013. PCR based detection of Phomopsisvexans (Sacc. and Syd.)- The causative agent of leaf blight and fruit rot disease of brinjal (*Solanum melongena* L.). *Int. Jr. Life Sciences* 7(1): 17-20.
5. United States Department of Agriculture. 2014. USDA National Nutrient Database for Standard Reference 2014; http://www.nal.usda.gov/fnic/foodcomp/search.
6. Raigón MD, Prohens J, Muñoz-Falcón JE, Nuez F. 2008. Comparison of eggplant landraces and commercial varieties for fruit content of phenolics, minerals, dry matter and protein. *Jr. Food Compos Analysis* 21(5): 370-376.
7. Mohamed AE, Rashed MN, Mofty A. 2003. Assessment of essential and toxic elements in some kinds of vegetables. *Ecotoxicol Environ Saf*. 55(3): 251-260.
8. Sanchez Castillo CP, Englyst HN, Hudson GJ, Lara JJ, Solano ML, Munguía JL, James WP. 1999. The non-starch polysaccharide content of Mexican foods. *Jr. Food Compos Analysis*. 12(4): 293-314.
9. Vinson JA, Hao Y, Su X, Zubik L. 1998. Phenol antioxidant quantity and quality in foods: vegetables. *Jr. Agric. Food Chemistry* 46: 3630-3634.
10. Somawathi KM, Rizliya V, Wijesinghe DGNG, Madhujith WMT. 2014. Antioxidant activity and total phenolics content of different skin coloured brinjal (*Solanum melongena*). *Trop. Agric. Research* 26(1): 152-161.
11. Tripathi M, Singh P, Praveen P, Pandey VR, Singh H. 2014. Antioxidant activities and biochemical changes in different cultivars of brinjal (*Solanum melongena* L.). *Am. Jr. Plant Physiology* 9: 24-31.
12. Cao G, Sofic E, Prior RL. 1996. Antioxidant capacity of tea and common vegetables. *Journal of Agricultural and Food Chemistry* 44: 3426-3431.
13. Bhat KL. 2011. *Brinjal*. Daya Publishing House, New Delhi.
14. Kumar V, Khan MR, Walia RK. 2020. Crop loss estimations due to plant-parasitic nematodes in major crops in India. *Natl. Acad. Sci. Lett*. https://doi.org/10.1007/s40009-020-00895-2.
15. Ornat C, Sorribas FJ. 2008. Integrated management of root-knot nematodes in Mediterranean Horticultural crops. *In*: (Eds). Ciancio A., Mukerji K. G. Integrated management and biocontrol of vegetable and grain crops nematodes: integrated management of plant pests and diseases, Vol. 2. Dordrecht, the Netherlands, Springer. pp. 295-319.
16. Kamran M, Anwar SA, Javed M, Khan SA, Sahi GH. 2010. Incidence of root-knot nematodes on tomato in Sargodha, Punjab, Pakistan. *Pak. Jr. Nematology* 28: 253-262.
17. Menjivar RD, Dababat AA, Sikora RA. 2012. Biological control of *Meloidogyne incognita* on cucurbitaceous crops by the non-pathogenic endophytic fungus *Fusarium oxysporum* strain162. *Int. Jr. Pest Management* 57(3): 70-72.
18. Taylor AL, Sasser JN, Nelson LA. 1982. Relationship of climate and soil characteristics of geographical distribution of *Meloidogyne* species in agricultural soil. IMP publication, Raleigh, North Carolina.0
19. Netscher C, Sikora A. 1990. Nematode's parasites of vegetables. *In*: lant parasitic nematodes in sub-tropical and tropical Agriculture. (Eds). Sikora, RA Luc, M. and Bridge J. CAB international 1990. pp 237-283.
20. Karajeh MR, Sellami SH. 2010. Root-knot nematodes: Their species, Races and Distribution. *In*: Nematodes of plant in

Arabian countries. (Eds) Abu- Gharbieh W. Al – Hazmi A. Stephan Z. and Dowaba A. Published by Arab Society for Plant protection, Amman, Jordan. pp 215-244.
21. Gowda MT, Rai AB, Singh B. 2017. Root knot nematode. A threat to vegetable production and its management. IIVR Technical Bulletin No. 76, IIVR, Varanasi. pp 32.
22. Azam T, Hisamuddin. 2008. Histo-pathological study of the roots of tomato infected with *Meloidogyne incognita*. Proceedings of the 31st All India Botanical Conference and International Symposium on Plant biology and Environment: Changing Scenario, December 17-19, 2008; Department of Botany, University of Allahabad, Allahabad, India. pp 67.
23. Escobar C, Barcala, M, Cabrera J, Fenoll C. 2015. Overview of root-knot nematodes and giant cells. *Adv. Bot. Res*. 73: 1-32. doi: 10.1016/bs.abr.2015.01.001.
24. Palomares-Rius JE, Escobar C, Cabrera J, Vovlas A, Castillo P. 2017. Anatomical alterations in plant tissues induced by plant-parasitic nematodes. *Frontier in Plant Science* 8: 1987. doi: 10.3389/fpls.2017.01987.
25. Anwar SA, Mckenry MC, Javed N. 2006. The root-knot nematodes: destructive pests of crops. Proceedings of International Symposium on Sustainable Crop Improvement and Integrated Management. Organized by Faculty of Agriculture, University of Agriculture, Faisalabad, Pakistan. pp 216-222.
26. Desaeger, J, Rao MR. 2000. Infection and damage potential of *Meloidogyne javanica* on *Sesbania sesban* in different soil types. *Nematology* 2: 169-178.
27. Asif M, Rehman B, Parihar K, Ganai MA, Siddiqui MA. 2015. Effect of various physico-chemical factors on the incidence of root knot nematode *Meloidogyne* species infesting tomato in district Aligarh (Uttar Pradesh). *Indian Jr. of Plant Sciences* 10: 234-243.
28. Gautam SK, Sahu G, Verma BK, Poddar AN. 2014. Status of root knot nematodes (*Meloidogyne* species) disease in vegetable crops of some districts of central plain region of Chhattisgarh state. *Afr. Jr. Microbiological Research* 8(16): 1663-1671.
29. Taylor AL, Sasser JN. 1978. Identification and control of root-knot nematodes (*Meloidogyne* species) crop. Publisher Department of Plant Pathology, North Carolina State University, Unitae State Agrency for International Development. Raleigh, North Carolina USA. pp 111.
30. Eisenback JDH, Hirschmann JN, Sasser, Triantaphyllou AC. 1981. A more complete characterization of the four most common species of root-knot nematodes (*Meloidogyne* spp.) with pictorial Key. IMP Publication Raleigh. 1981; N.C.U.S.A.
31. Sasser JN. 1979. Economic importance of Meloidogyne in tropical countries. *In*: Root-knot nematode (Meloidogyne spp.) systematic, biology, and control. (Eds.) F. Lamberti and C. E. Taylor). Academic Press, London. pp 359-374.
32. Jepson SB. 1987. Identification of root-knot nernntodes (*Meloidogyne* species). Wallingford, UK, CAB International. pp 265.
33. Fargette M, Braaksma R. 1990. Use of the esterase phenotype in the taxonomy of the genus *Meloidogyne*. 3. A study of some "B" race lines and their taxonomic position. *Revue Nematology* 13: 375-386.
34. Roberts PA. 1992. Current status of the availability, development and use of host plant resistance to nematodes. *Jr. Nematology* 24: 213-227.
35. Ehwaeti ME, Phillips MS, Trudgill DL. 1998. Dynamics of damage to tomato by *Meloidogyne incognita*. *Fundamentals of Applied Nematology* 21: 627-635.
36. Abawi GS, Widmer TL. 2000. Impact of soil health management practices on soil-borne pathogens, nematodes and root diseases of vegetable crops. Department of Plant Pathology, NYSAES, Cornell University, Geneva, USA G.S. *Appl. Soil Ecology* 15: 37-47.
37. Davis RF, Earl HJ, Timper P. 2003. Interaction of root-knot nematode stress and water stress in cotton. *University of Georgia, Cotton Res. Ext. Rep*. 2003: 312-315.
38. Anwar SA, McKenry MV. 2010. Incidence and reproduction of *Meloidogyne incognita* on vegetable crop genotypes. *Pakistan Journal of Zoology* 42: 135-141.
39. Anwar SA, Mahdi MM, McKenry MV, Qadir A. 2013. Survey of plant-parasitic nematodes associated with four vegetable crops cultivated within Tunnels. *Pakistan Journal of Zoology* 45(3): 595-603.
40. Khan M, Wajid MR Khan, Khan AA. 1984. Identity of root –knot nematodes on certain vegetables of Aligarh District in Northern–India. *Int. Nematol. Network Newsletter* 1: 67.
41. Khan AA, Khan MW. 1991. Race composition of *Meloidogyne incognita* and *M. arenaria* population in vegetable fields in Uttar Pradesh. *Journal of Nematology* 23: 615-619.
42. Esfahani MN. 2009. Distribution and identification of root-knot nematode species in tomato fields. *Mycopath* 7: 45-49.
43. Ganaie MA, Khan TA. 2016. Race composition of Meloidogyne species infecting *Pseuderanthemum atropurpureum* in Aligarh district of Western Uttar Pradesh. *Asian Journal of Nematology* 5: 8-13.
44. Kayani MZ, Mukhtar T, Hussain MA, Ul - Haque MI. 2013. Infestation assessment of root knot nematodes (*Meloidogyne* species) associated with cucumber in the Pothowar region of Pakistan. *Crop Protection* 47: 49-54.
45. Sasser JN. 1989. Plant parasitic nematodes: the farmer's hidden enemy. Raleigh, North Carolina: North Carolina State University. pp 115.