Data Article

Phytonematode Diversity in Tomato Crops of Chittoor District, Andhra Pradesh, India: A Comprehensive Survey, Distribution, and Community Analysis

ABSTRACT

The present study was undertaken to analyze the distribution and community analysis of important plant parasitic nematodes associated with the vegetable crop tomato in Chittoor District of Andhra Pradesh. The study revealed that maximum infestation is observed in somala mandal and least in Chowdepalle mandals of Chittoor District of Andhra Pradesh. Plant parasitic nematodes viz., *Meloidogyne incognita*, *Hoplolaimus* spp., and *Tylenchorynchus* spp. etc. was found to be associated with tomato crops. It has been observed that *M. incognita* population was found to be maximum in tomato crops at Chittoor Districts of Andhra pradesh. The prominence value was found to be maximum for root knot nematode in tomato crops having 8.76/200 cc. The data also revealed that *M. incognita* absolute frequency in tomato was 100% and absolute density is around 87.60% while the genera *Hoplolaimus* showed the least occurrence frequency of 40% and absolute density of 1.56%. From these studies it can be interpreted that *M. incognita* is most predominant nematode and cause damage substantially to tomato crop grown in Chittoor District of Andhra Pradesh.

Keywords: Tomato, Meloidogyne incognita, *Hoplolaimus* spp., and *Tylenchorynchus* spp., community analysis

1. INTRODUCTION

Plant Parasitic nematodes cause great destruction to most of the cultivated crops in tropical as well as subtropical regions [11] [5]. Globally, India ranks second in tomato production next to China Vegetable production in India is estimated to be around 183.17 million in 2019-2020. India produced 20,573 million tonnes of tomatoes in 2019-2020, with an area of 812 million hectares and a productivity of 25.33 MT/ha (second advance estimates). Tomato, Onion, Chilli, and Brinjal are among the major crops grown in Andhra Pradesh. In Andhra Pradesh tomato crop has reported an area of 17.84 million hectares and with the productivity of 312.34 million tonnes in 2017-2018 [15]. On a commercial basis, tomato crop is grown in practically all of India as a vegetable crop.

Amongst plant-parasitic nematodes, root-knot nematodes (RKN, included within the genus *Meloidogyne*) belong to a relatively small but crucial polyphagous group of highly adapted obligate plant pathogens. They are distributed worldwide, parasitizing nearly every species of higher plants [14] [7].

During a survey conducted by [12] in Andhra Pradesh, India, soil and root samples were collected from major crops across 33 different locations, resulting in the identification of 23 genera of plant parasitic nematodes. Among these nematodes, *Rotylenchulus reniformis*, *Bitylenchus brevilineatus*, *Macrosposthonia ornata*, and *Basirolaimus indicus* exhibited the widest distribution. Notably, *Heterodera cajani* and *H. zeae* were documented for the first time in the coastal and Rayalaseema regions of the State during this survey. These shed light on the diversity and distribution of plant parasitic nematodes in various agricultural areas of Andhra Pradesh, contributing to a better understanding of their presence and potential impact on crops in the region. [9] surveyed Andhra Pradesh and recorded the presence of root-

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knot nematode (*Meloidogyne incognita* and M. *Javanica*), *reniform* nematode (*Rotylenchus reniformis*), spiral nematode (*Helicotylenchussincies*), Lesion nematode (*Pratylenchusdelattrei*), *Tylenchorynchuscapitatus*, *Xiphinema* spp., *Criconema* spp. and *Aphelenchus* spp. infecting vegetables (chilli, tomato, okra, cucurbits, and cluster bean).

Despite the economic loss they cause, they are relatively overlooked because their occurrence is poorly understood by small scale farmers [6]. The symptoms of RKN in inflicted tomato plants such as yellowing, stunted growth and wilting may also be attributed to environmental stress or nutrient deficiency [4,16,17]. Poor awareness and management of RKN have resulted to declining tomato productivity in major tomato producing areas in rayalaseema zone of Andhra Pradesh. Furthermore, there is limited information associated with RKN prevalence and how they are perceived by tomato growers in Chittoor District. Therefore, this study focused on assessing the prevalence, incidence, and farmers awareness on RKN affecting tomato in Chittoor District of Andhra Pradesh.

2. MATERIAL AND METHODS

A roving survey across various mandals in Chittoor District of Andhra Pradesh, with the primary objective of assessing the severity of phyto nematode infestation in tomato crops. Soil and root samples were diligently collected from the surveyed regions for subsequent extraction and identification of phyto nematodes. Throughout the survey, diligent care was taken to collect the soil and root samples, ensuring their preservation in polyethylene bags to maintain their integrity during transportation to the laboratory for further analysis.

The infestation of phyto nematodes in tomato crops across farmers fields in various mandals of Chittoor District, Andhra Pradesh. As nematode distribution can be highly variable within a single field, multiple samples were collected from different areas within each field. A systematic and structured sampling approach, known as the zig-zag manner, was adopted during both surveys and experiments to maintain consistency and reliability. This sampling method was chosen due to its consideration of the field's nature and the distribution patterns of nematodes, ensuring a comprehensive representation of the nematode population in the study area.

The infestation of phyto nematodes in tomato crops cultivated in farmers fields across various mandals in Chittoor District, Andhra Pradesh. To quantify the extent of infestation accurately, the average of 15 observations was calculated for each village, and this data was then expressed as a percentage of plant infestation. This approach allowed for a comprehensive assessment of the nematode infestation levels in the study area, providing valuable insights into the potential impact on tomato crops and informing effective management strategies. Per cent, plant infestation was worked out by using the following formula.

$$\text{Per cent Plant Infestation} = \frac{No\ of\ Plant\ \ Infested}{Total\ \ No\ of\ Plant\ \ Taken} \times 100$$

2.1 Collection of soil and root samples:

The collection of soil and root samples from 10 to 15 randomly selected spots within the root zone of standing crops. A shovel was used to facilitate the collection process. Subsequently, composite samples comprising 200 cc of soil and 5 g of roots were carefully placed in polythene bags with appropriate labeling for identification. In addition to the samples, relevant information regarding the crop, locality, and soil conditions was collected and recorded in a datasheet. To maintain sample integrity, all collected specimens were stored under refrigerated conditions. Later, these preserved samples were subjected to thorough analysis to determine the presence of plant parasitic nematodes. This meticulous approach ensures accurate data acquisition and contributes to a comprehensive assessment of nematode populations in the study area, thereby aiding in further research and the development of effective crop management strategies.

2.2 Estimation of nematode population in soil samples:

Soil sample of 200 cc was washed thoroughly and processed using combined “Cobb’s sieving and Baermann’s funnel method” [2] as given below.

1) Two hundred cc of soil was taken in 1000 ml beaker and sufficient quantity of water was added to make soil solution.
2) This was stirred thoroughly and allowed to stand for heavier particles to settle down.
3) Then the soil solution was passed through a set of sieves of 100, 250, 325 and 400 mesh sizes, respectively.
4) Residue from 325 and 400 mesh sieves were collected and poured over a tissue paper spread on a wire gauge and placed on Baermann’s funnel.
5) Level of water in the Baermann’s funnel was maintained to keep the tissue paper wet and left undisturbed for 48 hours

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6) After incubation of 48 hours, the volume of suspension was made to 200 ml, out of which 10 ml was pipetted out and used for counting of various plant parasitic nematodes present. Nematode population from this was finally estimated for 200 cc soil.

2.3 Estimation of nematode population in soil samples:

Nematode populations in 5 g of roots were estimated by root incubation method [2] as explained below:

2.3.1 Procedure:

1. Roots were washed.
2. Washed roots were cut into small bits of 2.5 cm and split longitudinally.
3. These were then placed over tissue paper spread on a wire gauge and kept in a petri plate.
4. Level of water was maintained in petri plate and left undisturbed or 48 hours.
5. Later, the suspension in the Petri plate was collected and observed for nematodes using stereo binocular microscope.

2.4 Counting the number of nematodes:

The number of nematodes in an aqueous suspension was determined by using a counting dish. A five cm diameter glass Petri plate was used as a counting dish. Squares were made on the outer surface of the bottom of the dish to facilitate counting.
A 10 ml volume of aqueous suspension from the beaker was placed into the Petri plates. Nematodes were counted in all squares under a stereo binocular microscope. After counting, the suspension was transferred back to the mother container. The counting of each sample was repeated three times in the same manner. The mean number of nematodes per 10 ml was determined by averaging the counts.

2.5 Morphological identification of Phyto nematodes:

1) The roots infested with root-knot nematode were washed.
2) The females were dissected out from well-developed galls of the root under stereo-binocular microscope and transferred to Petri plate containing water. The posterior portion of the female was cut with a perennial pattern-cutting knife [13] and the body contents were cleaned.
3) Cleaned posterior portion of the female was further trimmed and transferred to drop of glycerine on a clean microscopic slide.
4) A cover slip was placed on it, sealed with nail polish and observed under stereo-binocular microscope. The species confirmation was done based on the perennial pattern as described by [3].

3. RESULTS AND DISCUSSION

The roving survey was conducted in tomato crop growing in District of Andhra Pradesh *viz.*, Chittoor to record the per cent damage of phyto nematodes. The collected data on phyto nematode infestation was presented as the mean incidence of phyto nematodes damaged plants (**Table 1).** *Meloidogyne* spp, *Tylenchorhynchus* spp and *Hoplolaimus* spp are identified upto genera level by following the key indices of *Goldi*, 1889, *Cobb*, 1913 and Daday, 1905 [8].

The per cent infestation of phyto nematodes in tomato crops was recorded as 70, 72, 69, 67 and 63 in Punganur, Somala, Baireddipalle, Santhipuram, and Chowdepalle mandals, respectively, among those surveyed in Chittoor District **(Table 1).**

Various mandals were surveyed in Chittoor District to assess the extent of phyto nematode infestation in tomato crops. The recorded percentage of infestation in different villages within these mandals was as follows: In Punganur Mandal, Madanapalle village had an infestation of 64%, Bodevaripalle village had 76%. Meanwhile, in Somala Mandal, Irikipenta village had 73 and Nellimanda village had an infestation of 71%. Moving on to Baireddipalle Mandal, Golla chimanapalle village was affected at 76, and Kamanapalle village at 62%. In Santhipuram Mandal, Chinnaradoddi village had 62%, and Regadadinnenalle village had 71%. Lastly, in Chowdepalle Mandal, Peddakondamari village experienced 62% infestation, and Diguvanlli village had 64% infestation **(Table 1).**

The recorded infestation percentages vary across the mandals, with Somala showing the highest infestation at 72%, followed closely by Punganur at 70%. Chowdepalle, Santhipuram and Baireddipalle also exhibit relatively high infestation levels ranging from 63% to 69% respectively **(Table 1).**

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Among the two highest infested villages, Bodevaripalle of Punganur mandal and Golla Chimanapalle in Baireddipalle Mandal had exhibited an infestation rate of 76%. This indicates a significant presence of phyto nematodes, posing a substantial threat to tomato crops in those villages. Moving on to the two lowest infested villages, Chinnaradoddi in Santhipuram Mandal and Kamanapalle showed a relatively lower infestation rate of 62%, suggesting better control over phyto nematodes in tomato crops **(Table 1).**

From the survey data from 10 samples analyzed, it was evident that *Meloidogyne* spp had the highest prevalence, constituting the predominant nematode with a maximum total soil population of 841. Following this, Stunt nematodes, *Tylenchorhynchus* spp, were found with a population of 104, and lance nematodes, *Hoplolaimus*, was present with a population of 15. The occurrence of *Meloidogyne* spp was notably the highest, accounting for 84.1 of the nematode population, while *Tylenchorhynchus* spp represented 10.4 and *Hoplolaimus* merely 1.5 of the total nematode occurrences. These findings underscore the prevalence of *Meloidogyne* spp compared to the other nematodes studied in the surveyed samples **(Table 2)**.

The maximum soil population of *Meloidogyne* (126/200 cc soil) was recorded in Golla Chimanapalle village of Baireddipalle mandal, as compared to other places, followed by Irikipenta of Somala (112/200 cc soil), Nellimanda village of Somala (109/200 cc soil), Bodevaripalle village of Punganur (102/200 cc soil) and Madanapalle of Punganur (96/ 200 cc soil) **(Table 2)**.

Nematode populations in the root samples collected from the rhizosphere of tomato fields in Chittoor District, Andhra Pradesh, were analyzed. Among the nematodes identified, *Meloidogyne* spp was the predominant species with the highest total root population recorded at 732. Following *Meloidogyne* spp, *Tylenchorhynchus* was found with a population of 77, and lance nematode, *Hoplolaimus*, was observed with a population of 9. Notably, the mean occurrence of *Meloidogyne* spp accounted for 73.2, the highest compared to the other nematodes in the samples. These findings highlight the prevalence of *Meloidogyne* spp in the rhizosphere of tomato fields in the Chittoor District **(Table 2)**.

The maximum root population of *Meloidogyne* spp (167/5 g of the root) was recorded in Nellimanda village of Somala mandal, as compared to other places, followed by Irikipenta of Somala (153/5 g of root), Diguvapalli of Chowdepalle (94/5 g of root) and Peddakondamari of Chowdepalle (83/ 5 g of root), Madanapalle of Punganur (59/5 g of root), respectively **(Table 2)**.

The study involved the collection of soil and root samples from 10 locations within Chittoor District. The phyto nematodes identified in the samples were *Meloidogyne* spp, *Tylenchorhynchus* spp, and *Hoplolaimus* spp. The distribution and densities of these nematodes in different locations. In soil samples, the absolute frequencies of *Meloidogyne* spp, *Tylenchorhynchus* spp, and *Hoplolaimus* spp were 100, 100, and 40, respectively. The corresponding absolute frequencies in root samples were approximately 100, 80, and 50, respectively **(Table 3)**. The absolute densities of *Meloidogyne* spp, *Tylenchorhynchus* spp, and *Hoplolaimus* spp in soil samples were 87.60, 10.83 and 1.56, respectively, while in root samples, they were 89.48, 9.41 and 1.1, respectively. Additionally, prominence values were calculated for each nematode species, resulting in 8.76, 1.08 and 0.09 in soil samples and 8.94, 0.84 and 0.07 in root samples for *Meloidogyne* spp, *Tylenchorhynchus* spp, and *Hoplolaimus* spp, respectively.

The above phyto nematode distribution and community analysis is similar with [8] in a survey of 75 soil and root samples from major crops in 33 localities in Andhra Pradesh, India, 23 plant parasitic nematode genera were identified. *Rotylenchulus reniformis*, *Bitylenchus brevilineatus*, *Macrosposthonia ornata* and *Basirolaimus indicus* were the most widespread. *Heterodera cajani* and H. zeae were recorded for the first time in the coastal and Rayalaseema regions of the State.

The above phyto nematode distribution and community analysis is similar with [9] surveyed Andhra Pradesh and recorded the presence of root-knot nematode (*Meloidogyne incognita* and M. *Javanica*), *reniform* nematode (*Rotylenchus reniformis*), spiral nematode (*Helicotylenchussincies*), Lesion nematode (*Pratylenchusdelattrei*), *Tylenchorynchuscapitatus*, *Xiphinema* spp., *Criconema* spp. and *Aphelenchus* spp. Infecting vegetables (chilli, tomato, okra, cucurbits, and cluster bean).

[12] The survey covering Anantapur, Chittoor, and Guntur, Kadapa, Kurnool, Mahaboobnagar, Nalgonda, Nellore, and Prakasam districts in Andhra Pradesh investigated the association of plant parasitic nematodes with economically important crops in these regions. The analysis of community structure revealed distinct patterns: *Meloidogyne incognita* was a significant issue in Anantapur and Chittoor, affecting crops like tomato, pomegranate, banana, chilli, muskmelon, brinjal, mulberry, and gourds. *Rotylenchulus reniformis* prevailed in Guntur and Mahaboobnagar, linked to turmeric, castor, red gram, and cotton. In Kadapa, Kurnool, Nalgonda, and Prakasam, *Helicotylenchus* spp. was dominant, associated with sunflower, banana, chilli, sugarcane, cotton, and tomato. Notably, *M. graminicola* was exclusively found in

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Nellore district. Cluster analysis revealed the similarity index of mandals across different districts. Among the nematodes, *Helicotylenchus* spp. obtained the highest prominence value (7.65) in Kadapa district, followed by *M. incognita* (7.33) in Chittoor district, while the lowest prominence value was observed for *R. reniformis* (3.53) in Mahaboobnagar district.

[1] A comprehensive survey conducted in central Saudi Arabia revealed a total of 18 plant-parasitic nematode genera associated with the six plant species studied. Among these, the most prevalent species were *Meloidogyne* (45.8%), *Aphelenchus* (16.6%), *Tylenchorhynchus* (12.9%), *Aphelenchoides* (12%), *Ditylenchus* (10.3%), *Pratylenchus* (3.7%), and *Tylenchus* (2.3%).

Table 1. Infestation of phyto nematodes in tomato crop in Chittoor District of Andhra Pradesh.

District	Mandal	Village	Latitude	Longitude	Fields	Total No of Plants	Infested Plants	%Damage	Mean for villages	Mean for mandals
Chittoor	Punganur	Madanapalle	13.5033° N	78.5131 °E	1	15	11	73	64	70
			13.5041° N	78.5139 °E	2	15	10	67		
			13.5048° N	78.5139 °E	3	15	8	53		
		Bodevaripalle	13.4815° N	78.5524 °E	1	15	12	80	76	
			13.4823° N	78.5538 °E	2	15	10	67		
			13.4819° N	78.5532 °E	3	15	12	80		
	Somala	Irikipenta	13.4663° N	78.7821 °E	1	15	13	87	73	72
			13.4671° N	78.7829 °E	2	15	10	67		
			13.4679° N	78.7826 °E	3	15	10	67		
		Nellimanda	13.5217° N	78.7896 °E	1	15	13	87	71	
			13.5228° N	78.7885 °E	2	15	11	73		
			13.5221° N	78.7883 °E	3	15	8	53		
	Baireddipalle	Golla Chimanapalle	13.1436° N	78.5613 °E	1	15	13	87	76	69
			13.1448° N	78.5619 °E	2	15	10	67		
			13.1443° N	78.5623 °E	3	15	11	73		
		Kamanapalle	13.0980° N	78.6100 °E	1	15	10	67	62	
			13.0995° N	78.6102 °E	2	15	10	67		
			13.0986° N	78.6119 °E	3	15	8	53		
	Santhipuram	Chinnaradoddi	12.8706° N	78.3617 °E	1	15	8	53	62	67
			12.8718° N	78.3626 °E	2	15	10	67		
			12.8701° N	78.3621 °E	3	15	10	67		
		Regadadinnepalle	12.9055° N	78.3724 °E	1	15	11	73	71	
			12.9067° N	78.3735 °E	2	15	11	73		
			12.9051° N	78.3729 °E	3	15	10	67		
	Chowdepalle	Peddakondamari	13.4162° N	78.6943 °E	1	15	9	60	62	63
			13.4171° N	78.6951 °E	2	15	9	60		
			13.4169° N	78.6949 °E	3	15	10	67		
		Diguvapalli	14.8579° N	77.9671 °E	1	15	11	73	64	

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			14.8584° N	77.96 75°E	2	15	10	67		
			14.85787 °N	77.9681 °E	3	15	8	53		

Table 2. Mean of occurrence of phyto nematodes from rhizosphere soil and root samples of tomato crop in Chittoor District of Andhra Pradesh.

District	Sample	Mandal	Village	Meloidogyne	Tylenchorhynchus	Hoplolaimus
Chittoor	Soil	Punganur	Madanapalle	96	12	2
			Bodevaripalle	102	11	-
		Somala	Irikipenta	112	24	3
			Nellimanda	109	19	8
		Baireddipalle	Golla Chimanapalle	126	1	2
			Kamanapalle	51	4	-
		Santhipuram	Chinnaradoddi	46	6	-
			Regadadinnepalle	86	13	-
		Chowdepalle	Peddakondamari	41	4	-
			Diguvapalli	72	10	-
			Total	**841**	**104**	**15**
			Mean	**84.1**	**10.4**	**1.5**
District	**Sample**	**Mandal**	**Village**	**Meloidogyne**	**Tylenchorhynchus**	**Hoplolaimus**
Chittoor	Roots	Punganur	Madanapalle	59	4	-
			Bodevaripalle	36	10	-
		Somala	Irikipenta	153	19	1
			Nellimanda	167	13	4
		Baireddipalle	Golla Chimanapalle	17	-	2
			Kamanapalle	41	-	-
		Santhipuram	Chinnaradoddi	43	14	1
			Regadadinnepalle	39	5	-
		Chowdepalle	Peddakondamari	83	3	-
			Diguvapalli	94	9	1
			Total	**732**	**77**	**9**
			Mean	**73.2**	**7.7**	**0.9**

Table 3. Community analysis of phyto nematodes from rhizosphere soil and root samples of tomato crop in Chittoor District of Andhra Pradesh.

District	Sample	Name of species	Absolute Frequency	Absolute Density	Prominance value
Chittoor	Soil	**Meloidogyne**	100	100	40
		Tylenchorhynchus	87.6	10.83	1.56
		Hoplolaimus	8.76	1.08	0.09
District	**Sample**	**Name of species**	**Absolute Frequency**	**Absolute Density**	**Prominance value**
Chittoor	Roots	Meloidogyne	100	80	50
		Tylenchorhynchus	89.48	9.41	1.1
		Hoplolaimus	8.94	0.84	0.07

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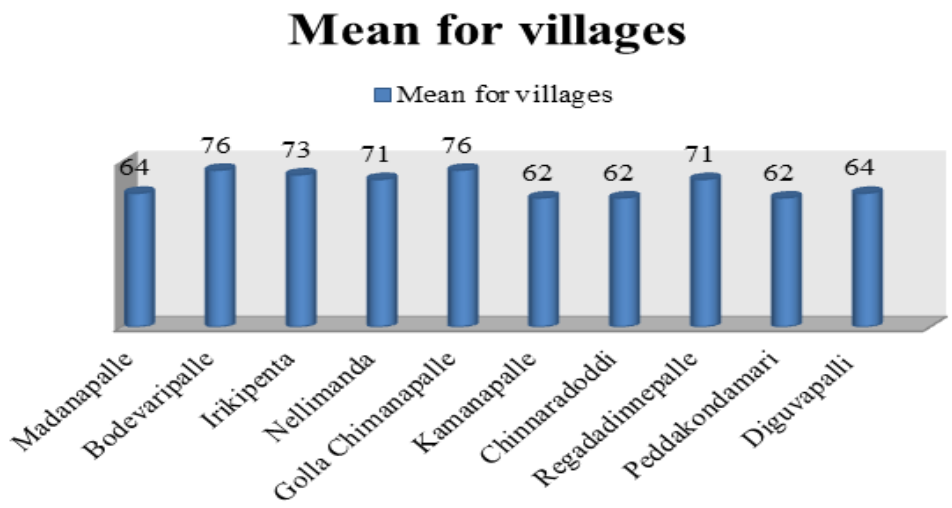

Fig. 1. Mean per cent infestation of phyto nematodes in various villages of Chittoor District of Andhra Pradesh.

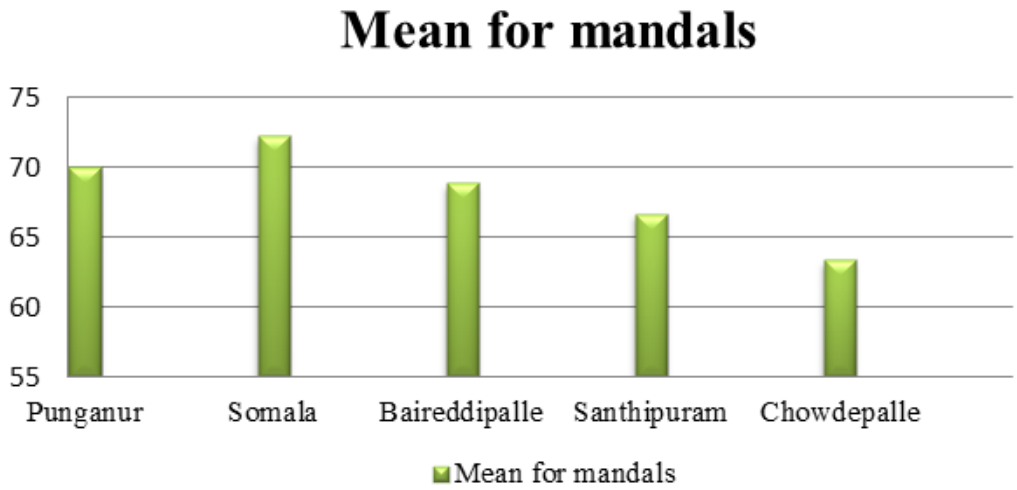

Fig. 2. Mean per cent infestation of phyto nematodes in various mandals of Chittoor District of Andhra Pradesh.

4. CONCLUSION

In conclusion, the findings of the present study indicate a significant phytonematode infestation rate of approximately 72% in Chittoor District, Andhra Pradesh. The results highlight the urgent need for proper nematode management strategies, especially in Somala mandal, which recorded the highest infestation levels. Effective measures are necessary to control phytonematodes and safeguard the tomato crop from potential damage. Conversely, Chowdepalle exhibited a comparatively lower infestation rate of 63%, attributing this to the farmers' awareness and implementation of appropriate care practices. The dominant nematode genus affecting the tomato crop was Meloidogyne spp, while Tylenchorhynchus and Hoplolaimus spp were also identified as infesting the crop. These findings shed light on the prevailing nematode diversity and distribution in tomato crops, providing valuable insights for targeted management approaches and sustainable agricultural practices in the region.

REFERENCES

1. Almohithef AH, Al-Yahya FA, Al-Hazmi AS, Dawabah AA, Lafi HA. Prevalence of plant-parasitic nematodes associated with certain greenhouse vegetable crops in Riyadh region, Saudi Arabia. Journal of the Saudi Society of Agricultural Sciences. 2020;19(1):22-5.
2. Ayoub SM. Plant Nematology. An Agricultural Training Aid. State of California. Dept. Food Agric. Div. Plant Ind., Sacramento. 1977.
3. Chitwood BG. 'Root-knot nematodes'. Part 1. A revision of the genus Meloidogyne Goeldi, 1887. Proceedings of the helminthological Society of Washington. 1949; 16(2):90-114.

4. Coyne DL, Cortada L, Dalzell JJ, Claudius-Cole AO, Haukeland S, Luambano N, Talwana H. Plant-parasitic nematodes and food security in Sub-Saharan Africa. Annual review of phytopathology. 2018; 56:381-403.
5. Fouda MM, Abdelsalam NR, Gohar IM, Hanfy AE, Othman SI, Zaitoun AF, Allam AA, Morsy OM, El-Naggar M. Utilization of High throughput microcrystalline cellulose decorated silver nanoparticles as an eco-nematicide on root-knot nematodes. Colloids and Surfaces B: Biointerfaces. 2020; 188:110805.
6. Janssen, T., Karssen, G., Topalović, O., Coyne, D., & Bert, W. Integrative taxonomy of root-knot nematodes reveals multiple independent origins of mitotic parthenogenesis. PLOS ONE, 2017; 12(3),1 -31.
7. Karssen G and Moens M; Root-knot Nematodes. In: Perry R N and Moens M (Eds). Pt nematol.Wallingford, CABI; 2006; pp. 59-88.
8. Mani A, Kumar GR. Plant parasitic nematodes associated with groundnut in Andhra Pradesh. Indian Journal of Nematology. 1990;20(1):44-8.
9. Rao GM, Sudheer MJ, Priya P. Community analysis of plant parasitic nematodes associated with vegetable crops in selected districts of Andhra Pradesh. Indian Journal of Nematology. 2007;37(2):221-3.
10. Ravichandra NG. Horticultural nematology. New Dehli: Springer India; 2014 Jun 5.
11. Sallam ER, Khairy HM, Elnouby MS, Fetouh HA. Sustainable electricity production from seawater using Spirulina platensis microbial fuel cell catalyzed by silver nanoparticles-activated carbon composite prepared by a new modified photolysis method. Biomass and Bioenergy. 2021; 148:106038.
12. Sudheer MJ, Kalaiarasan P, Senthamarai M, Prabhu S, Rao GM, Priya P, Naidu PH, Haritha V, Kumar MR, Rani S. Diversity and community structure of major plant parasitic nematodes in selected districts of Andhra Pradesh, India. Indian Journal of Nematology. 2008;38(1):68-74.
13. Taylor DP, Netscher C. An improved technique for preparing perineal patterns of Meloidogyne spp. Nematologica. 1974; 20(2):268-9.
14. Williamson, V.M. and Gleason, C.A., Plant–nematode interactions. *Current opinion in plant biology*, 2003; *6*(4), pp.327-333.
15. www.indiastatagri.com
16. Ali AA, El-Ashry RM, Aioub AA. Animal manure rhizobacteria co-fertilization suppresses phytonematodes and enhances plant production: evidence from field and greenhouse. Journal of Plant Diseases and Protection. 2022 Feb 1:1-5.
17. Mohan S, Kiran Kumar K, Sutar V, Saha S, Rowe J, Davies KG. Plant root-exudates recruit hyperparasitic bacteria of phytonematodes by altered cuticle aging: Implications for biological control strategies. Frontiers in plant science. 2020 Jun 9;11:763.

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