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Screening and evaluation of tomato (*Solanum lycopersicon* L.) cultivars against root-knot nematode (spp. *Meloidogyne incognita* and *Meloidogyne javanica*)

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Abstract
Twenty tomato cultivars were screened to study their reaction to root-knot nematode (*Meloidogyne incognita* and *Meloidogyne javanica)* in microplot experiment. At 60 days after nematode infected plants, whole plants were uprooted, washed and ranked for root galling on the basis of root-knot index (1-5 scales). All the tomato varieties had shown varying degree of responses. Twenty tomato cultivars were screened against root knot nematode observation recorded on number of galls/plants, root-knot index, root-knot reaction, shoot length, Shoot weight, root length and root weight in root and reactions of the varieties to the test nematode, *Meloidogyne incognita* and *Meloidogyne javanica.* The observation was recorded at 60 days after transplanting nematode inoculation and the root galling on the basis of root knot index (1- 5 scale) was given to respect cultivars. Out of twenty varieties for three cultivars, eight varieties and nine cultivars, moderately resistance, susceptible and highly susceptible respectively, *Meloidogyne incognita* and *Meloidogyne javanica*. After the infection of root knot nematode in roots of tomato significantly reduced in growth characters like root weight, root length, shoot weight and shoot length against *Meloidogyne incognita* and *Meloidogyne javanica*.

Keywords: Tomato, nematode, *Meloidogyne incognita*, *Meloidogyne javanica*, screening, resistance, susceptible

Introduction
Tomato (*Solanum lycopersicon* L., 2n=2x=24) belongs to the genus *Solanum* under the *Solanaceae* family and owing to its high nutritive value and diversified use. Tomato is the world's largest vegetable crop after potato and sweet potato, but it tops the list of canned vegetables. In world, tomato is second most widely cultivated vegetable crop after potato. (Anonymous, 2020) [2].

Tomato (*Solanum lycopersicon* L.) is affected by various disease caused mainly by fungi, bacteria and nematodes. Nematodes found to be very fatal infective agents and cause severe yield loses. Root-knot nematodes (*Meloidogyne* spp.) are phytopathogenic obligate endoparasites nematodes that infect many plant species and cause serious damage to agricultural crops per year (Abad *et al.*, 2008) [1]. Root-knot nematodes (*Meloidogyne* species), one of the most important groups of plant parasitic nematodes, have an exceedingly wide host range and interact with other plant pathogens.

The low yield is attributable a number of abiotic and biotic factors including bacteria, fungi, virus and particularly nematodes (Bird *et al.*, 2003) [4] which reduce quality and quantity of tomato. Among nematodes, the root knot nematode, Meloidogyne incognita is a major pest and is reported to cause yield loss of 35% (Manjuatha *et al*., 2017) [8] in India. Damage to plants is influenced by root penetration, development, reproduction potential and inoculums density of M. incognita in adjacent soil (Shahab *et al*., 2011) [10]. It also alters the host physiology and on severe infestations can kill the tomato plant outright (Kamran *et al*., 2010) [6]. Various approaches such as chemical application, good agricultural practices (GAP), resistance breeding etc. have been devised to manage RKN.

The degree of root galling generally depends on the magnitude of Meloidogyne population density, host plant species and cultivar. Severe nematode infections result in decreased yield of tomato and the quality of the marketable products is reduced and cause tissue breakdown, deformation or discoloration. Several researchers have suggested the utilization of resistant varieties is one of the cheap, primary, economically feasible and environmentally benign methods to combat *M. incognita* menace in tomato as compared to nematicides (Darban *et al*.,

2003, Tariq *et al*., 2016, Sujatha *et al*., 2017) [5, 13, 12]. It has been found that root-knot nematodes may enter susceptible and resistant tomato varieties in about equal numbers. Hence breaking of resistance in tomato cultivars to M. incognita may occur naturally or by selection of tomato plants with one or more resistant genes (Khan *et al*., 2000) [7]. The primary objective of the current research was to evaluate the available tomato genotypes by screening method against root knot nematode *M. incognita*.

Materials and Methods

Seeds of twenty tomato (*Solanum lycopersicon* L.) cultivars were procured from Main vegetable research station (MVRS), Anand Agricultural University, Anand. Microplot culture experiment was carried out in CRD design with three replications in the green house of Department of Nematology, B. A. College of Agriculture, Anand, during Rabi 2020-21. Earthen sterilized pots of 15 cm diameter were filled with denematised, sterilized sand, Soil and FYM mixture in 2:1:1 ratio @ 1kg/pot. Seeds of each cultivars were sown in the earthen pots containing steam sterilized soil. *M. incognita* and *M. javanica* pure culture was initiated from single egg masses and propagated on roots of highly susceptible tomato genotype in the greenhouse. Eggs were collected from galled roots of tomato and inoculated with the potted plants maintained as pure culture. These seedlings are ready of 20 days then transfer inoculated microplot. This was done two months prior to the start of the experiment.

Observations recorded

Evaluation of tomato cultivars against root-knot nematode Observations were recorded on number of galls/plants, Root-knot index, root-knot reaction, shoot length, shoot weight, root length and root weight in root and reactions of the varieties to the test nematode, *Meloidogyne incognita* and *Meloidogyne javanica* were determined as per the ISTA Rules.

Screening of tomato varieties against root-knot nematode

At 60 days after inoculation, inoculated plants were removed from the pot soil carefully. Roots were washed free from soil and other adhering particles by gentle stream of water. Roots were observed under a stereoscopic microscope and the numbers of galls produced on each plant roots were counted. Tomato varieties were categorized as per the Root-knot Index Scale given below

Table 1: Root-knot Index Scale (Taylor and Sasser, 1978)

Scale	No. of gall/eggs/egg mass	Reaction
1	0 (no gall)	Highly resistance
2	1-10	Resistant
3	11-30	Moderate resistance
4	31-100	Susceptible
5	> 100	Highly susceptible

Statistical methods

The observed data were statistically analysed by appropriate statistical procedures as suggested for completely randomized Design under microplot conditions by Steel and Torrie (1960) [11].

Results and Discussion

Evaluation of tomato cultivars against root knot nematode for Nematological and growth character at 60 DAI. (Spp. *Meloidogyne incognita* and *Meloidogyne javanica*)

(A) Screening of tomato cultivars in response to root knot nematode *Meloidogyne incognita* and *Meloidogyne javanica*

The present investigation was carried out at Department of Biochemistry in collaboration with Department of Nematology, Anand Agricultural University, Anand. The seeds of tomato cultivars for the present study were procured from the MVRS, Anand Agricultural University, Anand.

Twenty tomato varieties were screened to study their reactions to root-knot nematode against to species of *Meloidogyne incognita* and *Meloidogyne javanica*. All the tomato varieties had shown varying degree of responses. The nematode reproduction in the nematode induced micro-plot culture experiment was observed and data are presented in Table 2(A). The observation was recorded at 60 days after transplanting nematode inoculation and the root galling on the basis of root knot index (1- 5 scale) was given to respect varieties. Out of twenty varieties for three cultivars (GP-11, GAT-5 and GT-7), eight cultivars (ATL 16-06, GACT-1, ATL 17-06, IET II FROM DT-2, 2015/TOLC ORES-5, NTL-12, selection from GP-11,

DVRT-2) and nine cultivars (GAT-4, ATL 97-26, ATL 11-05, AVTOV 1007, Kashi Aman, Thai 18-27, Thai 18-27(R)-, GAT-5(0), ATL 16-09) moderately resistance, susceptible and highly susceptible respectively Meloidogyne incognita. As per report of Taylor and Sasser, (1978) our results are indicated that moderately resistant, susceptible, highly susceptible having 3, 4 and 5 scale indexes, respectively.

The nematode reproduction in the nematode induced micro-plot culture experiment was observed and data are presented in Table 2(B). The observation was recorded at 60 days after transplanting nematode inoculation and the root galling on the basis of root knot index (1- 5 scale) was given to respect varieties. Out of twenty Results and Discussion 90 varieties for three cultivars (GP-11, GAT-5 and GT-7), eight varieties (ATL 16-06, GACT-1, ATL 17-06, IET II FROM DT-2, 2015/TOLC ORES-5, NTL-12, selection from GP-11, DVRT-2) and nine varieties (GAT-4, ATL 97-26, ATL 11-05, AVTOV 1007, Kashi Aman, Thai 18-27, Thai 18- 27(R)-, GAT-5(0), ATL 16-09) moderately resistance, susceptible and highly susceptible respectively *Meloidogyne javanica*. As per report of Taylor and Sasser, (1978) our results are indicated that moderately resistant, susceptible, highly susceptible having 3, 4 and 5 scale indexes, respectively. Thus above results suggested the cultivars GT-7, GAT-5 and GP-11 were register for moderately resistance in response to both the species (*Meloidogyne incognita* and *Meloidogyne javanica*) and eight cultivars (ATL 16-06, GACT-1, ATL 17-06, IET II FROM DT-2, 2015/TOLC ORES-5, NTL-12, selection from GP-11, DVRT-2) and nine cultivars (GAT-4, ATL 97-26, ATL 11-05, AVTOV 1007, Kashi Aman, Thai 18-27, Thai 18-27(R)-, GAT-5(0), ATL16-09) also recorded for susceptible and highly susceptible for (*Meloidogyne incognita* and *Meloidogyne javanica*). The highly susceptible genotypes supported greatest number of juveniles penetrated and completed their development to maturity as shown by high

gall index with high reduction in root length and root weight present while in resistant cultivar limited numbers of juveniles were able to penetrate, develop to maturity and lay egg masses.

Plant growth reduction in tomato genotypes might be due to severe root galling and arrested root system by nematode infection. The ability of galled roots lead to modification in absorption of water and nutrient from soil and their translocation to foliage resulting in foliage chlorosis and stunting of vegetative growth. The arrested root system could not be able to fully explore the soil for water and nutrients. The results observed here are in agreement with the result obtained by Patra and Nayak (2019) [9] have studied Screening and evaluation of tomato varieties against root-knot nematode, Meloidogyne incognita.

Similar results are also reported by Sujatha *et al.* (2017) [12]. They have studied the screening of tomato genotypes for root-knot nematode (Meloidogyne incognita Kofoid and White Chitwood) in tomato.

Table 2(A): Screening of tomato cultivars in response to root knot nematode *Meloidogyne incognita*

Table: Screening of tomato Year: 2020-2021									
Sr. no	**Cultivars**	***M. incognita* INP:273/200 cm3Soil (Source: Main Vegetable Research Station, AAU, Anand) No. of Root**							
			Galls/plant Repetitions				**e of**		**-Knotinde**
		1	**2**	**3**	**4**	**5**	**Gall**		**x**
1	ATL 16-06	78	91	32	89	45	32-91	S	4
2	Selection from GP-11	48	38	97	85	99	38-99	S	4
3	DVRT-2	59	70	74	55	42	42-74	S	4
4	GAT-4	111	129	148	133	147	111-148	HS	5
5	GAT-5	18	15	22	27	25	15-27	M R	3
6	GT-7	18	16	28	26	24	18-28	M R	3
7	Kashi Aman	157	128	142	149	163	128-157	HS	5
8	GAT-5(0)	136	149	188	196	132	132-188	HS	5
9	NTL 12	38	46	63	96	67	38-96	S	4
10	IET II From DT-2	41	86	52	36	74	36-86	S	4
11	GP-11	12	28	16	27	22	12-28	M R	3
12	ATL 97-26	118	136	149	125	163	118-163	HS	5
13	AVTOV 1007	125	145	136	147	134	125-147	HS	5
14	Thai 18-27	128	163	147	137	174	128-174	HS	5
15	ATL 16-09	142	176	169	178	189	142-189	HS	5
16	2015/TOLCORES-5	36	49	58	98	67	36-98	S	4
17	Thai 18-27(R)-	128	146	186	149	136	128-186	HS	5
18	ATL 17-06	37	49	66	78	36	36-78	S	4
19	ATL 11-05	124	136	187	169	175	124-187	HS	5
20	GACT-1	38	40	33	97	56	33-97	S	4

Table 2 (B): Screening of tomato cultivars in response to root knot nematode *Meloidogyne javanica*

Table: Screening of tomato Year: 2020-2021									
Sr.no	**Cultivars**	***M. javanica* INP:218/200 cm3 Soil (Source: Main Vegetable Research Station, AAU, Anand)**							
			No. of galls/plant Repetitions				**Range**	**Reaction**	**Root- knot**
		1	**2**	**3**	**4**	**5**	**of gall**		**index**
1	ATL 16-06	38	98	73	92	91	38-98	S	4
2	Selection from GP-11	63	96	72	97	85	63-97	S	4
3	DVRT-2	39	99	78	49	55	39-99	S	4
4	GAT-4	134	142	196	132	121	121-196	HS	5
5	GAT-5	20	27	26	21	17	17-26	MR	3
6	GT-7	25	28	22	17	15	15-28	MR	3
7	Kashi Aman	185	165	127	152	117	117-185	HS	5
8	GAT-5(0)	154	196	147	153	175	147-196	HS	5
9	NTL 12	45	69	72	67	88	45-88	S	4
10	IET II From DT-2	34	96	75	35	58	34-96	S	4
11	GP-11	18	17	22	25	37	17-37	MR	3
12	ATL 97-26	148	136	175	185	145	136-185	HS	5
13	AVTOV 1007	118	173	153	124	115	115-173	HS	5
14	Thai 18-27	182	127	135	148	186	127-186	HS	5
15	ATL 16-09	128	119	187	167	134	128-187	HS	5
16	2015/TOLC-ORES-5	39	75	85	96	47	39-96	S	4
17	Thai 18-27(R)-	118	167	175	125	121	118-175	HS	5
18	ATL 17-06	88	34	73	91	48	34-91	S	4
19	ATL 11-05	119	138	140	125	167	119-167	HS	5
20	GACT-1	41	49	57	96	48	41-96	S	4

(B) Evolution of root knot nematode on growth characters of tomato cultivars: The data depicted in Table 3 indicated that the root length was affected by *Meloidogyne incognita* was varied from 17.49 to 29.60 cm significantly the higher and no significant difference were recorded among GAT-5 (29.60 cm), GT-7(28.82 cm) and ATL16-06(27.86cm).

The root weight of twenty cultivars was observed and data are presented in Table 3. The result indicated that the cultivar GAT-5 was registered with significantly the highest root weight (6.81 g) at 60 DAI. Which was followed by GT-7(5.37 g), ATL-16- 06(4.54 g), GAT- 4(3.98 g) in response to *Meloidogyne incognita*. However, the minimum root weight was found for Kashi Aman (3.0 g). Non-significant difference was recorded among Thai18-27(R)-, Selection from GP-11, ATL 16-09, GP-11, IET II from DT-2, ATL11-05, AVTOV 1007, ATL 17-06, DVRT-2, GAT-5(0), NTL-12, 2015/TOLC ORES5, ATL 97-26, GACT-1, Kashi Aman.

The maximum and minimum shoot length was found for GAT-5(45.52 cm) and Thai 18-27(23.95 cm), respectively. The shoot length of GT-7 (42.02 cm), GP-11(40.89 cm), ATL 16-06 (40.29 cm) and IET II From DT-2(39.06 cm) were found significantly at par with other. The significantly minimum shoot length for Thai 18-27 (23.95 cm) which was significantly at par with Kashi Aman (26.75 cm), GAT-5(0) (26.64 cm), Thai 18-27 (R)- (26.54), ATL 11-05 (25.96 cm), ATL 16-09 (25.33 cm) and Thai 18-27 (23.95 cm).

The shoot weight was varied between 13.53 to 29.04 (g) among all tomato cultivars. The significantly maximum and non-significant difference recorded between GAT-5 (29.04 g) and GACT-1(27.91 g). The minimum shoot weight was found for GAT-5(0) (13.53 g) which was followed by Kashi Aman (14.78 g) and ATL-16-09 (14.84 g).

The data depicted in Table 3 indicated that the root length was affected by *Meloidogyne javanica* was varied from 15.45 to 27.17 cm. Significantly the higher and non-significant difference were recorded among GAT-5 (27.17 cm), ATL 16-06 (26.80 cm), DVRT-2 (26.79 cm) and GT-7 (26.38 cm).

The root weight of twenty cultivars was observed and data are presented in Table 4.2. The result indicated that the cultivar GAT-5 was registered with significantly the highest root weight (6.69 gm) at 60 DAI. Which was followed by GT-7 (5.26 gm) and GP11 (5.13 gm) in response to *Meloidogyne javanica*. However, the minimum root weight was found for 2015/TOLC ORES-5 (2.97 gm). Non-significant difference was recorded among GAT-4 (3.82 gm), Thai 18-27(R)- (3.8 gm), ATL 16-06 (3.79 gm), ATL 17-06 (3.76 gm), NTL 12 (3.72 gm), Kashi Aman (3.55 gm), GACT-1 (3.55 gm), Thai 18-27 (3.54 gm), GAT-5(0) (3.43 gm), AVTOV 1007 (3.34 gm), ATL 16-09 (3.33 gm), DVRT 2 (3.28 gm), ATL 11-05 (3.28 gm), ATL 97-26 (3.27 gm), Selection From GP-11 (3.25 gm) and IET II From DT-2 (3.19 gm).

The maximum and minimum shoot length was found for GAT-5 (43.99 cm), Thai 18-27(22.56 cm). The shoot length of ATL 16-06 (40.87 cm), GT-7 (40.7 cm), GP11(38.78 cm), NTL 12 (37.58 cm) and 2015/TOLC ORES-5 (36.12 cm) were found significantly at par each other. The significantly minimum shoot length for Thai 18-27 (22.56 cm), which was significantly at par with AVTOV 1007 (26.94 cm), Kashi Aman (26.36 cm), ATL 16-09 (25.38 cm) and ATL 11-05 (22.77 cm).

The shoot weight was varied between 13.98 to 26.95 (g) among all tomato cultivars. Significantly the maximum and non-significant difference recorded amongGAT-5 (26.95 g), GP-11 (23.36 g), ATL 16-06 (23.13 g), GT-7 (23.09 g) and 2015/TOLC ORES-5 (23.03 g).

The minimum shoot weight was found for GAT-5(0) (13.98 g), which was followed by ATL 16-09 (14.89 g), Kashi Aman (14.52 g) and Thai 18-27(R)-(14.45 g).

Significant differences were noticed among tomato genotypes in decline of top and root growth and increase of J2 population in *M. incognita* and *M. javanica*. infested plants at uprooted after 60 days of transplantation. The extent of reduction in plant growth of tomato genotypes inflicted by nematodes was directly proportionate to increase in reproduction potential of *M. incognita* and *M. javanica* on specific tomato genotypes/cultivars/variety/germplasm.

Plant growth reduction in tomato genotypes might be due to severe root galling and arrested root system by nematode infection. The decrease is possibly due to improper uptake and transport of elements, nutrients and water resulted from nematode infection. The results observed here are in agreement with the Patra and Nayak (2019) [9]. Similar results are also reported by Sujatha *et al*. (2017) [12] have studied the Screening of Tomato Genotypes for Root Knot Nematode (*Meloidogyne incognita Kofoid* and White Chitwood) in tomato.

Similar results are also reported by Bendezu and Starr, (2003) [3]. They have reported two types of mechanisms for nematodes resistance in plants (1) pre-infection resistance, where the nematodes cannot enter the plant roots due to the presence of toxic or antagonistic chemicals in root tissue, and (2) post-infection resistance, in which nematodes are able to penetrate roots but fail to develop. Post-infection resistance is often associated with an early hypersensitive reaction (HR), in which rapid localized cell death in root tissue around the nematode prevents the formation of a developed feeding site, leading to resistance.

Table 3: Effect of root knot nematode on growth characters of tomato cultivars

		M. incognita				*M. javanica*			
Sr.no	**Cultivars**	**RL (cm)**	**RW (g)**	**SL (cm)**	**SW (g)**	**RL (cm)**	**RW (g)**	**SL (cm)**	**SW (g)**
1	ATL 16-06	27.86	4.54	40.29	23.92	26.80	3.79	40.87	23.13
2	Selection from GP- 11	27.67	3.53	36.71	21.77	22.82	3.25	33.27	21.55
3	DVRT-2	27.62	3.27	35.21	22.92	26.79	3.28	32.71	21.62
4	GAT-4	20.66	3.98	27.46	16.89	20.22	3.82	34.19	15.86
5	GAT-5	29.60	6.81	45.52	29.04	27.17	6.69	43.99	26.95
6	GT-7	28.82	5.37	42.02	23.61	26.38	5.26	40.70	23.09
7	Kashi Aman	20.33	3.00	26.75	14.78	20.97	3.55	26.36	14.52
8	GAT-5(0)	19.71	3.25	26.64	13.53	18.97	3.43	28.19	13.98
9	NTL 12	27.57	3.10	27.81	18.59	23.90	3.72	37.58	18.58
10	IET II From DT-2	22.17	3.46	39.06	16.08	21.91	3.19	33.75	15.06
11	GP-11	24.15	3.49	40.89	23.17	25.92	5.13	38.78	23.36
12	ATL 97-26	17.69	3.06	28.30	15.81	15.45	3.27	28.13	15.29
13	AVTOV 1007	22.49	3.33	27.87	16.56	23.50	3.34	26.94	17.95
14	Thai 18-27	22.41	3.81	23.95	16.67	22.07	3.54	22.56	15.17
15	ATL 16-09	20.77	3.51	25.33	14.84	20.85	3.33	25.38	14.89
16	2015/TOLC ORES-5	22.88	3.09	36.56	24.18	24.01	2.97	36.12	23.03
17	Thai 18-27(R)-	24.48	3.54	26.54	19.18	22.65	3.80	28.89	14.45
18	ATL 17-06	26.16	3.29	33.45	23.61	25.15	3.76	34.10	22.70
19	ATL 11-05	22.25	3.41	25.96	25.51	20.84	3.28	22.77	17.02
20	GACT-1	26.34	3.03	29.81	27.91	22.13	3.55	29.70	22.99
S.Em.		0.630	0.128	1.175	0.666	0.700	0.170	0.898	0.641
C.D at 5%		1.799	0.365	3.356	1.902	1.998	0.484	2.564	1.830
C.V %		4.62	6.11	6.32	5.69	5.39	7.82	4.89	5.87

Conclusion

This study indicated that the moderately resistant cultivar (GAT-5, GT-7 and GP-11) are therefore recommended for cultivation under integrated production systems because these would be a profitable alternative for the production of healthy, toxic free tomato to the consumers and in developing new resistant cultivars.

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