Effect of Physico-Chemical Properties of soils related to root-knot nematode on Turmeric Grown soils in Nizamabad district-Telangana state of India.

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Abstract

This study was conducted to assess the effect of soil quality and fertility in relations to rootknot nematodes infestations on turmeric growing soils of Nizamabad district of Telangana sate during *kharif*, 2018. Twenty-eight surface soil samples representing seven turmeric (*Curcuma longa* L.) growing mandals of Nizamabad districts of Telangana namely Sirikonda, Armoor, Kammarpally, Velpur, Balkonda, Jakranpally and Dharpally. The climate of the study area was semi-arid and monsoonic climate. The sites selected were confined to nearly level to gently undulating slopes and have granular to sub angular blocky structures. All the soils showed well developed structural variation and exhibited granular to sub angular blocky structure. The soil texture varied from sandy loam to clay. The soils are neutral to slightly alkaline in reaction and non-saline. The soils are low to medium in available nitrogen, medium to high in available phosphorus and potassium. This study indicates that turmeric crops grown in the selected localities with four major turmeric genotypes (Duggirala red, ACC-79, ACC-48 and Rajapuri). All the turmeric genotypes except ACC-79 were infested with root-knot nematodes occurrence in which almost all the roots have knot-like appearance was reported and also soil sampling revealed that crop showed the significant presence of *Meloidogyne* species as a pathogen. In all the turmeric growing soils, prominent disease symptoms were developed as gall formation in the root region and poor plant growth resulting crop yield loss to the farmers.

Keywords: *Turmeric Root knot nematode, Nizamabad, Meloidogyne species, soil quality and soil fertility.*

Introduction

India is called the "Spice Bowl of the World" as it cultivates 63 spices out of total 107 spices identified. Among the spices turmeric *(Curcuma longa* L.) is one of the most important and ancient spice of India and also a traditional item of export. It is extensively used in the preparation of tasty curried dishes by all classes of people for its typical colour and flavor. It is used as a dye with varied application in drug and cosmetic industries. India is the largest producer of turmeric in the world accounting to 82 per cent of world turmeric production and 60 per cent of world export. In Telangana the major turmeric growing districts are Karimnagar and Nizamabad. Nizamabad is second largest producer of turmeric having an area of 11943 ha, with production of 97933 tons and productivity of 8200 kg/ha. The major varieties of turmeric cultivated in Nizamabad district are Duggirala red, ACC-79, ACC-48 and Rajapuri. The important soils prevailing in the district are black and red chalka (Sandy loams) soils covering 55% and 45% respectively of the total area. The blocks of Armoor, Bheemgal are predominantly dominated with red and red associated soils followed by black soils. To comprehend and understand the potential capability of turmeric growing soils, the systemic study of turmeric cultivated soils is important for better management and scientific utilization of its resources. The soil fertility status exhibits the status of different soils with regard to amount and availability of nutrients essential for plant growth. The crop growth and yield largely depend upon potential of soil resources and their characteristic provides water, nutrients and anchorage for the growth and yield of crops. Keeping in view the above facts, the present study was carried out to find soil fertility status of some Turmeric Growing soils in relation to study the Root-Knot Nematode of Nizamabad District. This paper deals with analysis of turmeric growing soils of Nizamabad district major and micronutrient nutrient status.

Root-knot nematode, *Meloidogyne* species is an important group of plant-parasitic nematode. *Meloidogyne* is an endo-parasitic nematode resides in almost all crops worldwide. These were recognized now a days as a major constraint in turmeric crop and it causing recognisable yield losses with infested plant parasitic nematodes and constitute the major pest crop all over the World. (Atkins *et al.*, 2003). Root-Knot nematodes are sedentary endoparasites (Crow, W.T. and Dunn, R.A 2009). These nematodes parasitise a wide variety of crops amounting to more than 2000 plant species most of which are higher plants (Karsen & Meons, 2006; Moens *et al.*, 2009). Root knot nematodes complete several generations in one cropping season and interfere with water and nutrient uptake by the host plant. The purpose of this study was to assess the effect of soil quality and fertility in relations to root-knot nematodes infestations on turmeric growing soils of Nizamabad district of Telangana sate.

Materials and methods

Location and description of the study area

The geographical area of the district is 4,288 square kilometres (1,656 sq mi) and it is located at 18°41′N 78°6′E.[6] Nizamabad is bounded on the North by Nirmal district, on the East by Jagtial and Rajanna Sircilla district, on the South lies Kamareddy district, and on the West by Nanded district of Maharashtra State. The Godavari River enters into Telangana from Nizamabad district at Kandakurthi.

The climate is semi-arid which is comparatively equitable and although it is very hot in May with mercury rising up to 47^{o} C. The temperature dips to 5^{o}C in winters during the months of December and January. The mean maximum and minimum temperature vary from 38 ^{o}C to 25°C. Mean humidity varies from 64 per cent in July to 75 per cent in December. The mean annual rainfall is 900 mm of which 75 per cent is received during the southwest monsoon (June to September), 15 per cent during the northeast monsoon (October to December) and 10 per cent during the pre-monsoon period (March to May). The rainfall is highest in the month of August. The major crops grown are rice, sugarcane, maize, turmeric, cotton, groundnut, sunflower and pulses etc.

Collection Methods used for soil sample analysis

The major turmeric growing villages from different mandals were selected. Surface soil samples (0-15 cm depth) from 28 turmeric growing villages of seven mandals. Soil samples were collected from surveyed villages randomly from the fields. Soil sampling is done in the rhizosphere region at a depth of 0-15cm and collected samples were stored at 10-15℃ to avoid the decay and drying of specimens and 100 Rhizomes of the turmeric plants of each villages were collected in polythene bags and neatly labelled. These were then brought to laboratory for examination. Upon arrival in laboratory, Soil samples were processed by Cobb's sieving and Decanting Method followed by modified Biermann's funnel Method (Cobb, 1918). These root-knot nematodes obtained were fixed in 4% formalin and stored in a glass vials. The number of samples positive to the nematode infection and % of infection is calculated. Plant-parasitic nematodes can be easily differentiated from free-living saprophytic nematodes with the presence of stylet in the head region.

The nematode identification was mainly based on the morphology of adults and second stage juveniles (Eisenback, 1985). The fixed specimens were identified by making temporary mounts. Root samples were examined for overall root structure following the infection, presence of galls on roots. Numbers of gall in each root were counted. In order to count the number of egg masses on root surface, roots were washed clean in running tap water for 10-15 minutes, these were then immersed in aqueous solution of acid fuschin (875 ml of lactic acid, 63 ml glycerol, 62 ml of water and 0.1gm of acid fuschin) for 30 minutes and then washed with tap water to examine the stained egg masses. Initially number of egg masses in each root were counted, gall index 1 was on a scale of 0 to 5 (Taylor and Sasser, 1978), where 0 = no galls; 1 = 1 to 2; 2 = 3 to 10; 3 = 11 to 30; 4 = 31 to 100; and 5 = more than 100 galls.

The representative soil samples of the villages were characterized for their important physical, physico-chemical and chemical properties using standard procedures. Particle size analysis was done according to International Pipette method (Piper,1966), bulk density (Blake and Hartze, 1986), water holding capacity (Sankaram, 1966), soil pH and EC was determined in 1:2.5 soil water suspensions. exchangeable cations (Jackson,1973), cation exchange capacity (Chapman, 1965), organic carbon and free calcium carbonate were determined (Walkly and Black, 1934 and Piper, 1966) respectively. The available nitrogen was determined by kjeldal method, available phosphorus was estimated by spectrophotometer and potassium by flame emission method (Jackson, 1973). The available micronutrients were determined using the method given by Lindsay and Norvell, 1978.

Results

Physical Properties

Physical characteristics of the surface soils is presented in (Table 1). The sand, silt and clay content ranges from 18.2 to 71.4, 4.4 to 18.7 and 20 to 68.2, per cent respectively. In red soils coarse to medium texture was observed and fine texture was found in black soils. The texture of the soils varied from sandy loam to clay. The maximum clay content of 68.2 per cent was recorded in Nyavanandi village, while minimum clay content 20 per cent was noticed in Dubbaka village. The maximum silt content of 18.7 per cent was noticed in Bhrahmanapalli village and minimum silt content of 4.4 per cent was noticed in Dubbaka village soils. The maximum sand content of 71.4 per cent was recorded in Konapur village soils, while minimum content 18.2 per cent was noticed in Nyavanandi village. Gravel was observed in all the surface soils and their distribution varied widely with soil types. The Gravel content ranges from 17.0 to 36.0 per cent. The maximum Gravel content of 36.0 per cent was recorded in division Dubbaka village, while minimum Gravel content of 17.0 per cent was noticed in Padgal village. The bulk density ranged from 1.32 to 1.65 Mgm^{-3} in surface soils, 1.34 to 1.69 Mgm^{-3} in subsurface soils at different moisture regimes respectively.

The maximum bulk density content of 1.73 Mgm^{-3} was recorded in Gadkole soils, while minimum content of 1.28 Mgm^{-3} was noticed in Laxmapur. Lower bulk density values of clay soil might be due to loose, porous nature and organic matter content (Walia and Rao, 1996). The maximum water holding capacity ranges from 22 to 58.0 per cent in surface soils. The maximum water holding capacity of 58.0 per cent was recorded in Nyavanandi village, while minimum water holding capacity of 22.0 per cent was noticed in Chinthalur and Govindpet villages. Water holding capacity of the surface soils vary with soil types due to the variation in clay, silt and organic carbon content (Rajeshwar *et al*., 2009).

Physico-Chemical Properties

Physico-chemical properties of the surface and subsurface soils are presented in (Table 2). All the soil samples studied were extremely acidic to moderately alkaline in reaction. The soil pH ranged from 6.5 to 8.1. The lowest pH (6.5) was recorded in Dammanapet village which might be due to accumulation of exchangeable H^+, Fe and Al oxides, soil organic matter and clay minerals (Bipul Deka *et al.*, 2009). The highest pH values (8.1) were noticed in Nyavanadi village. Similar results were observed by Rajeshwar and Mani (2013) and stated that the parent materials, rainfall and topography, were greatly influenced by the characteristics and behaviour of soil environs. The E.C ranges from 0.12 to 0.36 dS m^{-1} and all the soils falls under non saline in nature. The low amount of soluble salts in surface and subsurface soils could be attributed to loss of bases (Sidhu *et al.*, 1994) due to heavy rainfall. The organic carbon content was found to be low to medium (4.6 to 7.0 g kg^{-1}) in surface soils of all the villages. The organic carbon content relatively medium in range in surface soils was attributed to the addition of farmyard manure and plant residues which resulted in higher organic carbon content in surface horizons. These observations are in accordance with results of Rajeshwar *et al.* (2009).

The CEC values were ranged from 16.7 to 38.9 c mol (p+) kg^{-1}. The CEC values are indicating that the soils are moderately weathered (Buol *et al*., 1998). The exchangeable bases in were in order of $Ca^{+2} > Mg^{+2} > Na^{+} > K^{+}$ on the exchange complex. From the distribution of Ca^{+2}

and Mg^{+2}, it is evident that Ca^{+2} shows the strongest relationship with all the species, comparing these ions (Ca^{+2}, Mg^{+2}, K^{+} and Na^{+}) it was clear that Mg^{+2} was present in low amount than Ca^{+2} because of its higher mobility. These results are in conformity with findings of Mahesh *et al.*, 2018. Low exchangeable Na and K percentage was noticed in all the soils as the exchange complex was dominated by divalent cations like Ca and Mg (Rajeshwar and Mani, 2018).

The base saturation of the soils was moderate to high in range and varied from 52.6 to 86.8 percent. This could be due to the dominance of smectitic type of clays and moderate to strongly alkaline reaction. These results were in accordance with the findings of Rajeshwar and Mani (2018). The variation in difference of CEC, base saturation and water holding capacity between soils may ascribe largely due to the varied type or content of soil colloids and soil pH values. The soils were non calcareous and $CaCO_3$ content was ranged from 1.1 to 5.0 g kg^{-1}.

Soil Fertility status

The available macronutrients status of soils is presented in (Table 3). The available nitrogen status was found to be low to medium (198.0 to 285.0 kg ha^{-1}) in all the villages of surface soils. However, available N content of all the above soils was found to be low to medium in surface soils. The reason for the maximum available nitrogen content observed in the surface could be attributed to the fact that cultivation of crops is mainly confined to the surface horizon (Rhizosphere) only and at regular interval the depleted nitrogen content is supplemented by the external addition of fertilizers during crop cultivation (Rajeshwar and Mani, 2014).The available phosphorus status was found to be medium to high in surface soils (14.0 to 34.0 kg ha^{-1}) in all the villages. The reason for higher P in surface soils might possibly be the confinement of crop cultivation to the rhizosphere and supplementing of the depleted phosphorus through external fertilizers. Similar results were reported by Rajeshwar and Mani (2014). The available potassium was medium to high (232.0 to 393.0 kg ha^{-1}) in soils of all villages. The available K status was more in surface soils which could be attributed to release of labile-K from organic residues, application of K fertilizers and upward translocation of K from lower depths along with capillary rise of ground water. Similar results were reported by Pal and Mukhopadyay (1992) and Mahesh *et al.*, 2018.

Available micro nutrient status:

The DTPA Zn status varied from 0.07 to 6.18 mg kg^{-1} in soils (Table 3). Considering 0.6 mg kg^{-1} as critical level (Lindsay and Norvel, 1978), it was found that 43% of the surface soils are deficient in availability. The available Zn content were low due to low organic carbon content

(Karthikeyan*et al*., 2014). The availability was sufficient in surface soils which might be due to accumulation of comparatively more amount of organic matter and supplementing $ZnSO_4$ through external sources. Similar results were reported by Jalali *et al.*, (1989) and Rajeshwar *et al*., (2009). Considering 0.6 ppm as critical limit, 36.4 per cent of soils were found deficit in available zinc. The DTPA Cu status varied from 0.60 to 11.52 mg kg^{-1}. Considering 0.2 mg kg^{-1} as critical level (Lindsay and Norvel, 1978), it was found that all the soils are sufficient which might be due to its association with organic carbon affecting its availability in surface layers (Rajeshwar and Ariff khan, 2007). The available Mn status of these soils varied from 5.75 to 24.40 mg kg^{-1}. Considering 2.0 mg kg^{-1} as critical level (Lindsay and Norvel, 1978), it was found that all the soils are high in availability which might be due to its presence in the reduced forms, higher biological activity and organic carbon in the surface soils. These observations were in agreement with the findings of Murthy *et al*., (1997) and Nayak *et al., (*2000). The DTPA Fe content varied from 3.93 to 20.60 mg kg^{-1}. Based on the critical limit of 3.7 mg kg^{-1} for non-calcareous soils ((Lindsay and Norvel, 1978), the soils were sufficient in available Fe. It was relatively high might be due to accumulation of humic material in the surface soils besides prevalence of reduced conditions in subsurface soils. The findings were in agreement with the findings of Prasad and Sakal (1991). The sufficiency status of Fe may be attributed to the non-calcareous nature of soils of the study area. The percentage of micronutrient deficiency and sufficiency is presented in Table 3.

Occurrence and frequency of root-knot knot nematodes in turmeric

In the study area of turmeric growing soils of Nizamabad district in some patches all the villages found that the parasitic root-knot nematodes (*Meloidogyne spp*.) are damaging to turmeric majorly by feed on tender rhizomes, roots and base of pseudostem causing stunting, chlorosis, poor tillering and necrosis of leaves are the common aerial symptoms. Characteristic root galls and lesions that lead to rotting are generally seen in rhizome roots. The infested rhizomes have brown, water-soaked areas in the outer tissues. Nematode infestation aggravates rhizome rot disease. Nematodes survive in soil and infected rhizomes as primary inoculum. therefore, tissues from infected crops remaining in the field serve as a reservoir of the fungus. It spreads from infected plants or through soil.

Root knot nematodes were recorded in all the surveyed villages of Nizamabad district. Number of galls and gall index in roots of different turmeric varieties due to infection of *M. incognita* is shown in [Table 4 and 5]. Among the four varieties (Duggirala red, ACC-79, ACC-48 and Rajapuri), the highest number of galls per root system was recorded in the variety Duggirala red in the range of 32-71 with gall index 4 of all villages and which is susceptible. The genotype ACC-79 found resistant with gall index 0. The ACC-48 turmeric genotype is in the range of 15-25 with gall index 3 and which is found moderately resistant. The genotype Rajapuri variety is in the range of 32-41 with gall index 4 and which was found susceptible (Niranjan Prabhu *et al.*, 2017).

This study finds that the soil type has profound effect on the nematode reproduction facing greatest in coarsely textured sandy loam soils and least in more finely textured soils (Table 3 and 4). The soil of Nizamabad District are mostly Red, red associated soils and Black soils with sandy loam, sandy clay loam and clay and clay loam textured soils respectively. Therefore, soil type, moisture and temperature enhance the degree of Root knot nematode infestation and population size and Root sampled in selected location had significant amount of infection. Based on the observations made during the survey it can be concluded that the incidence of the root-knot nematode infection in four major turmeric genotypes (Duggirala red, ACC-79, ACC-48 and Rajapuri) as detailed below in selected villages.

This study has revealed that the numbers root-knots of nematode (galls) per turmeric root system are abundant in sandy loam to sandy clay loam soils (51-72) having larger populations of plant-parasitic nematodes than clay and clay loam soils (32-46) where there is more aeration and easy movement (Table 4&5). The penetrating capacity of nematodes was more in sandy loam soils (Nadakal. A.M, 1966). Increase in nematode numbers could be due to multiplication of the nematode as a result of continuous cultivation of turmeric without crop rotation and diversification (Kratochil *et al*., 2004). The intensity of Root knot nematode damage increased with the increase in the age of the plant. Extensive root galling was observed in Duggirala red turmeric genotype.

Host reaction

Among the four varieties studied, the turmeric cultivar ACC-79 was found immune to *M. incognita*, however the variety ACC-48 was found to be moderately resistant with gall index of 3 and Duggirala red & Rajapuri were found susceptible with the gall index of 4 (Niranjan Prabhu *et al.*, 2017).

Conclusion

The studied soils showed well developed structural variation and exhibited granular to sub angular blocky structure. The soil texture varied from sandy loam to clay. The soils are neutral to slightly alkaline in reaction and non-saline. The soils are low to medium in available nitrogen, medium to high in available phosphorus and potassium. Results of this study indicates that selected turmeric genotype Duggirala red and Rajapuri were susceptible to root knot nematode infection.

The genotype ACC-48 is Moderately resistant and ACC-79 is found to immune. The galling index indicates that the extent of damage is really a serious problem for turmeric growers. There is need for continued research in order to come up with cheap yet effective nematode management techniques. This may include screening various cultivars for resistance to various plant parasitic nematodes (PPN) with an aim of designing a proper nematode management strategy and promotes the plants to with stand unfavourable condition with better exploitation of nutrients and moisture.

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Table 1. Physical characteristics of turmeric growing soils of Nizamabad district.

S.No	Mandal	Villages	Depth (cm)	Gravel (%)	Particle size distribution (%)			Texture	Structure	Pore space (%)	B.D (Mgm^{-3})	MWHC (%)
					Sand	Silt	Clay					
1	Sirikonda	Nyavanandi	0-15	20.0	18.2	14.0	68.2	C	m2abk	59.0	1.19	58.0
		Gadkole	0-15	22.0	68.6	5.7	25.7	Scl	f1sbk	43.0	1.73	34.0
		Valgote	0-15	19.0	33.8	8.8	57.1	C	m2abk	58.0	1.20	56.0
		Kondur	0-15	21.0	37.1	10.9	51.8	C	m2abk	52.0	1.14	33.0
2	Armoor	Ankapoor	0-15	19.0	65.0	7.6	27.4	scl	m1gr	44.0	1.48	27.0
		Govindpet	0-15	25.0	66.7	4.8	28.6	Scl	m1sbk	45.0	1.65	20.0
		Pipri	0-15	12.0	25.0	11.0	63.8	C	m2 sbk	55.0	1.12	56.0
		Mamidipally	0-15	19.0	63.8	7.1	29.0	Scl	f1 sbk	45.0	1.64	28.6
3	Kammarpally	Konapur	0-15	22.0	71.4	7.1	21.4	scl	m1sbk	50.0	1.63	28.0
		Choutapally	0-15	24.0	62.9	8.6	28.6	scl	m3gr	49.9	1.59	31.0
		Kammarpally	0-15	21.0	44.4	8.9	46.7	cl	c1abk	48.0	1.45	50.0
		Narsapur	0-15	26.0	55.2	9.9	34.6	Scl	m1 sbk	46.0	1.61	29.0
4	Velpur	Velpur	0-15	24.0	62.9	8.6	28.6	Scl	m1abk	49.9	1.59	31.0
		Kothapally	0-15	22.0	60.0	10.0	30.0	Scl	m1sbk	48.3	1.58	26.7
		Kuknoor	0-15	25.0	55.2	9.9	34.6	Scl	m1sbk	46.0	1.61	29.0
		Padgal	0-15	17.0	47.9	14.6	37.5	Cl	c1 abk	47.0	1.46	52.0
5	Balkonda	Balkonda	0-15	29.0	68.1	6.9	24.0	Scl	m1sbk	43.9	1.34	25.9
		Mendora	0-15	30.0	62.3	9.0	28.8	Scl	f2gr	45.6	1.58	32.0
		Bodepally	0-15	24.0	63.1	11.0	27.0	Scl	f2gr	47.1	1.59	28.0
		Kothapalley	0-15	23.0	65.2	10.1	29.5	Scl	f2gr	45.0	1.56	27.0
6	Jakranpally	Jakrampally	0-15	34.0	67.7	9.0	23.2	Scl	m2gr-m1sbk	53.97	1.60	54.9
		Lakshmapur	0-15	32.0	64.3	7.0	28.5	Scl	f2sbk	44.98	1.12	28.7
		Brahmnapally	0-15	20.0	38.7	18.7	42.3	Cl	m1sbk	54.98	1.15	47.5
		Chintalur	0-15	28.0	69.8	8.8	21.3	Scl	m1sbk	44.98	1.47	20.0
7	Dharpally	Dharpally	0-15	29.6	66.9	10.1	24.0	Scl	m1abk	53.97	1.60	54.9
		Dubbaka	0-15	36.0	75.6	4.4	20.0	Sl	f2gr	41.0	1.70	23.0
		Dammanapet	0-15	35.0	66.4	7.4	26.1	Sl	f1gr	43.0	1.70	21.0
		Honnajipet	0-15	30.1	65.0	7.6	27.4	Scl	f2gr	44.0	1.48	27.0

Soil texture : ls – Loamy sand, sl- Sandy loam, scl –Sandy clay loam, sc- Sandy clay, cl- Clay loam and c- Clay; BD-Bulk density
Soil Structure : c-coarse, m- medium, f- fine, 1- weak, 2- moderate,3 - strong, gr- granular, abk- angular blocky, sbk- sub-angular blocky

Table 2. Physico-chemical properties of turmeric growing soils of Nizamabad district.

S.No	Mandal	Villages	Depth (cm)	pH (1:2.5)	EC (d Sm^{-1})	OC (g kg^{-1})	$CaCO_3$ (g kg^{-1})	Ca	Mg	Na	K	Total Ex.Bases	BS (%)	CEC (c mol (p+) kg^{-1})
								(c mol (p+) kg^{-1})						
1	Sirikonda	Nyavanandi	0-15	8.1	0.29	5.5	5.0	22.6	7.3	0.95	0.64	31.6	71.6	31.0
		Gadkole	0-15	7.3	0.26	7.0	3.0	11.9	7.8	0.65	26.1	20.9	80.2	26.1
		Valgote	0-15	8.1	0.36	6.5	2.3	18.3	7.0	0.76	0.53	26.7	63.4	32.1
		Kondur	0-15	7.9	0.28	6.8	4.1	12.1	8.4	0.75	26.4	21.9	82.9	26.4
2	Armoor	Ankapoor	0-15	6.58	0.18	5.8	3.0	16.7	7.0	0.58	0.69	25.0	73.7	33.9
		Govindpet	0-15	7.00	0.14	4.2	2.5	17.6	6.7	0.67	0.53	25.7	77.3	33.3
		Pipri	0-15	7.50	0.18	5.9	4.8	18.1	6.5	0.47	0.61	25.7	73.2	35.1
		Mamidipally	0-15	7.03	0.22	5.6	1.8	12.4	8.7	0.87	28.2	22.7	80.5	28.2
3	Kammarpally	Konapur	0-15	7.40	0.29	2.0	2.0	11.2	7.8	0.61	25.3	20.1	79.5	25.3
		Choutapally	0-15	7.24	0.22	4.6	3.1	10.5	7.1	0.58	24.9	18.7	75.1	24.9
		Kammarpally	0-15	7.25	0.19	5.8	2.2	9.8	7.5	0.55	23.5	18.4	78.2	23.5
		Narsapur	0-15	7.50	0.22	5.7	1.9	11.4	7.5	0.69	25.0	20.0	79.1	24.0
4	Velpur	Velpur	0-15	7.50	0.25	5.9	1.5	7.6	3.0	0.59	0.63	11.5	56.8	20.3
		Kothapally	0-15	7.40	0.21	5.6	2.0	7.5	3.5	0.45	1.02	11.9	70.2	16.9
		Kuknoor	0-15	7.32	0.20	6.4	1.9	14.8	6.3	0.42	0.64	22.0	86.8	25.3
		Padgal	0-15	6.94	0.18	5.3	1.8	21.8	9.8	0.55	0.75	32.8	84.4	38.9
5	Balkonda	Balkonda	0-15	7.00	0.15	4.8	2.1	7.2	4.0	1.37	0.28	13.3	66.5	20.0
		Mendora	0-15	7.90	0.18	6.9	1.6	6.2	2.9	0.44	0.35	9.9	63.1	15.7
		Bodepally	0-15	7.36	0.21	5.0	4.0	8.1	3.3	0.28	0.33	12.1	55.6	21.8
		Kothapalley	0-15	7.90	0.20	5.7	1.5	7.8	2.9	0.61	0.36	11.7	56.1	20.9
6	Jakranpally	Jakrampally	0-15	6.99	0.22	5.5	2.1	7.3	2.9	0.48	0.32	11.2	66.8	16.7
		Lakshamapur	0-15	6.80	0.14	5.9	1.9	6.4	5.5	0.6	22.7	12.9	57.0	22.7
		Brahmnapally	0-15	6.70	0.22	5.4	2.5	11.6	7.9	0.68	26.0	20.8	80.1	26.0
		Chintalur	0-15	6.80	0.12	5.4	3.0	6.9	5.4	0.48	22.6	13.2	58.6	22.6
7	Dharpally	Dharpally	0-15	7.01	0.19	5.9	1.5	6.6	6.2	0.55	19.0	13.8	72.7	19.0
		Dubbaka	0-15	7.40	0.19	5.1	1.1	8.9	5.8	0.45	0.41	15.6	74.0	21.0
		Dammanapet	0-15	6.50	0.22	4.6	1.1	6.6	3.2	0.12	0.33	10.4	52.6	19.8
		Honnajipet	0-15	7.30	0.22	5.2	2.1	6.9	4.0	0.66	0.25	12.0	66.5	18.0

Table 3. Available major and micro nutrient status of turmeric growing soils of Nizamabad district.

S.No	Mandals	Villages	Depth (cm)	Available macronutrients (kg ha^{-1})			Micro Nutrient status (mg/kg)			
				N	P	K	Zn	Cu	Mn	Fe
1	Sirikonda	Nyavanandi	0-15	240.0	22.0	315.0	0.32	1.66	14.44	10.60
		Gadkole	0-15	278.7	30.5	357.0	1.08	3.01	14.25	11.60
		Valgote	0-15	264.0	34.0	368.0	0.57	3.90	16.20	16.66
		Kondur	0-15	231.0	26.0	290.0	0.52	5.00	20.00	12.46
2	Armoor	Ankapoor	0-15	275.1	27.6	336.7	0.09	0.99	5.75	9.24
		Govindpet	0-15	277.0	15.0	282.0	0.55	0.98	22.00	16.74
		Pipri	0-15	201.9	19.9	341.3	0.57	1.61	24.60	13.96
		Mamidipally	0-15	263.0	26.0	262.0	0.82	2.36	20.00	13.80
3	Kammarpally	Konapur	0-15	259.7	20.8	393.0	0.40	1.51	20.60	17.86
		Choutapally	0-15	212.7	18.9	364.4	0.09	1.26	10.80	9.92
		Kammarpally	0-15	240.0	18.0	271.0	0.47	2.47	18.60	15.70
		Narsapur	0-15	271.4	26.1	381.9	0.26	0.99	14.20	15.30
4	Velpur	Velpur	0-15	184.0	14.0	296.0	0.07	0.60	16.40	3.93
		Kothapally	0-15	256.6	17.5	307.2	1.41	9.03	18.00	9.20
		Kuknoor	0-15	277.3	22.0	388.9	6.18	11.52	20.40	10.40
		Padgal	0-15	244.0	14.0	391.0	1.47	5.48	19.98	6.80
5	Balkonda	Balkonda	0-15	264.0	18.0	268.0	1.97	6.90	20.24	15.92
		Mendora	0-15	278.7	25.0	370.7	1.37	6.66	20.46	8.20
		Bodepally	0-15	269.7	17.8	293.0	0.15	7.80	24.40	6.22
		Kothapalley	0-15	208.1	18.1	372.7	1.69	8.67	22.60	11.60
6	Jakranpally	Jakranpally	0-15	285.0	28.1	355.3	2.48	8.90	24.60	13.00
		Lakshamapur	0-15	258.0	15.0	294.0	1.22	5.89	18.40	24.60
		Brahmnapally	0-15	263.2	19.6	326.4	1.29	6.01	17.40	19.78
		Chintalur	0-15	261.0	24.0	271.0	2.62	4.14	15.60	18.00
7	Dharpally	Dharpally	0-15	2450	18.0	232.0	1.38	3.15	13.80	15.32
		Dubbaka	0-15	266.5	15.6	295.0	1.21	4.49	14.40	18.16

S.No	Mandals	Villages	Depth (cm)	Available macronutrients (kg ha^{-1})			Micro Nutrient status (mg/kg)			
				N	P	K	Zn	Cu	Mn	Fe
		Dammanapet	0-15	198.0	20.0	275.0	0. 40	4.00	17.60	11.56
		Honnajipet	0-15	278.0	26.7	355.7	0.87	4.59	21.60	19.46

Table 4: Occurrence and distribution of root-knot nematode on each turmeric growing genotype in selected villages of Nizamabad district.

S.No	Mandals	Villages	Depth (cm)	Soil texture*	Village wise cultivated Turmeric genotypes				Turmeric genotypes wise Samples +ve and -ve for Root Knot Nematode				No of plants rhizome observed
					Duggirala red	ACC-79	ACC-48	Rajapuri	Duggirala red	ACC-79	ACC-48	Rajapuri	
1	Sirikonda	Nyavanandi	0-15	c	Duggirala red	-	-	-	+ve	-	-	-	100
		Gadkole	0-15	scl	Duggirala red	-	-	-	+ve	-	-	-	100
		Valgote	0-15	c	Duggirala red	-	-	-	+ve	-	-	-	100
		Kondur	0-15	c	Duggirala red	-	-	-	+ve	-	-	-	100
2	Armoor	Ankapoor	0-15	scl	Duggirala red	ACC-79	ACC-48	Rajapuri	+ve	-ve	+ve	+ve	100
		Govindpet	0-15	scl	Duggirala red	-	ACC-48	-	+ve	-	+ve	-	100
		Pipri	0-15	c	Duggirala red	ACC-79	ACC-48	Rajapuri	+ve	-ve	+ve	+ve	100
		Mamidipally	0-15	scl	Duggirala red	ACC-79	-	-	+ve	-ve	-	-	100
3	Kammarpally	Konapur	0-15	scl	Duggirala red	-	-	-	+ve	-	-	-	100
		Choutapally	0-15	scl	Duggirala red	-	-	Rajapuri	+ve	-	-	+ve	100
		Kammarpally	0-15	cl	Duggirala red	ACC-79	ACC-48	Rajapuri	+ve	-ve	+ve	+ve	100
		Narsapur	0-15	scl	Duggirala red	-	-	-	+ve	-	-	-	100
4	Velpur	Velpur	0-15	scl	Duggirala red	ACC-79	ACC-48	Rajapuri	+ve	-ve	+ve	+ve	100
		Kothapally	0-15	scl	Duggirala red	-	-	-	+ve	-	-	-	100
		Kuknoor	0-15	scl	Duggirala red	-	-	-	+ve	-	-	-	100
		Padgal	0-15	cl	Duggirala red	-	-	-	+ve	-	-	-	100
5	Balkonda	Balkonda	0-15	scl	Duggirala red	-	-	-	+ve	-	-	-	100
		Mendora	0-15	scl	Duggirala red	ACC-79	ACC-48	Rajapuri	+ve	-ve	+ve	+ve	100
		Bodepally	0-15	scl	Duggirala red	-	-	-	+ve	-	-	-	100
		Kothapalley	0-15	scl	Duggirala red	-	-	-	+ve	-	-	-	100

6	Jakranpally	Jakranpally	0-15	scl	Duggirala red	-	ACC-48	-	+ve	-	+ve	-	100
		Lakshamapur	0-15	scl	Duggirala red	-	-	-	+ve	-	-	-	100
		Brahmnapally	0-15	cl	Duggirala red	-	-	-	+ve	-	-	-	100
		Chintalur	0-15	scl	Duggirala red	-	-	-	+ve				100
7	Dharpally	Dharpally	0-15	scl	Duggirala red	-	-	-	+ve	-	-	-	100
		Dubbaka	0-15	sl	Duggirala red	-	-	-	+ve	-	-	-	100
		Dammanapet	0-15	sl	Duggirala red	-	-	-	+ve	-	-	-	100
		Honnajipet	0-15	scl	Duggirala red	-	-	-	+ve	-	-	-	100

*Soil texture: ls – Loamy sand, sl- Sandy loam, scl –Sandy clay loam, sc- Sandy clay, cl- Clay loam and c- Clay

Table 5: Frequency of root-knot nematode on each turmeric growing genotypes in selected villages of Nizamabad district.

S.No	Mandals	Villages	Depth (cm)	Soil texture *	Root Galling index*				No. of galls/ root system				Host reaction			
					Duggirala red	ACC-79	ACC-48	Rajapuri	Duggirala red	ACC-79	ACC-48	Rajapuri	Duggirala red	ACC-79	ACC-48	Rajapuri
1	Sirikonda	Nyavanandi	0-15	c	4	-	-	-	33	-	-	-	Susceptible	-	-	-
		Gadkole	0-15	scl	4	-	-	-	60	-	-	-	Susceptible	-	-	-
		Valgote	0-15	c	4	-	-	-	40	-	-	-	Susceptible	-	-	-
		Kondur	0-15	c	4	-	-	-	39	-	-	-	Susceptible	-	-	-
2	Armoor	Ankapoor	0-15	scl	4	0	3	4	55	0	15	33	Susceptible	immune	Moderately resistant	Susceptible
		Govindpet	0-15	scl	4	-	3	-	51	-	25	-	Susceptible	-	Moderately resistant	-
		Pipri	0-15	c	4	0	3	4	32	0	19	36	Susceptible	immune	Moderately resistant	Susceptible
		Mamidipally	0-15	scl	4	0	-	-	53	0	-	-	Susceptible	immune	-	-
3	Kammarpally	Konapur	0-15	scl	4	-	-	-	56	-	-	-	Susceptible	-	-	-
		Choutapally	0-15	scl	4	-	-	4	60	-	-	41	Susceptible	-	-	Susceptible
		Kammarpally	0-15	cl	4	0	3	4	43	0	23	32	Susceptible	immune	Moderately resistant	Susceptible
		Narsapur	0-15	scl	4	-	-	-	60	-	-	-	Susceptible	-	-	-
4	Velpur	Velpur	0-15	scl	4	0	3	4	52	0	16	35	Susceptible	immune	Moderately resistant	Susceptible

		Kothapally	0-15	scl	4	-	-	-	61	-	-	-	Susceptible	-	-	Susceptible
		Kuknoor	0-15	scl	4	-	-	-	57	-	-	-	Susceptible	-	-	-
		Padgal	0-15	cl	4	-	-	-	45	-	-	-	Susceptible	-	-	-
5	Balkonda	Balkonda	0-15	scl	4	-	-	-	61	-	-	-	Susceptible	-	-	-
		Mendora	0-15	scl	4	0	3	4	58	0	18	39	Susceptible	immune	Moderately resistant	Susceptible
		Bodepally	0-15	scl	4	-	-	-	51	-	-	-	Susceptible	-	-	-
		Kothapalley	0-15	scl	4	-	-	-	52	-	-	-	Susceptible	-	-	-
6	Jakranpally	Jakranpally	0-15	scl	4	-	3	-	49	-	23	-	Susceptible	-	Moderately resistant	-
		Lakshamapur	0-15	scl	4	-	-	-	66	-	-	-	Susceptible	-	-	-
		Brahmnapally	0-15	cl	4	-	-	-	46	-	-	-	Susceptible	-	-	-
		Chintalur	0-15	scl	4	-	-	-	63	-	-	-	Susceptible	-	-	-
7	Dharpally	Dharpally	0-15	scl	4	-	-	-	58	-	-	-	Susceptible	-	-	-
		Dubbaka	0-15	sl	4	-	-	-	71	-	-	-	Susceptible	-	-	-
		Dammanapet	0-15	sl	4	-	-	-	68	-	-	-	Susceptible	-	-	-
		Honnajipet	0-15	scl	4	-	-	-	55	-	-	-	Susceptible	-	-	-

***Gall index: Gall index 1 was on a scale of 0 to 5; where 0 = no galls; 1 = 1 to 2; 2 = 3 to 10; 3 = 11 to 30; 4 = 31 to 100; and 5 = more than 100 galls.**
Root-knot Index for *Meloidogyne incognita*: Grade; Description; Reaction
0= No galls Immune; 1= 1 to 2 galls/ root system Highly resistant; 2 =3 to 10 galls/ root system Resistant; 3= 11 to 30 galls/ root system Moderately resistant; 4 =31 to 100 galls/ root system Susceptible; 5= >100 galls/ root system Highly susceptible.