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# Soil Nematofauna Diversity of Paddy Fields of Goa, India

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***Abstract*:** Paddy field is a specialized habitat in which the soil has a very high water-holding capacity. Many nematode taxa are present in paddy fields including those that are specific parasites of the roots, stem and leaves of rice plants. Twenty-five species of nematodes were identified, belonging to five orders, 15 families and 19 genera. Nematodes were aggregated, not randomly or uniformly distributed. Herbivores belonging to order Tylenchida were most abundant. Peak densities and high diversity were in *morod* lands (rain-fed uplands) and in *kher* lands (rain-fed midlands) than in *khazan* lands (coastal saline lowlands). Higher densities and diversity were in the soil samples collected prior to paddy harvesting and lower in soil samples collected before transplant and after harvest. *Hirschmanniella oryzae* and *H. mucronata* were the dominant plant parasites.

***Keywords***: Agro-ecosystem, Different land types, Soil nematodes, Diversity, Density, Different stages of paddy cultivation

Paddy fields are biodiversity hotspots, nurturing a wide variety of organisms including nematodes. Nematodes are important pests of rice, but they often have gone unnoticed because of difficulties in identification. Among the significant species that attack rice, *Ditylenchus angustus* (Ufra) and *Aphelenchoides besseyi* (white-tip nematode) are main pests of deep-water rice in several countries (Varaprasad et al 2006). In irrigated rice, infections by *Hirschmanniella* spp. and *Aphelenchoides besseyi* are common, whereas upland rice is regularly diseased by *Meloidogyne* and *Pratylenchus* species. In India, losses in grain yield are estimated to be 16-32%. Yield loss due to rice stem nematode may vary from year to year depending on variety, time of infection, degree of infection and the environmental condition during crop season. The entire State of Goa is in the 12th agro-ecological zone of India viz., the west coast plains and Ghat region (http://farmech.dac.gov.in/06035-04-ACZ12-15052006.pdf ). Total area under rice cultivation in Goa is 49,966 hectares comprising 12 talukas (townships). (Korikanthmath et al 2011). Rice cultivation occurs on 27.4% of this total area. While upland rice cultivation dominates rice plantations in talukas adjacent to Western Ghats, lowland rice and salt-tolerant rice cultivation predominates in the coastal ecosystem. Extensive work has been done on the fauna of Goa (Anonymous 2008). However, invertebrates have been largely ignored and unrecorded in biodiversity studies. The Goa Foundation, one of the best known of Goa's environmental action groups, has listed 10 known Goan nematode species (http://goafoundation.org/biodiversity-in-goa/). Further perusal of the literature reveals very few published and unpublished reports on nematodes of Goa (Koshy and Sosamma 1988, Ahmad and Ahmad 1992, Pai and Gaur 2010). No specific literature is available on the nematofauna of the paddy fields of Goa. The objectives of this study were to document density, diversity and distribution of soil nematodes in paddy fields and compare the nematofaunal diversities in the three different land types *(khazan, kher and morod*).

## MATERIAL AND METHODS

*Kharif* crop or Sorod crop cultivation (monsoon crop) occurs from the first week of June to early July and the harvesting is done in September to October. The study was carried out in July, September and November 2013 to collect nematodes at three different times during paddy cultivation season. Soil samples were collected from different paddy fields chosen randomly in both districts of Goa (North Goa and South Goa). The samples were taken from three different land types: khazan (coastal saline / alluvial soils, lowlands), kher (arable, sandy to sandy loam soils, rain-fed midlands) and morod (lateritic soils, rain-fed uplands). Khazan lands or lowlands (32%) consist of low-lying areas, often below sea level and along the estuaries. They are mostly used for monsoon paddy crop. Kher lands or midlands (32%) are flatlands at low and have a high water table. The arable, sandy to sandy loams soils are suitable for multiple cropping through irrigation. Morod lands or uplands (16.4%) refer to lateritic uplands or terraced fields with a single rain-fed crop of rice.

A total of 30 soil samples for each of the land types were collected when the saplings were about 25 cm high. The ten sample each before transplanting ,at pre-paddy harvesting

(10 samples) and at post-harvesting of paddy were collected The samples were taken in the rhizosphere area 5-25 cm beneath the soil surface by taking precaution to avoid the top soil of about 1–5 cm depth. Each sample was placed in a self-sealing plastic bag with a label covering the required field information. They were either processed immediately after being brought to the laboratory or stored in the refrigerator at 4°C to be processed later. Samples were soaked in water for a few minutes then nematodes were concentrated by means of Cobb's sieving and decanting method (Cobb 1918, Ahmad 1996) and isolated in modified Baermann funnels (Thorne 1961). Nematodes were fixed in warm 4% formalin and processed with a slow glycerine method (Seinhorst 1959) to pure glycerine, then mounted on permanent slides and used for identification of nematode species.

The nematodes were identified and classified using the available literature (Goodey 1963, Jairajpuri and Khan 1982, Jairajpuri and Ahmad 1992, Andrassy 1999, Siddiqi 2000). Information was also retrieved for identification and classification from the websites of NEMAPLEX and Nema Species Masterlist A-Z (http://nematode.unl.edu/masterlist A-Z. htm). Shannon (H'), Simpson (D) and Brillouin's Evenness (J) Indices were analyzed for the nematode species using a standard statistical package (PAST version software).

**Density, diversity and distribution of nemafauna:** In this investigation, a total of 25 nematode species were identified in five orders, 15 families and 19 genera (Table 1). The order Tylenchida had the highest number of families (5), genera (7) and species (11) followed by Dorylaimida with four families, six genera and eight species. Mononchida was represented by three families, three genera and three species while Araeolaimida had only one family, one genus and one species (Fig. 1). Among the trophic groups, in genera as well as in abundance, herbivores dominated with 47.4% of genus diversity and 60% abundance diversity followed by the other four groups: omnivores, predators and fungivores and bacterivores (Fig. 2). Among orders for diversity of genera

**Table 1.** Taxonomic status of soil nematodes of paddy fields of Goa

| Orders | Families | Scientifc names |
|---|---|---|
| Dorylaimida | Xiphinematidae | *Xiphinema insigne* Loos 1949 |
| | | *X. brevicolle* Lordello & da Costa 1961 |
| | Dorylaimidae | *Dorylaimus stagnalis* Dujardin 1845 |
| | | *Laimydorus uterinus* Loof 1995 |
| | | *Thornenema mauritianum* (Williams 1959) Baqri & Jairajpuri 1969 |
| | Nordiidae | *Lenonchium oryzae* Siddiqi 1965 |
| | | *L. macrodorus* Ahmad & Jairajpuri 1988 |
| | Qudsianematidae | *Ecumenicus monohystera* (De Man 1880) Thorne 1974 |
| Tylenchida | Hoplolaimidae | *Hoplolaimus indicus* Sher 1963 |
| | | *Helicotylenchus dihystera* (Cobb 1893) Sher 1961 |
| | | *H. abunaamai* Siddiqi 1972 |
| | | *H. indicus* Siddiqi 1963 |
| | Meloidogynidae | *Meloidogyne graminicola* Golden & Birchfield 1965 |
| | Criconematidae | *Criconemella onoesis* ( Luc 1959) Luc & Raski 1981 |
| | | *C. xenoplax* (Raski 1952) Luc & Raski 1981 |
| | | *Ditylenchus angustus* (Butler 1913) Filipjev 1934 |
| | Belonolaimidae | *Tylenchorhynchus annulatus* (Cassidy 1930) Golden 1971 |
| | Pratylenchidae | *Hirschmanniella oryzae* (Van Breda de Haan1902) Luc & Goodey 1963 |
| | | *H. mucronata* (Das 18891960) Luc & Goodey 1963 |
| Araeolaimida | Plectidae | *Plectus cirratus* Bastian 1865 |
| Aphelenchida | Aphelenchoididae | *Aphelenchoides besseyi* (Christie 1942) Allen 1952 |
| | Aphelenchidae | *A. avenae* Bastian 1865 |
| Mononchida | Mylonchulidae | *Mylonchulus minor* (Cobb 1893) Andrássy 1958 |
| | Iotonchidae | *Iotonchus trichurus* (Cobb 1916) Andrássy 1958 |
| | Mononchulidae | *Oionchus obtuses* Cobb 1913 |

and abundance, Tylenchida dominated (36.84% and 44 %) followed by Dorylaimida (Mononchida, Aphelenchida and Araeolaimida , respectively (Fig. 2). Species densities per 100 gm of dry soil were 96-116 individuals (Table 2). *Oionchus obtuses* (116) and *Aphelenchoides besseyi* (116) had the maximum density while *Laimydorus uterinus* and *Lenonchium oryzae* the minimum (Table 2).

**Nemafauna diversity of land types:** Nematodes were most diverse in morod land type with 22 taxa and least diverse in the khazan land type (13 species) (Table 3, Fig. 3). Five species (*Lenonchium oryzae, Lenonchium macrodorum, Meloidogyne graminicola, Criconemella onoesis* and *Plectus cirratus*) were present in all three land types. Four of these five common species are herbivores while *Plectus cirratus* is a bacterivore (Table 2). Besides the five (20% of all species) common to the three land types, 32% were common to khazan and kher, 68% were common to kher and morod land type and 40 % were common to khazan and morod land types (Fig. 4). Fungivores were absent in khazan land type (coastal saline/alluvial soils) but present in the other two land types. Predators were more diverse in kher land type (flatlands with high water table) compared to khazan and morod (upland/terraced) land types (Table 5). Species diversity was highest in morod land (22) and lowest in khazan land (13) while kher land had 20 species. Abundance was highest in morod land (299) and lowest in khazan land (163). Dominance values were low in all three land types and evenness values were very high. The Shannon and Fisher diversity indices were highest in morod land and lowest in khazan land (Table 4, Fig. 3).

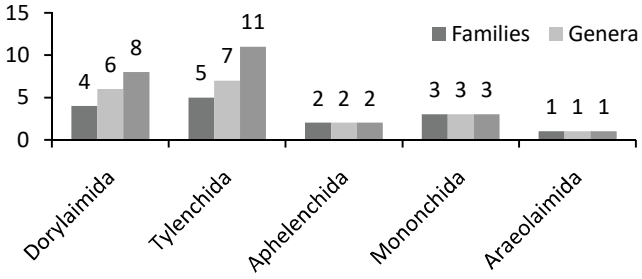


**Fig. 1.** Order-wise soil nematode diversity of paddy fields of Goa

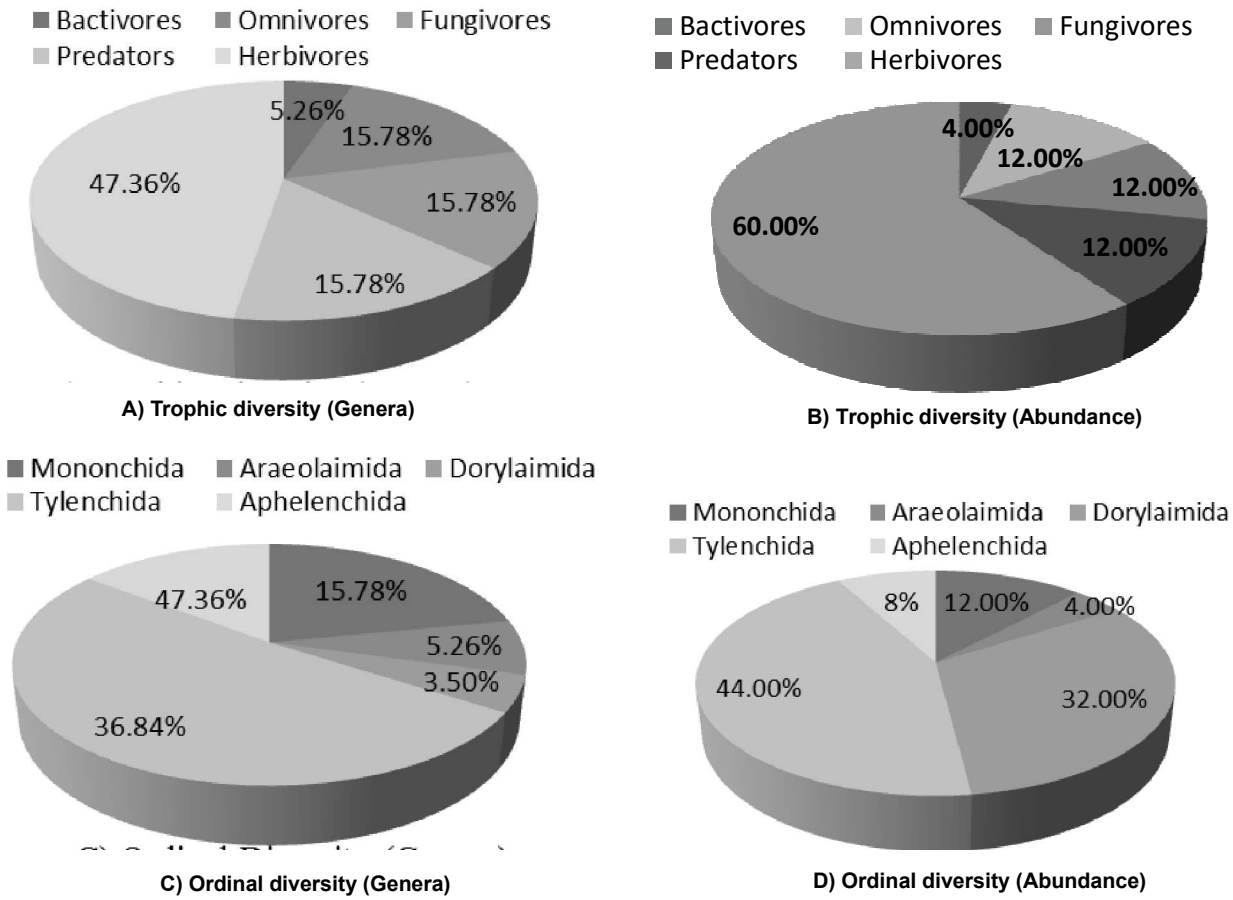


**Fig. 2.** Community Structure of soil nematodes of paddy fields of Goa (A, B, C & D)

**Soil nematofaunal diversity at different stages of paddy crop:** In all three land types, nematode densities were higher prior to harvesting and lower before transplanting and post harvesting season. *Hirschmanniella oryzae* was not observed in khazan land type (Table 6) while *Hirschmanniella mucronata* was not found in Kher land type (Table 3, 6), but both species had their highest densities in the morod land type samples collected prior to harvest . The khazan land type had the highest numbers of *Dorylaimus stagnalis* and *Lenonchium oryzae* and the lowest numbers of *Laimydorus uterinus, Helicotylenchus abunaamai* and *Criconemella onoesis, Laimydorus uterinus* and *Dorylaimoides constrictus* were lowest in the kher land type prior to harvesting. Densities of *Aphelenchoides besseyi* were highest in samples collected before transplanting in both kher and morod, but this species was absent in khazan . In kher *Mylonchulus minor* (8/100 gm dry soil) numbers were lowest in samples collected after harvesting while *Laimydorus uterinus* densities were lowest before transplanting.

In this study, a total of 25 species were reported. Species belonging to the order Tylenchida which mostly represents plant feeders were more. The genera and the abundance in the ordinal diversity were dominated by the order Tylenchida (McNeely et al 1995). The present investigation also had similar results. The present also agrees with Háněl (2003) that omnivore nematodes with their versatile feeding habits would probably intervene in the soil food web resulting in the absence of the species that are dependent on undisturbed habitats. The free space that is created might be utilized by the herbivores and their population increases. So the species density among the herbivores was more. Fungivores were minimum in density, this is in agreement with Yeates et al (1993) and Yeates (1999), that omnivores are multi-feeders thus affecting adversely the population of fungal feeders. Species belonging to omnivores had maximum density as these are versatile feeders, increase in the population of hyphae, bacteria, microfaunal prey might result in the increase in the growth of their population. Herbivores showed high value of H' (2.74) which almost agrees with the values recorded by Háněl (1995). In this study, khazan lands had the fewest number of species. Conditions in khazans pose

**Table 2.** Diversity and density (no. of individuals / 100 gms of moist soil) of different tropic groups of soil nematodes of paddy fields of Goa

| Trophic group | Order | Scientific names | Species density/ 100 gm of moist soil (m) |
|---|---|---|---|
| Omnivores | Dorylaimida | *Dorylaimus stagnalis* | 103 |
| | | *Ecumenicus monohystera* | 108 |
| | | *Laimydorus uterinus* | 96 |
| Predators | Mononchida | *Mylonchulus minor* | 112 |
| | | *Iotonchus trichurus* | 105 |
| | | *Oionchus obtuses* | 116 |
| Fungivores | Dorylaimida | *Thornenema mauritianum* | 102 |
| | Aphelenchida | *Aphelenchus avenae* | 97 |
| | | *A. besseyi* | 116 |
| Herbivores | Dorylaimida | *Xiphinema brevicolle* | 109 |
| | | *X. insigne* | 115 |
| | | *Lenonchium oryzae* | 96 |
| | | *L. macrodorum* | 101 |
| | Tylenchida | *Hoplolaimus indicus* | 98 |
| | | *Helicotylenchus dihystera* | 114 |
| | | *H. abunaamai* | 106 |
| | | *H. indicus* | 97 |
| | | *Meloidogyne graminicola* | 108 |
| | | *Criconemella onoesis* | 98 |
| | | *C. xenoplax* | 111 |
| | | *Ditylenchus angustus* | 107 |
| | | *Tylenchorhynchus annulatus* | 99 |
| | | *Hirschmanniella oryzae* | 104 |
| | | *H. mucronata* | 112 |
| Bactivores | Araeolaimida | *Plectus cirratus* | 100 |

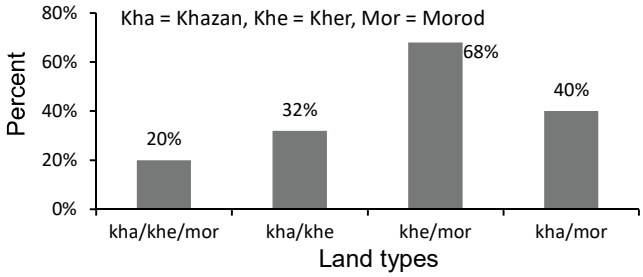


**Fig. 3.** Percent occurrence of common species of soil nematodes in different land types

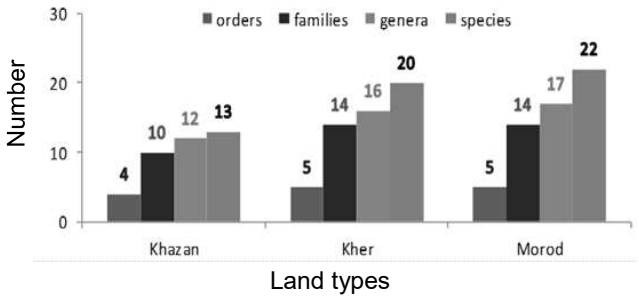


**Fig. 4.** Taxonomic hierarchy of soil nematodes present in different land types

**Table 3.** Nematode diversity in different land types

| Presence or absence of species in the different land types | | | | | |
|---|---|---|---|---|---|
| Orders | Families | Scientific names | Khazan Lowland land | Kher Midland | Morod Upland |
| Dorylaimida | Dorylaimidae | *Dorylaimus stagnalis* | + | + | - |
| | Qudsianematidae | *Ecumenicus monohystera* | - | + | + |
| | Dorylaimidae | *Laimydorus uterinus* | + | - | + |
| | Dorylaimidae | *Thornenema mauritianum* | - | + | + |
| | Xiphinematidae | *Xiphinema brevicolle* | + | - | + |
| | Xiphinematidae | *X. insigne* | - | + | + |
| | Nordiidae | *Lenonchium oryzae* | + | + | + |
| | Nordiidae | *L. macrodorum* | + | + | + |
| Mononchida | Iotonchidae | *Iotonchus trichurus* | - | + | + |
| | Mononchulidae | *Oionchus obtuses* | + | + | - |
| | Mylonchulidae | *Mylonchulus minor* | - | + | + |
| Aphelenchida | Aphelenchidae | *Aphelenchus avenae* | - | + | + |
| | Aphelenchoididae | *Aphelenchoides besseyi* | - | + | + |
| Tylenchida | Hoplolaimidae | *Hoplolaimus indicus* | + | - | + |
| | Hoplolaimidae | *Helicotylenchus dihystera* | - | + | + |
| | Hoplolaimidae | *H. abunaamai* | + | + | - |
| | Hoplolaimidae | *H. indicus* | - | + | + |
| | Meloidogynidae | *Meloidogyne graminicola* | + | + | + |
| | Criconematidae | *Criconemella onoesis* | + | + | + |
| | Criconematidae | *C. xenoplax* | - | + | + |
| | Criconematidae | *Ditylenchus angustus* | - | + | + |
| | Belonolaimidae | *Tylenchorhynchus annulatus* | + | - | + |
| | Pratylenchidae | *Hirschmanniella oryzae* | - | + | + |
| | Pratylenchidae | *H. mucronata* | + | - | + |
| Araeolaimida | Plectidae | *Plectus cirratus* | + | + | + |
| | | | Total | 13 | 20 22 |

+ = present, - = absent

**Table 4.** Diversity indices of nematofauna for different land types

| Diversity indices | Khazan | Kher | Morod |
|---|---|---|---|
| Species Richness | 13 | 20 | 22 |
| Abundance | 163 | 265 | 299 |
| Simpson's Dominance_D | 0.07915 | 0.05148 | 0.04683 |
| Shannon_H | 2.55 | 2.981 | 3.076 |
| Evenness_e^H/S | 0.9854 | 0.9853 | 0.9847 |
| Equitability_J | 0.9943 | 0.9951 | 0.995 |
| Fisher alpha | 3.322 | 5.018 | 5.475 |

**Table 5.** Percent occurrence of genera and species based on trophic structure in different land types

| Trophic groups | Khazan land | | Morod land | | Kher land | |
|---|---|---|---|---|---|---|
| | Genera | Species | Genera | Species | Genera | Species |
| Omnivores | 16.66 | 15.38 | 12.00 | 9.09 | 12.50 | 10 |
| Predators | 8.33 | 7.69 | 11.76 | 9.09 | 18.75 | 15 |
| Fungivores | - | - | 17.64 | 13.63 | 18.75 | 15 |
| Herbivores | 66.66 | 69.00 | 53.00 | 63.63 | 44.00 | 55 |
| Bactivores | 8.33 | 7.69 | 5.88 | 4.54 | 6.25 | 5.0 |

**Table 6.** Species density of nematodes in all the three land types at three different stages of paddy cultivation

| Species | Different stages of paddy cultivation in different land types | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | Khazan | | | Kher | | | Morod | | |
| | B.T. | Pre H. | Post H. | B.T. | Pre H. | Post H. | B.T. | Pre H. | Post H. |
| *Xiphinema insigne* | - | - | - | 25 | 34 | 29 | 20 | 42 | 37 |
| *X.brevicolle* | 26 | 45 | 31 | - | - | - | 28 | 39 | 30 |
| *Dorylaimus stagnalis* | 16 | 48 | 32 | 35 | 49 | 30 | - | - | - |
| *Laimydorus uterinus* | 14 | 31 | 19 | - | - | - | 28 | 34 | 22 |
| *Thornenema mauritianum* | - | - | - | 10 | 21 | 13 | 37 | 53 | 33 |
| *Lenonchium oryzae* | 22 | 48 | 33 | 19 | 29 | 20 | 29 | 37 | 31 |
| *L. macrodorus* | 10 | 35 | 21 | 29 | 37 | 24 | 32 | 49 | 27 |
| *Ecumenicus monohystera* | - | - | - | 26 | 37 | 29 | 21 | 37 | 31 |
| *Hoplolaimus indicus* | 19 | 37 | 23 | - | - | - | 16 | 23 | 12 |
| *Helicotylenchus dihystera* | - | - | - | 15 | 29 | 20 | 17 | 25 | 16 |
| *H. abunaamai* | 14 | 31 | 19 | 18 | 32 | 26 | - | - | - |
| *H. indicus* | - | - | - | 27 | 40 | 31 | 17 | 30 | 05 |
| *Meloidogyne graminicola* | 21 | 42 | 29 | 34 | 49 | 23 | 38 | 53 | 42 |
| *Criconemella onoesis* | 23 | 44 | 31 | 29 | 41 | 30 | 35 | 51 | 41 |
| *C.xenoplax* | - | - | - | 23 | 39 | 27 | 31 | 43 | 37 |
| *Ditylenchus angustus* | - | - | - | 17 | 29 | 20 | 27 | 42 | 38 |
| *Tylenchorhynchus annulatus* | 18 | 31 | 20 | - | - | - | 34 | 49 | 40 |
| *Hirschmanniella oryzae* | - | - | - | 44 | 52 | 37 | 44 | 65 | 50 |
| *H. mucronata* | 17 | 33 | 24 | - | - | - | 39 | 54 | 43 |
| *Plectus cirratus* | 27 | 41 | 30 | 30 | 49 | 34 | 31 | 45 | 39 |
| *Aphelenchoides besseyi* | - | - | - | 42 | 37 | 24 | 46 | 31 | 27 |
| *A. avenae* | - | - | - | 39 | 30 | 26 | 25 | 17 | 22 |
| *Mylonchulus minor* | - | - | - | 12 | 19 | 8 | 16 | 25 | 20 |
| *Iotonchus trichurus* | - | - | - | 12 | 15 | 21 | 15 | 24 | 17 |
| *Oionchus obtuses* | 16 | 28 | 17 | 34 | 58 | 41 | - | - | - |

Species density / 100 gm of moist soil
B.T. = Before Transplantation, Pre H. = Pre harvesting, Post H. = Post harvesting

special problems for agriculture as khazan soils are poorly drained and have an acidic pH, relatively high organic carbon and iron, low calcium and high salinity.These are alluvial soils with high water tables and are subjected to inundation by salt water. Salinity varies during monsoon (2–3ºBé) and non-monsoon times (4–5ºBé) (Mani et al 2012). The low pH values of khazan lands (4.8–5.3) may contribute to a reduction in nematode diversity. Morod and kher lands, with higher nematode diversity, have less acidic soils; kher lands consist of arable sandy loam soil and morod lands are upland or terraced fields suitable for horticulture as well as agricultural crops. The results are in agreement with Jairajpuri and Baqri (1991) as nematodes are the most abundant components of the mesofauna in agronomic soils. Herbivores were the dominant trophic group, comprising more than 50% of total specimens. Predators were characteristics of morod land type as these lands mostly have laterite soils and confined to upland or terraced fields. Though this is uncommon in most ecosystems but may be related to rich food web of the site (Baniyamuddin et al 2007). Kher land type showing highest number in genera and abundance of fungivores represented that these lands are arable sandy loams and are used for multiple cropping through irrigation. *Hirschmanniella* spp. have been reported to be present in all the irrigated rice fields all over the world. *H. oryzae* and *H.mucronata* are the dominant species infecting rice crops in all parts of India, including irrigated, semi-deep and deep-water rice environments (Prasad et al 1987, Varaprasad et al 1992). The highest greatest species densities of *A. besseyi* were before transplanting. Qiu et al

(1991) suggested that *A. besseyi* invades rice mainly during sowing to the 3-leaf stage.

## CONCLUSION

From this study it can be concluded that at least 25 nematode species are present in the paddy fields of Goa. The paddy field ecosystem favors plant-parasitic Tylenchids. Of the three land types, species diversity was highest in the well-drained, fertile morod land type and least in the khazan land type. Khazan lands, being saline, are not as favorable for terrestrial nematodes that are adapted to rice agriculture. Morod land also had generally high densities of individual species. Soil samples at pre-harvest generally had the highest densities of nematodes regardless of trophic group or land type. Root growth is most extensive during this stage of paddy cultivation, and therefore herbivores dependent on plant roots for their food had higher numbers. Increased root mass likely stimulated other trophic groups and provided more prey for predacious species. Fertilization patterns, use of natural fertilizers or chemical fertilizers, use of pesticides and field management methodologies can be studied for their effects on nematode communities as bio-indicators of the health of paddy field ecosystem and for effective means of controlling pest species.

## REFERENCES


Ahmad W and Ahmad I 1992. *Makatinus heynsi* n. sp. Dorylaimida: Aporcelaimidae. *Fundamental Applications of Nematology*. Section of Nematology, Department of Zoology, AMU, Aligarh **15**(2): 149-152.

Ahmad W 1996. *Plant Parasitic Nematodes of India, an identification manual.* Aligarh, India, Aligarh Muslim University. 348, 49 figs. Litho Offest Printers, Achal Tal, Aligarh, U.P. 202001.

Andrassy I 1999. A census of genera and subgenera of free-living nematodes. *Journal of Nematode Morphology and Systematics* **2:** 45-68.

Anonymous 2008. *Fauna of Goa, State Fauna Series, 16*. Zoological Survey of India, Kolkata, 531pp.

Baniyamuddin M, Tomar VVS and Ahmad W 2007. Functional diversity of soil inhabiting nematodes in natural forests of Arunachal Pradesh, India. *Nematologia Mediterranea* **35:** 109-121.

Burns NC 1971. Soil pH effects on nematode populations associated with soybeans. *Journal of Nematology* **3:** 238-245.

Cobb NA 1918. *Estimating the nema population of the soil.* (Washington): United States Department of Agriculture, (Agricultural Technical Ciruclar, 1) : pp 48.

De Maeseneer J and D'Herde J 1963. Methodes utilisees pour l'etude des anguillules libres du sol. *Revue de l' Agriculture* Bruxelles **16:** 441-447.

Goodey T 1963. *Soil and Freshwater Nematodes*. Second edition, revised and rewritten by J. B. Goodey, London: Methuen & Co. Ltd.

Háněl L 1995. Comparison of soil nematodes communities in three spruce forests at the Boubin Mount, Czech Republic. *Biologia Bratislava* **51:** 485-493.

Háněl L 2003. Soil nematodes in cambisol agroecosystem of the Czech Republic. *Biologia Bratislava* **58:** 205-216.

Jairajpuri MS, Azmi MI and. Bajaj HK 1974. Studies on nematode behaviour. I. Effect of pH and salt concentrations on the survival of *Hoplolaimus indicus, Helicotylenchus indicus Xiphinema basiri* and *Mylonchulus minor*. *Indian Journal of Nematology* **4:** 171- 181.

Jairajpuri MS and Khan WU 1982. *Predatory Nematodes (Mononchida)*. Associated Publishing Company, New Delhi, India.

Jairajpuri MS and Baqri QH 1991. *Nematode pests of rice*, Oxford & IBH Publ. Co. Pvt Ltd Calcutta.

Jairajpuri MS and Ahmad W 1992. *Dorylaimida, Predaceous and Plant - Parasitic Nematodes*. Oxford & IBH Publ. Co.

Korikanthmath VS, Manjunath BL and Manohara KK 2011. *Status paper on rice in Goa,* Rice Knowledge Management Portal (RKMP), Directorate of Rice Research, Hyderabad, 500030:1-23.

Koshy PK and Sosamma VK 1988. Occurrence of the burrowing nematode *R. similis* in the state of Goa. *Indian Journal of Nematology* **18**(1): 130.

Malhotra SK and Chaubey AK 1993. High salinity tolerance of Eucalyptus and interactions with soil and plant nematodes of pathogenic significance, In: Towards the rational use of high salinity tolerant plants task for vegetation science **28:** 239-145.

Mani K, Salgaonkar BB and Braganca JM 2012. Culturable halophilic archaea at the initial and final stages of salt production in a natural solar saltern of Goa, India. *Aquatic Biosystems* **8:** 15.

Mathur VK and Prasad SK 1971. Occurrence and distribution of *Hirschmanniella oryzae* in the Indian Union with description of *H. mangalorensis*. *Indian Journal of Nematology* **1**(2): 220-226.

Mohandas C, Pattanaik NKC and Prasad JS 1979. Host range of the rice root nematode, *Hirschmanniella oryzae*. *Indian Journal of Nematology* **9:** 177-178.

McNeely JA, Gadgil M, Leveque C, Padoch C and Redford K 1995. Human influence in biodiversity. In *Global Biodiversity Assessment* (V.H. Heywood, ed.), pp. 711-822. Cambridge: Cambridge University Press.

Norton DC 1978. Ecology of plant-parasitic nematodes. Wiley–Interscience, Iowa State University, Ames.

Qiu TX, Yan MF and Lu Q 1991. Study on the occurrence, regulation and control of *Aphelenchoides besseyi*. *Zhejiang Nongye Kexue* **6:** 290-292.

Pai IK and Gaur HS 2010. First report on the occurrence of an economically important spiral nematode (*Helicotylenchus multicinctus* Cobb.) from Goa. *Journal of the Bombay Natural History Society* **107**(1): 68-69.

Prasad JS, Panwar MS and Rao YS 1987. Nematode problems of rice in India. *Tropical Pest Management* **33**(2): 127-136.

Seinhorst JW 1959. A rapid method for the transfer of nematodes from fixatives to anhydrous glycerin. *Nematologica* **4:** 67-69.

Sivakumar CV and Khan E 1982. Description of *Hirschmanniella kaverii* sp.n. (Radopholidae: Nematoda) with a key to identification of *Hirschmanniella* spp. *Indian Journal of Nematology* **12:** 86-90.

Siddiqi MR 2000. *Tylenchida. Parasites of plants and insects*. 2nd edition. CAB International Wallingford Oxon OX10 8DE. UK.

Thorne G 1961. *Principles of nematology*. McGraw-Hill, New York. 533 pp.

Tikhinova LV 1966. Bioecology of the agent responsible for "white tip" disease of rice: *Aphelenchoides besseyi. Vest. Sel'-khoz.NaukiAlma-Ata.* 2: 45-47. In Russian.

Varaprasad KS, Reddy MCM and Prasad JS 1992. Occurrence of rice root nematode in Andhra Pradesh, India. *Oryza* **29:** 171-172.

Varaprasad KS, Prasad JS, Chakrabarty SK and Anitha K 2006. Global pest status of white-tip and *ufra* nematodes and their role in transboundary movement of rice. In: *International Rice Congress* Oct, 2006, New Delhi. pp 84.

Yeates GW, Bongers T, de Goede, RGM, Freckman DW and Georgieva SS 1993. Feeding habits in soil nematode families and genera-an outline for soil ecologists. *Journal of Nematology* **25**: 315-331.

Yeates GW 1999. Effects of plants on nematode community structure, *Annual Review of Phytopathology* **37:** 127-149.

http://www.goacom.com/goafoundation/biodiversity (Goafaoundation.org: NBSAPS Report: google.com-goafoundation.org/complete projects/biodiversity-in-goa / Checklist of Goa's Biodiversity (Accessed on 20 January 2014).

*NEMAPLEX: The Nematodes Plant Expert Information System.* http://nematode.unl.edu/masterlist A-Z. htm.

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