TEMPORAL VARIATION IN ABUNDANCE OF NEMATODES IN A BANANA PLANTATION OF WEST BENGAL, INDIA

V.V. Gantait[1]*, T. Bhattacharya[**] and A. Chatterjee[*]

[*] *Nemathelminthes Section, Zoological Survey of India, M-Block, New Alipur, Kolkata-700053, West Bengal, India*
[**] *Department of Zoology, Vidyasagar University, Medinipur-721102, Paschim Medinipur, West Bengal, India*

Summary. An ecological investigation was undertaken in a banana plantation of West Bengal, India, from March 2004 to February 2006 during which fourteen species of soil and plant parasitic nematodes were collected and identified. Of these, eight species belonged to the order Dorylaimida and six to the order Tylenchida. They exhibited a bimodal pattern of population fluctuation with a prominent peak during August or September and a low peak during March. Likewise, there were two minima, one during January and another in May or June. Nematode populations increased after rainfall but declined during the post-monsoon period and remained at a low level during winter. During early spring, populations again increased but declined in summer. Temporal variation of the nematode population was statistically correlated with the edaphic factors temperature, moisture, pH and organic carbon. Simple correlation analysis revealed that the abundances of all the species were significantly correlated with moisture and organic carbon. Soil temperature was significantly correlated with the abundance of only three species. Soil pH was negatively and significantly correlated with that of all the species. Multiple regression revealed that all the edaphic factors had a significant influence on the abundance of all the nematode species, except two viz., *Laimydorus siddiqii* and *Pratylenchus coffeae*. Canonical Correspondence Analysis further proved this finding.

Key words: Abundance, banana, Dorylaimida, edaphic factors, nematodes, Tylenchida.

Banana is an economically important crop that is extensively cultivated in tropical and subtropical countries (Gowen *et al.*, 2005). It is one of the major fruit crops forming an important item in the diet of millions of people across the globe (Harish and Nanje Gowda, 2001). India is the largest banana producing country of the world (Devi *et al.*, 2007), with 332.2 thousand hectares and an annual production of 3,633 thousand tonnes (Jonathan and Rajendran, 2003). West Bengal is the second largest banana producing State of India, with its 25.73 thousand hectares and a total production of 502.1 thousand tonnes per annum.

Nematodes are one of the major limiting factors in banana production. Tylenchids have been recognized as a major constraint in banana production and are responsible for serious yield losses (Sundararaju, 2006). Dorylaimids act as vectors of various fungal and bacterial diseases of this important crop (Khan, 2006). Thus, dorylaimids and tylenchids have considerable direct and indirect effects on this valuable fruit crop. Information on population structure is important in the study of the plant-nematode relationship (Oostenbrink, 1966), for the development of an effective management schedule and advisory service (Barker and Nusbaum, 1971; Barker and Campbell, 1981; Chawla and Mittal, 1995). Edaphic factors, such as temperature, moisture, pH and organic carbon content of soil greatly influence the nematode population (Jones *et al.*, 1969; Korthals *et al.*, 1996; Bilgrami *et al.* 2003). Therefore, an investigation was undertaken from March 2004 to February 2006 to ascertain temporal variation of abundance of dorylaimid and tylenchid nematodes in relation to different edaphic factors in a banana plantation of West Bengal, India, to provide a valuable data base for the development of effective management schedules and advisory services in the future and thereby increase production of this valuable fruit crop.

[1] Corresponding author: v.gantait@rediffmail.com

MATERIALS AND METHODS

For the present study, a plot of 15 m × 10 m was selected in a banana (*Musa paradisiaca* L. cv. Kanthali) plantation in Sabang block under Paschim Medinipur district (22°57'10"-21°36'35" N, 88°12'80"-86°35'50" E) of West Bengal, India. For sampling, five spots, separated by equal distances, were fixed in the plot. A rhizospheric soil sample of 250 g was taken from each spot, each at a distance of about 25 cm from the main bole of a banana plant. A root sample of 5 g was also taken from the same plant at the same spot. Thus five soil and five root samples were collected from the plot on each sampling occasion. The samples were collected during the first week of every month, preferably on the first Sunday, from March 2004 to February 2006. Soil temperature was measured by a soil thermometer, and soil pH and moisture were estimated by a soil pH and moisture meter, Model DM-15, Takemura Electric Works Ltd., Tokyo, Japan. Organic carbon content of soil was determined in the laboratory following Walkley and Black's rapid titration method (Walkley and Black, 1947). Bars on the graphs of temporal variation in soil pH (Fig. 3) and temporal variation in organic carbon content of soil (Fig. 4) are representing the SE values of the edaphic factors.

Nematodes were extracted from soil by Cobb's sieving technique (Cobb, 1918) and from the roots using the mechanical maceration technique (Reddy, 1983). They were cleaned using the modified Baermann's funnel technique (Christie and Perry, 1951) before counting in a Syracuse counting dish under a stereoscopic binocular microscope. Nematodes were then processed using Seinhorst's slow dehydration method (Seinhorst, 1959). Dehydrated nematodes were mounted permanently on glass slides and identified to species level following the keys of Jairajpuri and Ahmad (1992) for the order Dorylaimida and of Siddiqi (2000) for the order Tylenchida. Specimens were deposited in the National Zoological Collections of the Zoological Survey of India, Kolkata, West Bengal, India.

Time-series analysis of the edaphic factors, simple correlation and multiple regression analyses between the edaphic factors and abundance of nematode species were done using STATISTICA version 7.0 (StatSoft, Inc., 2007). Correlations between the abundance of species and the measured set of environmental variables were analyzed with Canonical Correspondence Analysis (CCA) on non-transformed data. CCA is a direct gradient analysis technique, done using the CANOCO program v 4.53 (Ter Braak, 1988). Eigen value in the Ordination diagram based on Canonical Correspondence Analysis (Fig. 7) is a special set of scalars associated with a linear system of equation (i.e. a matrix equation) that is sometime also known as characteristic root or characteristic value which is ultimately represented as an interpreting value corresponding to its eigenvector in a multivariate analysis (i.e. CCA). Considering this value, it is predicted that the change under consideration may be accepted or rejected based on its P-value.

RESULTS

During the study, the soil temperature ranged from 17 °C (January, 2005) to 36 °C (June, 2005). From April to October, the temperature was high and in the range 31-36 °C; while from November to March it was lower (17-28 °C). After October, the temperature declined and reached the minimum level of 17-19 °C during December and January. Thereafter, it increased and reached the maximum level (35 °C-36 °C) during May and June (Fig. 1). Soil moisture content varied from 18.0% (January, 2005) to 35% (August, 2004); it remained at a high level during July/August and then declined until January. Thereafter, it increased until March and then declined again by May (Fig. 2). Soil pH ranged from 5.2 (August, 2004) to 7.4 (January, 2005). The soil was mostly acidic in nature (5.2-6.9) during almost the

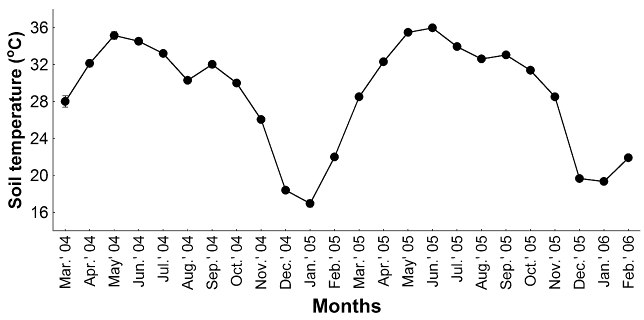

Fig. 1. Temporal variation in soil temperature.

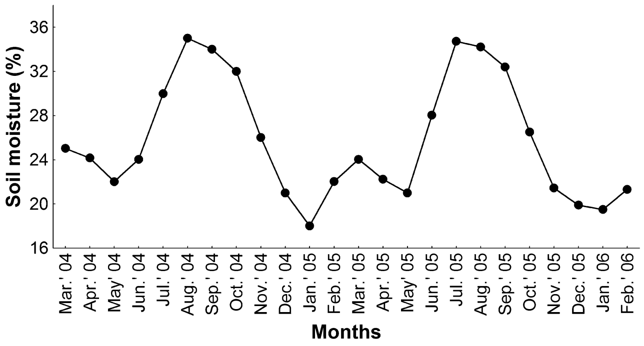

Fig. 2. Temporal variation in soil moisture.

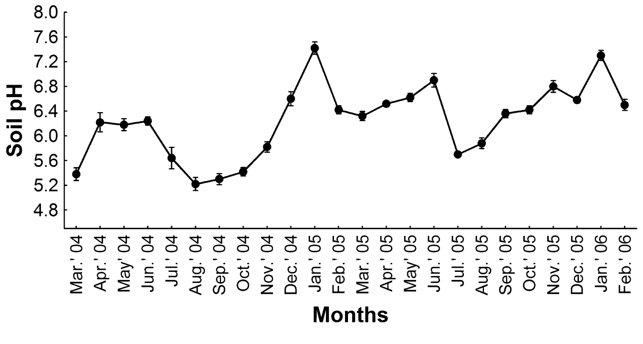

Fig. 3. Temporal variation in soil pH.

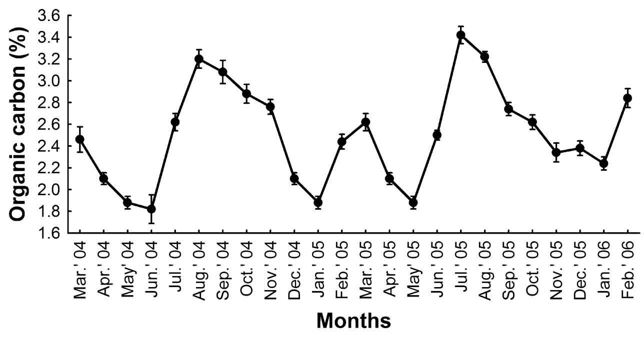

Fig. 4. Temporal variation in organic carbon content of soil.

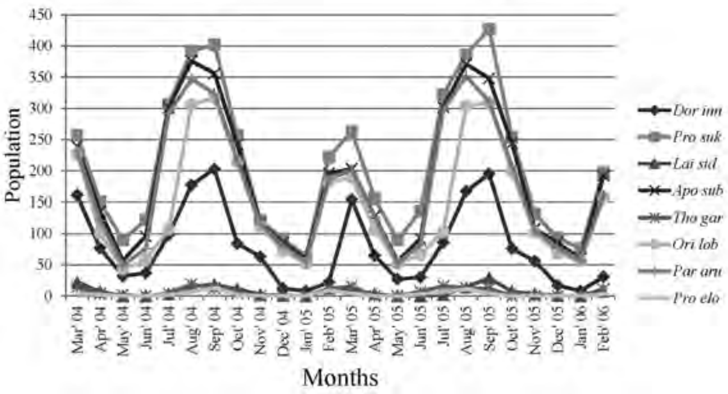

Fig. 5. Population fluctuation of dorylaimid nematodes.

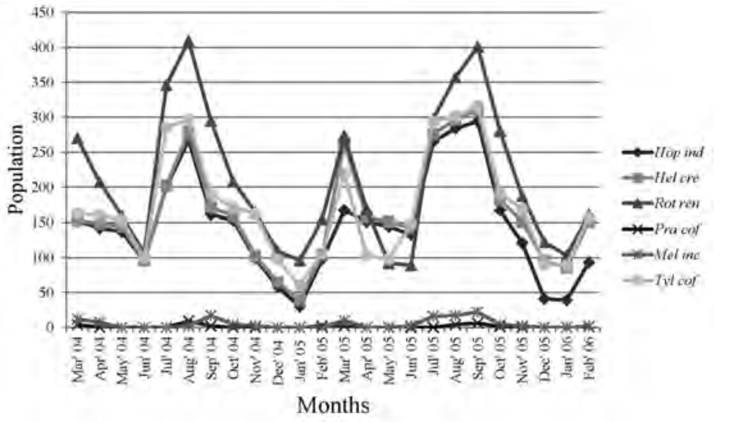

Fig. 6. Population fluctuation of tylenchid nematodes.

entire study period, except in January, when it was alkaline (7.3-7.4). During monsoon and post-monsoon periods, the soil was highly acidic, but was only slightly acidic in the other months (Fig. 3). Organic carbon content of soil varied from 1.82% (June, 2004) to 3.42% (July, 2005), with the greatest level being observed during July/August. Thereafter, it declined until January and then increased again to March (Fig. 4).

Fourteen species of soil and plant parasitic nematodes were collected and identified. Of these, eight species belonged to the order Dorylaimida and six species to the order Tylenchida (Table I). Among the dorylaimids five species, *Dorylaimus innovatus* Jana *et* Baqri, *Prodorylaimus sukuli* Baksi *et* Baqri, *Aporcelaimellus subhasi* Gantait, Bhattacharya and Chatterjee, *Oriverutus lobatus* Siddiqi and *Paractinolaimus aruprus* Khan, Ahmad *et* Jairajpuri, were found all the year round and in large numbers. The remaining three species, *Laimydorus siddiqii* Baqri *et* Jana, *Thonus garhwaliensis* Ahmad, Nath *et* Haider and *Promumtazium elongatum* Ahmad *et* Jairajpuri, were found during some months of the year, and their numbers were very low. Among the tylenchids, four species, *Hoplolaimus (Basirolaimus) indicus* Sher, *Helicotylenchus crenacauda* Sher, *Rotylenchulus reniformis* Linford *et* Oliveira and *Tylenchorhynchus coffeae* Siddiqi *et* Basir, were found in large numbers all the year round. The remaining two species, *Pratylenchus coffeae* (Zimmermann) Filipjev *et* Schuurmans Stekhoven and *Meloidogyne incognita* (Kofoid *et* White) Chitwood, were found occasionally in scant numbers.

All the nematode species encountered exhibited a bimodal pattern of population fluctuation with a prominent peak during August or September and a low peak during March each year (Figs 5 and 6). Likewise, there were two minima, one during January and another in May or June. The populations increased after rainfall but declined during the post-monsoon period and remained at a low level during winter. During early spring, populations again increased but summer again caused a decline in their sizes.

Simple correlation analysis revealed that the abundances of all the species were significantly correlated with soil moisture and organic carbon contents, whereas only *H.* (*B.*) *indicus*, *H. crenacauda* and *T. coffeae* were significantly correlated with soil temperature. Contrarily to these findings, the soil pH was negatively and significantly correlated with abundances of all nematode species (Table II). However, multiple regression revealed that all the edaphic factors studied had a significant influence on the abundance of all the species except *L. siddiqii* and *P. coffeae* (Table III). Canonical Correspondence Analysis (CCA) further proved this finding. The CCA diagram clearly shows that all the environmental variables had a significant influence on the nematode species (Fig. 7). However, the influence of pH is different to that of other variables.

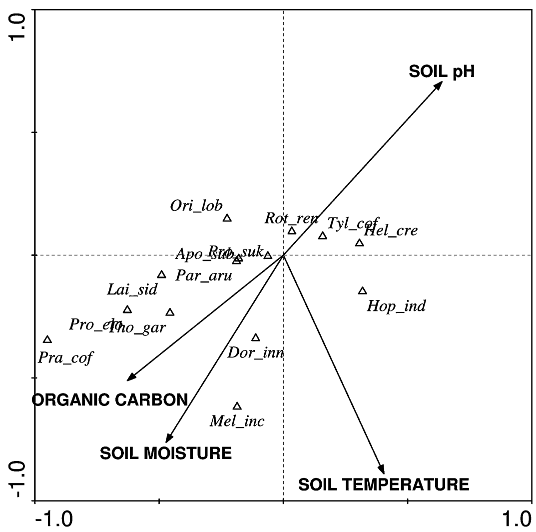

Fig. 7. Ordination diagram based on Canonical Correspondence Analysis. Test of significance of first canonical axis: Eigen value = 0.014; F-ratio = 7.308; P-value = 0.002. Test of significance of all canonical axes: Eigen value = 0.021. F-ratio = 3.367; P-value = 0.002.

DISCUSSION

Our investigation shows that abundance of all the nematode species was low in December and January due to low temperature and low moisture content of the soil, similar to the findings of Khan *et al.* (1971) and Dwivedi and Misra (1990). Khan and Sharma (1990) and Pandey (1999) reported that, in general, the nematode population was low in December, which may be due to low temperature and moisture. As the temperature increased in March, the nematode populations tended to increase. Boag (1980) stated that temperature influences the feeding rate of nematodes, their reproduction, etc. and, therefore, populations increase as the temperature begins to rise. This trend reversed and the abundance of nematodes declined in summer (May/June). This decline in abundance was associated with high temperature and low soil moisture content. This agrees with findings by Griffin and Darling (1964). Our findings also support observations by Ahmad and Jairajpuri (1982) and Azmi (1995). But Pandey (1999) reported that the nematode population was greatest in April-May. During periods of rain the soil moisture content gradually increases, so reducing the temperature of the soil. Thus, it can result in increased population build-up. Nematode abundance in our plot increased from July onwards, reaching a peak in August/September. This might be due to optimum moisture conditions of the soil and moderate temperature, as observed by Azmi (1995). On the contrary, Mani and Hinai (1996) observed that in the Sultanate of Oman population densities of nematodes, in both soil and roots of banana, declined sharply from May onwards and reached their lowest levels during June-July, coinciding with the highest soil temperature. As in the present study, Nath *et al.* (1998) also showed that favourable conditions for growth and reproduction of different species of plant parasitic nematodes prevailed during pre-monsoon (March) and post-monsoon (October) periods. However, this is in contrast with the observations of Kable and Mai (1968), Robbins and Barker (1974), and Singh and Sharma (1995). These authors found that high soil moisture levels exert a negative pressure on the growth and reproduction of nematodes. In our study, from the post-monsoon period onward the nematode population decreased. This decline in abundance followed the decline in soil temperature and moisture content, as observed also by Mukherjee and Dasgupta (1983). Thus, the present study suggested that soil temperature and moisture favoured nematode population growth but that the extremes of both had an adverse effect on nematode populations.

The soil of the study field was mostly acidic during almost the entire study period, except in January, when it was slightly alkaline. The maximum abundance of nematodes was found when the pH was in the range 5.3-6.4 and was minimum in January. This indicates that nematode populations increased in acidic soil and decreased in alkaline soil. A similar finding was also reported by Szczygiel *et al.* (1983). Das *et al*. (1990) observed increased biotic activities of nematodes in acidic soil and rapid decline in alkaline soil. In other studies Choudhury and Phukan (1995) found that when soil pH increases above 6.9, the density of most of the nematodes decreases; while Bilgrami *et al*. (2003) reported that nematodes preferred less alkaline pH. Ahmad and

Table I. Nematode species encountered during the study.

Sl. No.	Name of species	Abbreviation of species
	ORDER : DORYLAIMIDA	
1.	*Dorylaimus innovatus* Jana *et* Baqri, 1982	Dor inn
2.	*Prodorylaimus sukuli* Baksi *et* Baqri, 1985	Pro suk
3.	*Laimydorus siddiqii* Baqri *et* Jana, 1982	Lai sid
4.	*Aporcelaimellus subhasi* Gantait *et al.*, 2006	Apo sub
5.	*Thonus garhwaliensis* Ahmad *et al*., 1986	Tho gar
6.	*Oriverutus lobatus* Siddiqi, 1971	Ori lob
7.	*Paractinolaimus aruprus* Khan *et al.*, 1994	Par aru
8.	*Promumtazium elongatum* Ahmad *et* Jairajpuri, 1984	Pro elo
	ORDER : TYLENCHIDA	
9.	*Hoplolaimus* (*Basirolaimus*) *indicus* Sher, 1963	Hop ind
10.	*Helicotylenchus crenacauda* Sher, 1966	Hel cre
11.	*Rotylenchulus reniformis* Linford *et* Oliveira, 1940	Rot ren
12.	*Pratylenchus coffeae* (Zimmermann, 1898) Filipjev *et* Schuurmans Stekhoven, 1941	Pra cof
13.	*Meloidogyne incognita* (Kofoid *et* White, 1919) Chitwood, 1949	Mel inc
14.	*Tylenchorhynchus coffeae* Siddiqi *et* Basir, 1959	Tyl cof

Table II. Simple correlation between edaphic factors and abundance of nematode species.

Sl. No.	Nematode species (Abbr.)	Temperature	Moisture content	pH	Organic carbon content
1.	Dor inn	0.418	0.763^{***}	-0.694^{***}	0.639^{***}
2.	Pro suk	0.391	0.874^{***}	-0.689^{***}	0.807^{***}
3.	Lai sid	0.148	0.548^{**}	-0.518^{**}	0.509^{*}
4.	Apo sub	0.330	0.874^{***}	-0.721^{***}	0.839^{***}
5.	Tho gar	0.190	0.636^{**}	-0.551^{**}	0.728^{***}
6.	Ori lob	0.190	0.711^{***}	-0.616^{**}	0.710^{***}
7.	Par aru	0.328	0.871^{***}	-0.729^{***}	0.844^{***}
8.	Pro elo	0.161	0.644^{***}	-0.507^{*}	0.679^{***}
9.	Hop ind	0.677^{***}	0.848^{***}	-0.599^{**}	0.657^{***}
10.	Hel cre	0.570^{**}	0.766^{***}	-0.507^{*}	0.693^{***}
11.	Rot ren	0.392	0.801^{***}	-0.672^{***}	0.719^{***}
12.	Pra cof	0.121	0.538^{**}	-0.450^{*}	0.494^{*}
13.	Mel inc	0.340	0.666^{***}	-0.429^{*}	0.607^{**}
14.	Tyl cof	0.497^{*}	0.847^{***}	-0.605^{**}	0.772^{***}

$^{*} = P \leq 0.05$, $^{**} = P \leq 0.01$, $^{***} = P \leq 0.001$

Jairajpuri (1982) also reported that mononchid nematodes generally prefer soil pH between 5 and 6 and that they cannot survive in highly acidic or alkaline media. While investigating the variation of nematode population with organic carbon content of the soil, it was found that as the organic carbon content increased the abundance of nematodes also increased, thus agreeing with findings by Krnjaic and Krnjaic (1974), Mishra and Prasad (1974), Abrar *et al.* (1974), Szczygiel and Zepp (1983), and Bilgrami *et al.* (2003).

Our attempt to correlate the temporal variation of the nematode populations with the edaphic factors revealed that soil moisture content and organic carbon content were positively correlated and pH was negatively correlated with all the species. Temperature exhibited a positive correlation with only three species of phytophagous nematodes (Table II). Mani and Hinai (1996) reported significant negative correlation between mean soil temperature and nematode population in soil and roots of banana in the Sultanate of Oman. Bell and Watson (2001) observed a positive correlation between temperature and population of *Paratylenchus nanus* Cobb. Gantait *et al.* (2006) also found a positive correlation between soil temperature and populations of *R. reniformis* Linford *et* Oliveira, *T. coffeae* Siddiqi *et* Basir, *H. crenacauda* Sher and *H.* (*B.*) *indicus* Sher. Khan and Sharma (1990) observed that soil moisture was not significantly correlated with population build-up of *M. incognita*, *Tylenchorhynchus mashhoodi* Siddiqi *et* Basir, *Pratylenchus pratensis* (de Man) Filipjev and *Helicotylenchus dihystera* (Cobb) Sher. Bell *et* Watson (2001) also observed a negative correlation between the population of *P. nanus* and soil moisture. Bilgrami *et al.* (2003), however, reported a positive correlation of nematode population with soil moisture in different localities of Shenyang Municipality, Northeast China. Gantait *et al.* (2006) observed positive correlation between the population of *R. reniformis*, *T. coffeae*, *H. crenacauda* and *H.* (*B.*) *indicus* with soil moisture. As in the present study, Smith and Wallace (1976), Das *et al.* (1990), Choudhury and Phukan (1995) and Gantait *et al.* (2006) reported that the abundance of nematodes was negatively correlated with the soil pH. With reference to organic carbon, Mishra and Prasad (1974) reported that the population of *H.* (*B.*) *indicus* increased with increase in organic carbon content of the soil, and Szczygiel and Zepp (1983) found a positive correlation between the organic carbon content of soil and the population of

Table III. Multiple regression between edaphic factors and abundance of nematode species.

Sl. No.	Nematode species (Abbr.)	R^2	F
1.	Dor inn	0.615	7.598^{*}
2.	Pro suk	0.791	18.005^{*}
3.	Lai sid	0.366	2.743
4.	Apo sub	0.824	22.307^{*}
5.	Tho gar	0.546	5.709^{*}
6.	Ori lob	0.592	6.903^{*}
7.	Par aru	0.827	22.748^{*}
8.	Pro elo	0.496	4.667^{*}
9.	Hop ind	0.793	18.237^{*}
10.	Hel cre	0.708	11.493^{*}
11.	Rot ren	0.663	9.364^{*}
12.	Pra cof	0.347	2.522
13.	Mel inc	0.469	4.192^{*}
14.	Tyl cof	0.758	14.861^{*}

$^{*} = P \leq 0.05$

Pratylenchus penetrans (Cobb) Filipjev *et* Schuurmans Stekhoven and *Longidorus elongatus* (de Man) Thorne *et* Swanger. Hazra (1994) observed that the organic carbon content of the soil exhibited a strong positive correlation with the nematode population in Schirmacher Oasis, Antarctica. Positive correlations of nematode population with the organic carbon of soil were also observed by Bilgrami *et al*. (2003) and Gantait *et al*. (2006).

It has been a common practice among soil zoologists to correlate various edaphic factors with the fluctuation of abundance of nematodes using simple correlation. Most of these attempts have provided conflicting conclusions. So in the present study, beside simple correlation, multiple regression has also been attempted. Multiple regression revealed that all the edaphic factors studied had a significant influence on the abundance of all the nematode species except two. Canonical Correspondence Analysis further showed that all the edaphic factors had a significant influence on the nematode species (P = 0.002). However, the soil pH showed the influence in a different way to the other factors. No such study on nematodes is available in this regard for comparison.

ACKNOWLEDGEMENTTS

The authors are thankful to the Director of the Zoological Survey of India, Kolkata, and the Vice Chancellor, Vidyasagar University, Paschim Medinipur for providing laboratory and other facilities.

LITERATURE CITED

Abrar M., Khan M., Mashkoor A. and Ahmad R., 1974. Mechanism of the control of plant parasitic nematodes as a result of the application of oil cakes to the soil. *Indian Journal of Nematology, 4*: 93-96.

Ahmad N. and Jairajpuri M.S., 1982. Effect of pH, mineral salts and fatty acids on the predatory nematode, *Prahadronchus shakili* (Jairajpuri, 1969) Mulvey, 1978. *Indian Journal of Nematology, 12*: 22-30.

Azmi M.I., 1995. Seasonal population fluctuations behaviour of plant parasitic nematodes in Caribbean Stylo. *Indian Journal of Nematology, 25*: 168-173.

Barker K.R. and Campbell C.L., 1981. Sampling nematode populations. Pp. 451-473. *In*: Plant Parasitic Nematodes, Vol. III (Zuckerman B.M. and Rhode R.A., eds). Academic Press, New York, USA.

Barker K.R. and Nusbaum C.J., 1971. Diagnostic and advisory programmes. Pp. 281-301. *In*: Plant Parasitic Nematodes, Vol. I (Zuckerman B.M., Mai W.F. and Rhode R.A., eds). Academic Press, New York, USA.

Bell N.L. and Watson R.N., 2001. Population dynamics of *Pratylenchus nanus* in soil under pasture: 1. Aggregation and abiotic factors. *Nematology, 3*: 187-197.

Bilgrami A.L., Liang W. and Li Q., 2003. Generic diversity, population structure and community ecology of plant and soil nematodes. *International Journal of Nematology, 13*: 104-117.

Boag B., 1980. Effects of temperature on rate of feeding of the plant-parasitic nematodes, *Rotylenchulus robustus*, *Xiphinema diversicaudatum* and *Hemicycliophora conida*. *Journal of Nematology, 12*: 193-195.

Chawla M.L. and Mittal A., 1995. Nematode population dynamics and modeling. Pp. 285-295. *In*: Nematode Pest Management – an Appraisal of Eco-friendly Approaches (Swarup G., Dasgupta D.R. and Gill J.S., eds). Nematological Society of India, New Delhi, India.

Chowdhury B.N. and Phukan P.N., 1995. Study on the variations of certain plant parasitic nematodes at different levels of soil pH. *Indian Journal of Nematology, 25*: 202-203.

Christie J.R. and Perry V.G., 1951. Removing nematodes from soil. *Proceedings of the Helminthological Society of Washington, 18*: 106-108.

Cobb N.A., 1918. *Estimating the nema population of the soil.* Agricultural Technology Circular I. Bureau of Plant Industry, Department of Agriculture, United States, 48 pp.

Das B.K., Sarkar J., Sarkar S., Das N.K., Ray I. and Sen S.K., 1990. Correlation between some edaphic factors and *Meloidogyne incognita* infestation on mulberry in Malda, West Bengal. *Indian Journal of Nematology, 20*: 91-94.

Devi A.N., Ponnuswami V., Sundararaju P., Soorianathasundaram K., Sathiamoorthy S., Uma S. and Bergh I.V.D., 2007. Mechanism of resistance in banana cultivars against root lesion nematode *Pratylenchus coffeae*. *Indian Journal of Nematology, 37*: 138-144.

Dwivedi B.K. and Misra S.L., 1990. Environmental correlates to the population dynamics of plant nematodes around root zones of *Citrus sinensis* at Allahabad. *Current Nematology, 1*: 25-30.

Gantait V.V., Bhattacharya T. and Chatterjee A., 2006. Fluctuation of nematode population associated with banana plantation in Paschim Medinipur district, West Bengal, India. *Indian Journal of Nematology, 36*: 223-225.

Gowen S.R., Queneherve P. and R. Fogain, 2005. Nematode parasites of bananas and plantains. Pp. 611-643. *In*: Plant Parasitic Nematodes in Subtropical and Tropical Agriculture – Second Edition (Luc M., Sikora R.A. and Bridge J., eds). CABI Publishing, Wallingford, England.

Griffin G.D. and Darling H.M., 1964. An ecological study of *Xiphinema americanum* Cobb in an ornamental spruce nursery. *Nematologica, 10*: 471-479.

Harish M. and Nanje Gowda D., 2001. Management of the burrowing nematode, *Radopholus similis* (Cobb, 1893) Thorne, 1949 infesting banana. *Indian Journal of Nematology, 31*: 23-25.

Hazra A.K., 1994. A study on the population ecology of soil nematode fauna in relation to some edaphic factors in Schirmacher Oasis, Antarctica. *Ninth Indian Expedition to Antarctica, Scientific Report*. Department of Ocean Development, Technical Publication No. 6: 65-90.

Jairajpuri M.S. and Ahmad W., 1992. *Dorylaimida*: *Free-living, Predaceous and Plant Parasitic Nematodes*. Oxford and IBH Publishing Company Private Limited, New Delhi, India, 458 pp.

Jonathan E.I. and Rajendran G., 2003. Spatial distribution of root-knot nematode, *Meloidogyne incognita* in Banana, *Musa* sp. *Indian Journal of Nematology, 33*: 47-51.

Jones F.G.W., Larbey D.W. and Parrott D.M., 1969. The influence of soil temperature and moisture on nematodes, especially *Xiphinema, Longidorus, Trichodorus* and *Heterodera* spp. *Soil Biology and Biochemistry, 1*: 153-165.

Kable P.F. and Mai W.F., 1968. Influence of soil moisture on *Pratylenchus penetrans*. *Nematologica, 14*: 101-122.

Khan A.M., Adhami A. and Saxena S.K., 1971. Population changes of some stylet-bearing nematodes associated with mango (*Mangifera indica* L.). *Indian Journal of Nematology, 1*: 99-105.

Khan M.R., 2006. Current options for managing nematode pest of crops in India. Pp. 16-50. *In*: Plant Nematology in India (Mohilal N. and Gambhir R.K., eds). Parasitology Laboratory, Department of Life Sciences, Manipur University, Manipur, India.

Khan M.L. and Sharma G.S., 1990. Effect of temperature and moisture on population fluctuation of nematodes in an apple orchard. *Indian Journal of Nematology, 20*: 10-13.

Korthals G.W., Alexiev A.D., Lexmond T.M., Kammenga J.E. and Bongers T., 1996. Long-term effect of copper and pH on the nematode community in an agro ecosystem. *Environment Toxicological Chemistry, 15*: 979-985.

Krnjaic D. and Krnjaic S., 1974. Influence of some factors on the distribution of nematodes in soil. *Zemljistu zastita Bilja, 25*: 39-48.

Mani A. and Hinai A., 1996. Population dynamics and control of plant parasitic nematodes on banana in the sultanate of Oman. *Nematologia Mediterranea, 24*: 295-299.

Mishra S.D. and Prasad S.K., 1974. Effect of soil amendments on nematode and crop yields I. Oil-seed cakes, organic matter, inorganic fertilizers and growth regulators on nematodes associated with wheat and their residual effect on mung. *Indian Journal of Nematology, 4*: 1-19.

Mukherjee B. and Dasgupta M.K., 1983. Community analysis of nematodes associated with banana plantations in the Hooghly District, West Bengal, India. *Nematologia Mediterranea, 11*: 43- 48.

Nath R.C., Mukherjee B. and Dasgupta M.K., 1998. Population dynamics of plant parasitic nematodes in a pineapple plantation of Tripura, India. *International Journal of Nematology, 8*: 185-190.

Oostenbrink M., 1966. Major characteristics of the relation between nematodes and plants. *Mededelingen Landbouwhogeschool Wageningen, 66*: 1046.

Pandey R., 1999. Population dynamics of phytonematodes in an arable soil planted with *Costus speciosus* (Koeti) Sm. *Indian Journal of Nematology, 29*: 81-82.

Reddy P.P., 1983. *Plant Nematology*. Agricole Publishing Academy, New Delhi, India, 287 pp.

Robbins R.T. and Barker K.R., 1974. The effects of soil type, particle size, temperature and moisture on reproduction of *Belonolaimus longicaudatus. Journal of Nematology, 6*: 1-6.

Seinhorst J.W., 1959. A rapid method for the transfer of nematodes from fixative to anhydrous glycerine. *Nematologica, 4*: 67-69.

Siddiqi M.R., 2000. *Tylenchida*: *Parasites of Plants and Insects*. CABI Publishing, Wallingford, U.K., 833 pp.

Singh M. and Sharma S.B., 1995. Infectivity, development and reproduction of *Heterodera cajani* on pigeonpea - influence of soil moisture and temperature. *Journal of Nematology, 27*: 370-377.

Smith A.D.M. and Wallace H.R., 1976. Fluctuation in the distribution of numbers of *Helicotylenchus dihystera* in Kikuyu turf (*Pennisetum elandestinum*). *Nematologica, 22*: 145-152.

StatSoft Inc., 2007. STATISTICA (Data Analysis Software System), Version 7.0. www.statsoft.com.

Sundararaju P., 2006. Community structure of plant parasitic nematodes in banana plantations of Andhra Pradesh, India. *Indian Journal of Nematology, 36*: 226-229.

Szczygiel A. and Zeep A., 1983. Effect of organic matter in soil on population and pathogenicity of *Pratylenchus penetrans* and *Longidorus elongatus* to strawberry plants. *Zeszyty Problemowe Postepow Nauk Rolniezych, 278*: 113-122.

Szczygiel A., Slowik K. and Saroka A., 1983. Effect of soil pH on host-parasite relationship of three plant parasitic nematodes of strawberry plants. *Zeszyty Problemowe Postepow Nauk Rolniezyeh, 278*: 95-104.

Ter Braak C.J.F., 1988. CANOCO – a FORTRAN Program for canonical community ordinations by (partial), (detrended), (canonical) correspondence analysis, principal components analysis and redundancy analysis. Groep Landbouw Wiskunde, Wageningen, The Netherlands, 95.

Walkley A. and Black I.A., 1974. Chromic acid titration method for determination of soil organic matter. *Soil Science, 63*: 251-264.

Accepted for publication on 18 March 2011.