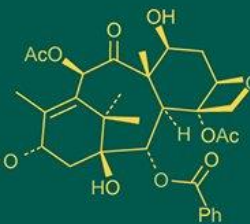
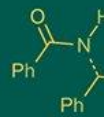


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Survey, distribution and mapping of maize cyst nematode *Heterodera zae* in Karnataka

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Abstract

Maize (*Zea mays* L.) is known as “Queen of Cereals” or “Miracle crop”, which is attacked by a number of phytonematodes, among them maize cyst nematode, *Heterodera zae* is an important nematode of this crop in India. Due to continuous monocropping of maize, favourable soil type, environmental conditions and ignorance of management practices outbreak of maize cyst nematode was noticed in parts of Shivamogga and Davanagere district of Karnataka. Roving survey was conducted during 2017 and 2018 in major maize growing districts of Karnataka revealed that out of 86 samples were collected from Bagalkote, Chitradurga, Chickmagalur, Chamarajanagara, Davanagere, Dharwad, Haveri, Hassan, Mandya, Mysore, Raichur, Shivamogga and Tumakuru districts, maximum number of cyst per root system and nematode population per 100 cc of soil was recorded in Haralahalli village of Holalkere taluk of Chitradurga district followed by Katihalli village of Chitradurga taluk and district surveyed. Among the 13 districts surveyed Chitradurga, Davanagere and Shivamogga districts were considered as ‘hot spots’ of *H. zae*. From Karnataka, it is the first work and the first report of *H. zae* infecting maize. Sandy loamy, red sandy soil supported the maximum number of infestation of *H. zae*. Mono-cropping system recorded the highest nematode infestation compared to the mixed cropping system. Haralahalli, Katihalli, Isuru, Siddapura, Goravarahatti and Chi-kadadakatte villages showed highest number of cysts per root system and nematode population per 100 cc of soil and were considered as ‘hot spots’ for *H. zae* in Karnataka.

Keywords: Maize, *Heterodera zae*, survey, Haralahalli, Hot spots

Introduction

Maize (*Zea mays* L.) is an annual C₄ plant belonging to the tribe *Maydeae*, of *Poaceae* family and globally, it is known as “Queen of Cereals” or “Miracle crop” because it has the highest genetic yield potential among the cereals (Binoy Chhetri, 2016). Among all the cereals, maize crop ranks next to wheat and rice in the world as well as in India, in terms of area contributing about 20 per cent share of world total cereal production. In India, it is cultivated in an area of 10.74 lakh ha and 3.54 t/ha productivity (Anonymous, 2024).

Plant parasitic nematodes are also recognized as one such constraint responsible to cause 10.2 per cent losses in maize (Sasser and Freckman, 1987). Worldwide crop losses caused by nematodes estimated as 157 billion dollars per annum. Out of which \$40.3 million is reported from India (Satyandra Singh *et al.*, 2015) [8]. Maize is attacked by a number of phytonematodes, amongst them, maize cyst nematode, *Heterodera zae*, is an important nematode of this crop (Koshy and Swarup, 1971) [3] in India and world.

Karnataka is well known for maize production. Recently, the area under maize cultivation is increasing tremendously, and it has occupied in most of the southern and northern districts of Karnataka. Now a days minor nematodes becoming a major constraint, due to continuous growing of maize year after year in the same land as monocropping. Due to climate change, the minor diseases are emerging as major and also new nematodes are emerging as a major threat to maize cultivation.

Recently, an outbreak of maize cyst nematode was noticed in parts of Shivamogga and Davanagere district especially in Isuru village of Shikaripura taluk, Shivamogga district and Chi-kadadakatte village of Honnali taluk, Davanagere district (Ravindra *et al.*, 2016) [6]. Since maize is an important crop in major trunks of Karnataka, the maize cyst nematode *H. zae* is considered as a major threat, and it has been increasing year after year in all the major maize growing districts of Karnataka. Since scanty work has been carried out, information regarding maize cyst nematode is very less.

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Hence, the present study was focused on survey, occurrence, distribution, mapping, and identification of maize plant parasitic nematodes in different agro-climatic regions of Karnataka. Therefore, to fill this gap of knowledge and aforesaid reasons, present investigation was carried out with the objective of Survey, distribution, mapping and identification of plant parasitic nematodes in maize different agro-climatic regions of Karnataka.

Material and Methods

Collection of samples

Roving survey was conducted during 2017-18 and 2018-19 in major maize growing districts of Karnataka namely, Bagalkot, Chitradurga, Chickmagalur, Chamarajanagar, Davanagere, Dharwad, Haveri, Hassan, Mandya, Mysore, Raichur, Shivamogga and Tumakuru, in each district, three taluks were selected and in each taluk, two to five villages were surveyed. While surveying, the following parameters were recorded such as, GIS/GPS information (Latitude and Longitude), soil types, cropping system, weed hosts, other pest and diseases etc., were also recorded along with the samples.

During the survey, nematode-infested maize fields were visited. The soil and root samples from five spots were collected randomly with the aid of shovel in the rhizosphere with proper labeling, and several sub-samples were drawn from each of the surveyed areas. The drawn samples were mixed together to make a composite bulk sample of at least one kg of soil and kept in a properly labeled polythene bag. These samples were preserved under the refrigerated condition and analysed for the population of the cyst and other plant parasitic nematodes and the same were maintained under glasshouse condition for further studies. Based on incidence and nematode population, the distribution maps were developed by using GPS/GIS information.

Results and Discussion

Survey and distribution

A systematic roving survey was undertaken during 2017-18 and 2018-19 to determine the occurrence and distribution of maize plant parasitic nematodes in different districts of Karnataka viz., Bagalkot, Chitradurga, Chickmagalur, Chamarajanagara, Davanagere, Dharwad, Haveri, Hassan, Mandya, Mysore, Raichur, Shivamogga, and Tumakuru. Total of eighty-six samples were collected from maize fields. Samples collected were brought to the laboratory and kept in refrigerator till processing. The samples were processed by using Cobb's sieving and decanting technique followed by modified Baermann's funnel technique and examined under a stereoscopic binocular microscope for the presence of maize cyst nematode *H. zae*, *Trichodorus* and *Tylenchorhynchus*. The observations recorded such as latitude-longitude, crop age, number of cysts per root system, genotypes, soil type, cropping system and nematode population per 100 cc of soil and other diseases and pests observed during the survey are presented in Table 1 and 2. Illustrated through Plate 1 and Figure 1.

Nematode population per 200 cc of soil

H. zae was widespread and distributed in all maize growing regions of Karnataka. Maximum number of cysts per root system and nematode population per 200 cc of soil were recorded from Haralahalli village of Holalkere taluk of

Chitradurga district (113 cysts, and 898.00 J₂) which was followed by Katihalli village of Chitradurgataluk and district (92 cysts, and 894.75 J₂) and Isuru village of Shikaripura taluk Shivamogga district (83 and 812.25). Among the 13 districts surveyed Chitradurga, Davanagere and Shivamogga districts were considered as 'hot spots' of *H. zae*. The lowest number of cyst per root system and number of juveniles of *H. zae* per 200 cc soil (15 and 189.50) was observed from B. Hosahalli village of Mandya taluk and district. Literature scanning suggested that, this is the first report of *H. zae* infecting maize in Karnataka.

Of the 86 samples collected, *H. zae* was noticed in 42 villages (48.84%), *Trichodorus* was observed in 29 villages (33.72%) and *Tylenchorhynchus* was observed in 25 villages (29.10%). *Trichodorus* was noticed in Bagalkot, Chickmagalur, Chamarajanagara, Davanagere, Haveri, Hassan and Shivamogga districts. *Tylenchorhynchus* was recorded in Chitradurga, Chamarajanagara, Davanagere, Hassan, and Shivamogga districts.

Among 13 different districts surveyed, maximum *Trichodorus* infection was noticed in Isuru village of Shikaripura taluk of Shivamogga district (568.00/200 cc soil) which was followed by Sankihalli village of Arasikere taluk of Hassan district (483.25/ 200 cc soil) and Nandihalli village of Shikaripurataluk of Shivamogga district (452/200 cc soil). Maximum *Tylenchorhynchus* (J₂) per 200 cc soil was recorded in Isuru and Nandihalli village of Shikaripura taluk of Shivamogga district (645.25 and 512.75) followed by and Yadegowdanahalli village of Holenarasipura taluk of Hassan district (456.25).

Distribution

The maize cyst nematode, *H. zae* was distributed in all the surveyed districts of Karnataka viz., Bagalkot, Chitradurga, Chickmagalur, Chamarajanagar, Davanagere, Dharwad, Haveri, Hassan, Mandya, Mysore, Raichur, Shivamogga and Tumakuru (Fig. 1).

Soil types

With respect to soil types, sandy, sandy loamy, red sandy, red soil, recorded the highest number of *H. zae* infestation followed by *Trichodorus* and also complex infestation of nematodes were also observed from Chitradurga, Shivamogga, Chickmagalur, Hassan, Mandya, Tumakuru and Davanagere district. The black soil type was noticed in Sharadal, Davaleshwar, Sasvehalli, Machagondanahalli, Mokbanahalli, Beriya, Harapur, Shantapura, Anveri, Balur, and Kugundi and Nagashetahalli (black sandy soil) villages where no *H. zae* infection was noticed except from Dharwad, Navalgunda, Basavapura and Nagalapur villages. Apart from *H. zae*, *Trichodorus* and *Tylenchorhynchus* was noticed in Sasvehalli village of Honnali taluk of Davanagere district and Shantapura village of Sorba taluk of Shivamogga district and only *Trichodorus* was noticed in Basavapura village of Belur taluk of Hassan district. Compared to black soil type, sandy, sandy loamy, red sandy and red soil recorded the maximum nematode population of *H. zae*, *Trichodorus* and *Tylenchorhynchus*. Out of 86, samples collected 70 (81.40%) samples collected were sandy, sandy loamy, red, red laterite and red sandy and remaining 16 (18.60%) samples were black and black sandy soil.

It is indicated that sandy, sandy loamy, red, red laterite and red sandy soil supported the maximum nematode infection

and cyst formation as compared to black soil. This might be due to increased pore space in soil, better aeration and available oxygen in light soils, which increased the nematode movement and reproduction. Light soils favoured higher multiplication of all the nematode species. Similar findings were reported by Rathore *et al.* (2007) observed that, cyst formation was more in sandy soil as compared to loamy sandy and sandy loam soil and maximum reproduction (RF-4.76 and 5.67) of *H. zae* and poor plant growth in light soil whereas, minimum reproduction (RF - 2.39 and 2.77) and better plant growth was noted in heavy soil.

Cropping system

Severity of the disease was varying in different cropping systems. Mono-cropping system recorded the highest nematode (J_2) infestation compared to the mixed cropping system. In mixed cropping system viz., coconut + coconut in Karehalli (*Trichodorus* 235.25 / 200 cc soil), Nagashetahalli (*Trichodorus* and *Tylenchorhynchus* of 123.25 and 233.50, respectively), Moodalahippe (no nematodes were noticed) and in Chatradalli recorded all three nematodes, i.e., *H. zae*, *Trichodorus* and *Tylenchorhynchus*, 578.50, 315.50, and 259.00/200 cc soil, respectively. In maize+ arecanut cropping system both *Trichodorus* and *Tylenchorhynchus* 200 cc soil, was recorded in Benakaanahalli (178.00 and 144.50, 345.50), Sasvehalli (289.75, and 256.75) and Machagondanahalli (289.50), respectively. Goravarahatti (*H. zae*, 799.50 /200 cc soil). And no nematodes were noticed in Nantur village. Maize+methi, maize + pigeon pea and maize + rubber cropping system was noticed in Mokbanahalli village of Arasikere taluk of Hassan district, Devagondanakatti village of Ranebennur taluk of Haveri district and Balur village of Hosnagara taluk of Shivamogga district where no nematodes were observed. Out of 86 samples collected, mixed cropping system (11.63%) was noticed in 10 villages and remaining was monocropping (88.37%) in 76 villages which showed maximum nematode infection of all the three nematodes compared to the mixed cropping system.

H. zae was noticed in weed (*Digitaria sanguinalis*) in maize fields, especially in Shivamogga and Chitradurga districts which, helps in survival of inoculum throughout the year by acting as a collateral host and enhancement of *H. zae* infection in maize (Plate 2a).

Continuous monocropping, improper cultural operations, spacing, soil type, temperature, climate change, latitude and longitude also play an important role in the enhancement of nematode infestation in maize in Karnataka. Table 2 and plate 2

Number of cysts per root system

Maximum mean cysts per root system (74.67) were noticed in Chitradurga and this was followed by Dharwad (33.00), Davanagere (28.43), Tumakuru (25.40) and Bagalkot (24.17). And the least mean value was noticed in Mysore (7.20). Table 2

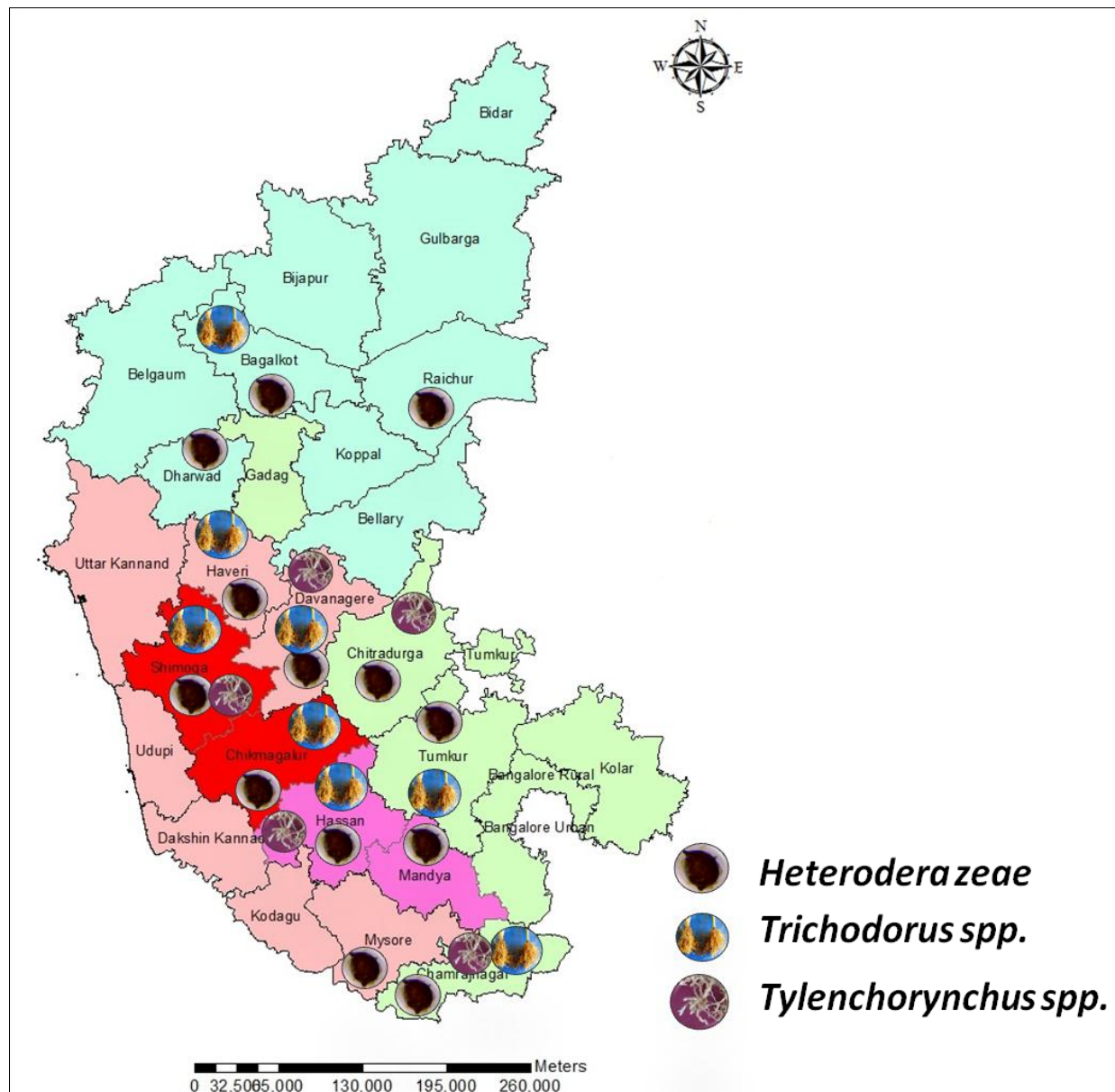
Nematode population per 200 cc soil

Maximum mean nematode (J_2) population (756.84) of *H. zae* per 200 cc soil was recorded in Chitradurga followed by Dharwad (386.38), Davanagere (316.50), Raichur (262.25) and Bagalkot (261.54). And the least district mean value was recorded in Mysore (88.55). Out of 13 districts surveyed, *Trichodorus* and *Tylenchorhynchus* were noticed in seven and five districts, respectively. For *Trichodorus*, the highest mean value was noticed in Chickmagalur (265.54) district followed by Davanagere (240.29) district and least was in Haveri (67.09) district. The highest mean value for *Tylenchorhynchus* was recorded in Chitradurga (256.04) district followed by Davanagere (227.39) district, and the least nematode population was observed in Hassan (117.65) district. Among all the three nematodes noticed, the maximum mean value was recorded for *H. zae* (756.84) in Chitradurga district which was followed by *Trichodorus* in Chikmagalur (265.54) district and least was *Tylenchorhynchus* population (256.04) in Chitradurga district.

Maximum number of cysts per root system and nematode population (J_2) per 200 cc of soil was recorded from Haralahalli, Katihalli, Isuru, Siddapura, Chi-kadakatte and Goravarahatti villages which were considered as 'hot spots' of

H. zae. Where in which mono-cropping was followed, and proper sanitation measures were not taken, which lead to an outbreak of nematodes in maize. The disease incidence was varied from locality to locality, because of cropping pattern, environmental conditions, soil type, soil moisture, soil temperature and buildup of inoculum. The higher disease incidence may be attributed to the previous crop, complex nature of cyst with other nematodes and diseases of maize and continuous monocropping system, which might have aggravated the nematode infestation.

The results are in conformity with the findings of Similarly, Mehta *et al.* (2017)^[4] during July-September, 2012 in maize growing areas of Rajasthan for maize cyst nematode reported that out of 133 samples collected, *H. zae* was recorded in 63 samples with 47.36 per cent occurrence. The highest occurrence was observed from Jhalawar (58.33%) followed by Kota (50.00%) and Baran (34.04%) districts of Rajasthan. On an average, 2.32 cysts per 5g root, 3.58 cyst per 200 cc soil and 147.65 juveniles per 200 cc soil were observed.



District mean of nematode population

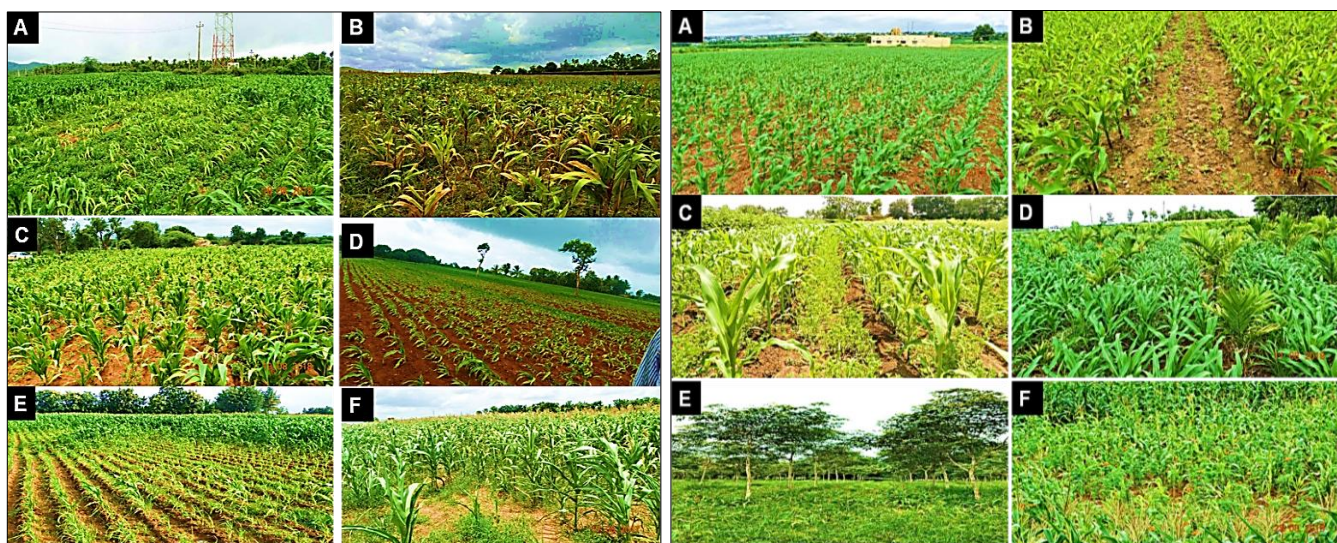
Fig 1: Distribution of maize plant parasitic nematodes in different districts of Karnataka**Plate 1:** Survey locations showing incidence of maize cyst nematodes; A) Haralahalli, B) Siddapura C) Katihalli, D& E) Isuru, F) Chikadadkatte**Plate 2:** Incidence of maize cyst nematode under different cropping system; A) Maize-(monocrop), B) Maize+ Redgram, C) Maize+ Methi, D) Maize+ arecanut, E) Maize+ Rubber, F) Maize+ Marigold



Plate 2a: Cysts observed on weed (*Digitaria sanguinalis*) and Ragi in surveyed fields

Table 1: Survey on incidence of plant parasitic nematodes in maize in different maize growing districts of Karnataka

District	Taluk	Village	Latitude and longitude	Cropping system	Soil type	No. of cysts /root system	Nematode population/200cc soil		
							<i>Heterodera zea</i>	<i>Trichodorus spp.</i>	<i>Tylenchorhynchus spp.</i>
Bagalkot	Badami	Bankaneri	15°87'11.9"N/ 75°55'69.2"E	Mono-cropping	Sandy loam	18	200.00	312.25	-
	Bagalkot	Niralkeri	15°97'35.4"N/ 75°45'66.7"E	Mono-cropping	Sandy loam	43	456.25	421.50	-
		Sharadal	16°23'21.4"N/ 75°47'24.6"E	Mono-cropping	Black	-	-	-	-
	Hungunda	Chinnapur	16°00'84.8"N/ 76°12'91.1"E	Mono-cropping	Sandy loam	47	513.00	-	-
		Chittargi	16°11'73.9"N/ 75°97'44.0"E	Mono-cropping	Sandy loam	37	400.00	-	-
	Mudhol	Davaleshwar	16°33'54.6"N/ 75°07'66.1"E	Mono-cropping	Black	-	-	-	-
Chitradurga	Holalkere	Shivaganga	14°15'54.0"N/ 76°31'91.3"E	Mono-cropping	Sandy loam	65	792.25	-	310.00
		Haralahalli	14°17'94.0"N/ 75°34'11.7"E	Mono-cropping	Red sandy	113	898.00	-	182.00
		T. Nulnur	14°70'48.7"N/ 76°13'56.3"E	Mono-cropping	Red	45	451.50	-	186.25
	Chitradurga	Katihalli	14°21'51.0"N/ 76°33'90.5"E	Mono-cropping	Red sandy	92	894.75	-	411.00
		Siddapura	14°21'00.9"N/ 76°34'71.1"E	Mono-cropping	Red lateritic	76	806.50	-	233.75
		Bheemasamudra	14°60'21.5"N/ 76°28'28.2"E	Mono-cropping	Sandy	57	698.00	-	213.25
Chickmagalur	Tarikere	Belenahalli	13°70'40.5"N/ 75°77'45.8"E	Mono-cropping	Sandy loam	32	402.00	354.00	-
		Karehalli	13°78'32.3"N/ 75°74'04.1"E	Maize+Coconut	Sandy loam	-	-	235.25	-
		Lakkavalli	13°70'10.2"N/ 75°65'64.9"E	Mono-cropping	Sandy loam	43	687.25	314.25	-
	Kaduru	Devanuru	13°42'54.5"N/ 76°09'20.3"E	Mono-cropping	Sandy loam	-	-	222.50	-
		Mallenahalli	13°53'51.9"N/ 76°22'98.3"E	Mono-cropping	Sandy loam	19	210.50	311.25	-
		Kammenahalli	13°41'02.4"N/ 76°09'88.1"E	Mono-cropping	Sandy loam	27	302.00	186.00	-
	Chickmagalur	Kottigenahalli	13°26'67.8"N/ 76°03'03.5"E	Mono-cropping	Sandy loam	-	-	235.50	-
Chamarajanagara	Kollegala	Chikinduvadi	12°08'54.4"N/ 76°11'60.0"E	Mono-cropping	Sandy loam	-	-	187.50	163.25
		Singanallur	12°08'40.9"N/ 77°12'48.3"E	Mono-cropping	Red	23	190.00	-	-
		Kongrahalli	12°07'43.3"N/ 77°14'08.0"E	Mono-cropping	Red	-	-	125.25	247.00
		Dhangere	12°13'32.5"N/ 77°08'47.6"E	Mono-cropping	Sandy	27	389.75	154.25	185.25
Davanagere	Honnali	Benakaanahalli	14°10'26.3"N/ 75°55'32.7"E	Maize+Areca nut	Sandy loam	-	-	178.00	144.50
		Chilurukadakat	14°12'06.6"N/ 75°67'29.3"E	Mono-cropping	Sandy loamy	73	799.50	366.50	289.50
		Sasvehalli	14°22'11.9"N/ 75°68'36.8"E	Maize+Areca nut	Black	-	-	345.50	289.75
		Goravarahatti	14°23'81.1"N/ 75°55'32.7"E	Maize+Areca nut	Sandy loam	71	725.75	-	-

			N/75° 64' 53.0" E	t					
		Chiluru	14°12'48.1"N/75°63'02.6"E	Mono-cropping	Red	55	690.25	412.00	345.00
		Machagondanahalli	14°11'20.2"N/75°50'35.8"E	Maize+Arecanut	Black	-	-	256.75	289.50
	Channagiri	Nagashetahalli	14°01'48.2"N/75°96'94.5"E	Maize+Coconut	Black sandy	-	-	123.25	233.50
Dharwad	Dharwad	Dharwad	15°45'40.5"N/75°00'66.5"E	Mono-cropping	Black	43	456.25	-	-
	Navalgunda	Navalgunda	15°55'82.2"N/75°35'38.4"E	Mono-cropping	Black	23	316.50	-	-
Haveri	Haveri	Thimmapura	14°74'46.7"N/75°30'52.7"E	Mono-cropping	Sandy loam	-	-	-	-
		Aladakatti	14°78'08.5"N/75°36'66.4"E	Mono-cropping	Sandy loam	34	356.00	-	-
		Kerimattihalli	14°75'69.5"N/75°37'35.9"E	Mono-cropping	Sandy loam	-	-	-	-
	Ranebennur	Devagondanakatti	14°55'68.3"N/75°69'05.6"E	Maize+ Methi	Sandy loam	-	-	-	-
		Kotihala	14°47'42.4"N/75°66'43.8"E	Mono-cropping	Sandy loam	-	-	286.50	-
		Halgere	14°55'60.0"N/75°60'86.8"E	Mono-cropping	Sandy loam	56	589.25	250.25	-
	Hanagal	Hunashettikoppa	14°75'68.7"N/75°07'82.0"E	Mono-cropping	Sandy loam	-	-	-	-
	Hirekeruru	Dudihalli	14°43'03.5"N/75°46'21.8"E	Mono-cropping	Sandy loam	23	278.75	-	-
Hassan	Hassan	Ankanahalli	12°47'20.1"N/76°03'21.7"E	Mono-cropping	Sandy loam	-	-	-	-
		Thattekere	12°58'21.9"N/76°05'37.8"E	Mono-cropping	Sandy loam	38	389.75	-	342.00
		Kattaya	12°53'33.0"N/76°04'34.9"E	Mono-cropping	Red sandy	-	-	-	-
	Holenarasipura	Yadegowdanahalli	12°39'27.6"N/76°18'53.4"E	Mono-cropping	Red clay	-	-	238.00	456.25
		Moodalahippe	12°81'10.6"N/76°30'23.4"E	Maize+ Coconut	Sandy loam	-	-	-	-
	Belur	Basavapura	13°06'51.2"N/76°00'32.5"E	Mono-cropping	Black soil	35	403.25	248.25	-
		Kadaravalli	13°16'44.4"N/75°43'56.0"E	Mano-cropping	Sandy	-	-	-	378.25
	Arasikere	Mokanahalli	13°23'39.2"N/76°24'86.3"E	Maize+ redgram	Black sandy	-	-	-	-
		Sankihalli	13°18'07.3"N/76°03'33.6"E	Mono-cropping	Red sandy	-	-	483.25	-
	Holenarasipura	Mudalahippe	12.81.24°N/76.29.78.1°E	Mono-cropping	Sandy soil	56	612.25	-	-
Mandya	KR Pete	Haralahalli	12°48'21.6"N/76°68'09.6"E	Mono-cropping	Sandy loam	-	-	-	-
		Kikkeri	12°76'32.3"N/76°42'57.0"E	Mono-cropping	Red soil	-	-	-	-
		Settihalli	12°75'28.7"N/76°45'85.7"E	Mono-cropping	Red clayey	23	319.00	-	-
	Malavalli	Shivanahalli	12°48'53.7"N/77°07'59.7"E	Mono-cropping	Red soil	-	-	-	-
		Dugganahalli	12°41'21.0"N/76°99'75.0"E	Mono-cropping	Red sandy	35	389.75	-	-
		Nadakalapura	12°39'46.5"N/77°14'12.5"E	Mono-cropping	Red soil	35	310.25	-	-
	Panadavapura	Vaddarahalli	12°51'75.3"N/76°63'12.6"E	Mono-cropping	Sandy loamy	-	-	-	-
	Mandya	B. Hosahalli	12°55'33.9"N/76°87'05.6"E	Mono-cropping	Red sandy	15	189.50	-	-
		Alakere	12°60'37.0"N/76°95'85.1"E	Mono-cropping	Sandy loam	-	-	-	-
		VC Farm	12°31'12.4"N/76°53'58.5"E	Mono-cropping	Red sandy	-	-	-	-
	Shrirangapatna	Agrahara	12°42'90.3"N/76°71'01.0"E	Mono-cropping	Red clay	-	-	-	-
Mysore	Hunsuru	Gowdikere	12°24'29.1"N/76°20'56.8"E	Mono-cropping	Sandy loam	-	-	-	-
	Piriyapatana	Kaggundi	12°36'81.7"N/76°11'41.3"E	Mono-cropping	Red	-	-	-	-
		Basalapura	12°34'78.8"N/76°14'35.7"E	Mono-cropping	Red sandy	36	442.75	-	-
	K R Nagara	Beriya	12°34'43.5"N/76°14'35.7"E	Mono-cropping	Black sandy	-	-	-	-

			21°26.9"E						
		KR Nagara	12°43'85.6"N/ 76°38'36.6"E	Mono-cropping	Red	-	-	-	-
Raichur	Raichur	Nagalapur	16°09'20.0"N/ 77°33'79.9"E	Mono-cropping	Black	42	524.50	-	-
	Sindhanur	Harapur	15°86'42.6"N/ 76°68'71.4"E	Mono-cropping	Black	-	-	-	-
Shivamogga	Shivamogga	ZAHRs, Navile	13°58'45.1"N/ 75°34'71.7"E	Mono-cropping	Sandy loam	26	210.00	-	-
	Thirthahalli	Nantur	13°62'45.1"N/ 75°34'71.7"E	Maize+Areca nut	Red soil	-	-	-	-
		Bidarhallitanda	14°12'74.5"N/ 75°48'41.1"E	Mono-cropping	Sandy soil	49	612.25	-	-
	Sorba	Chatradalli	14°38'12.2"N/ 75°22'47.0"E	Coconut+Maize	Red laterite	52	578.50	315.50	259.00
		Shantapura	13°56'24.4"N/ 75°10'18.8"E	Mono-cropping	Black	-	-	289.25	245.00
	Shikaripura	Nandihalli	14°13'44.3"N/ 75°23'19.9"E	Mono-cropping	Sandy loamy	35	389.50	452.00	512.75
		Isuru	14°21'12.6"N/ 75°34'24.5"E	Mono-cropping	Red sandy	83	812.25	568.00	645.25
		Kutrhalli	14°27'86.2"N/ 75°33'24.2"E	Mono-cropping	Red sandy	27	289.25	-	386.25
	Badhravathi	Anveri	14°06'13.4"N/ 75°76'11.7"E	Mono-cropping	Black	17	210.25	450.00	211.25
	Sagara	Sasaravalli	14°13'44.3"N/ 75°23'19.9"E	Mono-cropping	Red laterite	-	-	286.25	412.50
	Hosanagara	Balur	14°01'39.7"N/ 75°14'39.5"E	Rubber +Maize	Black	-	-	-	-
		Kusgundi	13°56'24.4"N/ 75°10'18.8"E	Mono-cropping	Black	-	-	-	-
		Nevtoor	14°02'52.1"N/ 75°14'16.4"E	Mono-cropping	Red sandy	-	-	-	-
Tumakuru	Tumkuru	Maraluru	13°31'99.0"N/ 77°09'33.0"E	Mono-cropping	Sandy loam	-	-	-	-
		Kora	13°43'83.8"N/ 77°06'38.7"E	Mono-cropping	Sandy	-	-	-	-
	Kunigal	Dodmavttur	12°54'13.3"N/ 77°02'23.0"E	Mono-cropping	Sandy	71	689.50	-	-
		Dyavapatna	12°17'51.1"N/ 77°06'40.2"E	Mono-cropping	Red sandy	56	512.00	-	-
		Kempanahalli	12°92'39.2"N/ 77°03'11.5"E	Mono-cropping	Red sandy	-	-	-	-

Table 2: Mean incidence of plant parasitic nematodes in maize in different maize growing districts of Karnataka

District	Taluk	Village	No. of cysts /root system	Nematode population/200cc soil			District mean of nematode population/200cc soil			
				<i>Heterodera zeae</i>	<i>Trichodorus spp.</i>	<i>Tylenchorhynchus spp.</i>	No. of cysts /root system	<i>Heterodera zeae</i>	<i>Trichodorus spp.</i>	<i>Tylenchorhynchus spp.</i>
Bagalkot	Badami	Bankaneri	18	200.00	312.25	-	24.17	261.54	122.25	-
	Bagalkot	Niralkeri	43	456.25	421.50	-				
		Sharadal	-	-	-	-				
	Hungunda	Chinnapur	47	513.00	-	-				
		Chittargi	37	400.00	-	-				
Chitradurga	Mudhol	Davaleshwar	-	-	-	-	74.67	756.84	-	256.04
	Holalkere	Shivaganga	65	792.25	-	310.00				
		Haralahalli	113	898.00	-	182.00				
		T. Nulnur	45	451.50	-	186.25				
	Chitradurga	Katihalli	92	894.75	-	411.00				
		Siddapura	76	806.50	-	233.75				
Chickmagalur	Tarikere	Belenahalli	32	402.00	354.00	-	17.29	228.75	265.54	-
		Karehalli	-	-	235.25	-				
		Lakkavalli	43	687.25	314.25	-				
	Kaduru	Devanuru	-	-	222.50	-				
		Mallenahalli	19	210.50	311.25	-				
		Kammenahalli	27	302.00	186.00	-				
	Chickmagaluru	Kottigenahalli	-	-	235.50	-				
Chamarajanagara	Kollegala	Chikinduvadi	-	-	187.50	163.25	12.50	144.94	116.75	148.88
		Singanallur	23	190.00	-	-				
		Kongrahalli	-	-	125.25	247.00				
		Dhangere	27	389.75	154.25	185.25				
Davanagere	Honnali	Benakaanahalli	-	-	178.00	144.50	28.43	316.50	240.29	227.39
		Chi-kadadakatte	71	725.75	366.50	289.50				

		Sasvehalli	-	-	345.50	289.75				
		Goravarahatti	73	799.50	-	-				
		Chiluru	55	690.25	412.00	345.00				
		Machagondanahalli	-	-	256.75	289.50				
	Channagiri	Nagashetahalli	-	-	123.25	233.50				
Dharwad	Dharwad	Dharwad	43	456.25	-	-	33.00	386.38	-	-
	Navalgunda	Navalgunda	23	316.50	-	-				
Haveri	Haveri	Thimmapura	-	-	-	-	14.13	153.00	67.09	-
		Aladakatti	34	356.00	-	-				
		Kerimattihalli	-	-	-	-				
	Ranebennur	Devagondanakatti	-	-	-	-				
		Kotihala	-	-	286.50	-				
		Haligere	56	589.25	250.25	-				
	Hanagal	Hunashettikoppa	-	-	-	-				
	Hirekeruru	Dudihalli	23	278.75	-	-				
Hassan	Hassan	Ankanahalli	-	-	-	-	12.90	140.53	96.95	117.65
		Thattekere	38	389.75	-	342.00				
		Kattaya	-	-	-	-				
	Holenarasipura	Yadegowdanahalli	-	-	238.00	456.25				
		Moodalahippe	-	-	-	-				
	Belur	Basavapura	35	403.25	248.25	-				
		Kadadaravalli	-	-	-	378.25				
	Arasikere	Mokanahalli	-	-	-	-				
Sankihalli		-	-	483.25	-					
Mandya	KR Pete	Mudalahippe	56	612.25	-	-	9.82	109.86	-	-
		Haralahalli	-	-	-	-				
		Kikkeri	-	-	-	-				
	Malavalli	Settihalli	23	319.00	-	-				
		Shivanahalli	-	-	-	-				
		Dugganahalli	35	389.75	-	-				
	Panadavapura	Nadakalapura	35	310.25	-	-				
		Vaddarahalli	-	-	-	-				
	Mandya	B. Hosahalli	15	189.50	-	-				
		Alakere	-	-	-	-				
VC Farm		-	-	-	-					
Mysore	Shrirangapatna	Agrahara	-	-	-	-	7.20	88.55	-	-
		Hunsuru	-	-	-	-				
	Piriyapatana	Gowdikere	-	-	-	-				
		Kaggundi	-	-	-	-				
	K R Nagara	Basalapura	36	442.75	-	-				
Beriya		-	-	-	-					
Raichur	KR Nagara	KR Nagara	-	-	-	-	21.00	262.25	-	-
		Nagalapur	42	524.50	-	-				
Shivamogga	Raichur	Sindhanur	-	-	-	-	22.23	258.50	196.75	222.67
		Shivamogga	ZAHRs, Navile	26	210.00	-				
	Thirthahalli	Nantur	-	-	-	-				
		Bidarahallitanda	49	612.25	-	-				
	Sorba	Chatradalli	52	578.50	315.50	259.00				
		Shantapura	-	-	289.25	245.00				
	Shikaripura	Nandihalli	35	389.50	452.00	512.75				
		Isuru	83	812.25	568.00	645.25				
		Kutrhalli	27	289.25	-	386.25				
	Badhravathi	Anveri	17	210.25	450.00	211.25				
	Sagara	Sasaravalli	-	-	286.25	412.50				
	Tumakuru	Hosanagara	Balur	-	-	-				
Kusgundi			-	-	-	-				
Nevtoor			-	-	-	-				
Tumkuru		Maraluru	-	-	-	-				
		Kora	-	-	-	-				
Kunigal	Dodmavttur	71	689.50	-	-					
	Dyavapatna	56	512.00	-	-					
	Kempanahalli	-	-	-	-					

- = No nematodes were noticed

Conclusion

From the results it is inferred that maize cyst nematode was widespread and distributed in all the surveyed districts. Among the 13 districts surveyed Chitradurga, Davanagere and Shivamogga districts were considered as 'hot spots' of *H. zae*. From Karnataka, it is the first work and the first report of *H. zae* infecting maize. Sandy loamy, red sandy soil, mono-cropping system supported the maximum number of nematode infestation of *H. zae*, *Trichodorus* and *Tylenchorhynchus*.

Haralahalli, Katihalli, Isuru, Siddapura, Goravarahatti and Chi-kadadakatte villages showed highest number of cysts per root system and nematode population per 100 cc of soil and were considered as 'hot spots' for *H. zae* in Karnataka and in these places proper management aspects need to be undertaken to combat the severe outbreak and crop loss from *H. zae*.

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