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Population behaviour of *Helicotylenchus multicinctus* in soil and roots of banana in Tripura, India

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Summary – Population behaviour of *Helicotylenchus multicinctus* in root and soil around banana plants was studied for 12 months at three sites in Tripura, India. The population levels reached three peaks during the year (March, June-July, and October-November) with concomitant increases in nematode numbers recorded both in soil and roots. Soil populations were lowest in December at all three sites when an abrupt increase in root populations occurred. Populations decreased both in soil and roots following heavy rainfall. A significant positive correlation between nematode numbers in the soil and monthly rainfall was observed. Pre-monsoon and post-monsoon rainfall patterns seemed to be the major environmental factor influencing population development. Temperature had no such effect. © Orstom/Elsevier, Paris

Résumé – ***Comportement d'*Helicotylenchus multicinctus *dans le sol et les racines de bananier au Tripura, Inde*** – Le comportement des populations d'*Helicotylenchus multicinctus* dans les racines et la rhizosphère de bananiers a été étudié dans trois localités, pendant 12 mois, au Tripura, Inde. Trois pics de population sont observés pendant l'année (mai, juin-juillet et octobre-novembre), avec une augmentation concomitante du nombre des nématodes dans les racines et dans le sol. Les populations dans le sol sont les plus faibles en décembre pour les trois localités, alors qu'une augmentation brutale des populations dans les racines se produit. Les populations diminuent, tant dans le sol que dans les racines, à la suite de fortes pluies. Une corrélation positive significative a été observée entre le nombre de nématodes dans le sol et la valeur de la pluviosité mensuelle. Les pluies précédant la mousson et celles de la mousson elle-même paraissent constituer le plus important facteur du milieu influençant le développement des populations, ce qui n'est pas le cas de la température. © Orstom/Elsevier, Paris

Keywords: *Helicotylenchus multicinctus, Musa*, nematodes, population behaviour.

The spiral nematode *Helicotylenchus multicinctus* (Cobb) Golden is probably the most widespread and abundant banana nematode after *Radopholus similis* (Blake, 1972; Gowen & Quénéhervé, 1990). Moreover, this species is considered to be the most damaging pathogenic nematode on bananas when environmental conditions such as temperature and rainfall are sub-optimal for the plant (Gowen & Quénéhervé, 1990).

H. multicinctus feeds within the outer layers of the root cortex, causing characteristic lesions, progressive root deterioration, toppling, and reduced yields, which ultimately results in the rapid decline of banana plantations (McSorley & Parrado, 1986).

In India, *H. multicinctus* has been recorded on banana in epidemic proportions in Andhra Pradesh (Jayaprakash, 1981) and occurs widespread in banana plantations in West Bengal (Mukherjee & Dasgupta, 1983) and Orissa (Ray & Parija, 1987). In an extensive survey throughout Tripura, the species was reported in high numbers (1000 nematodes/g of roots) in most of the banana plantations: it was found in seven of the ten administrative sub-divisions of the state where it constituted 63% of the root populations, whereas *R. similis* was less frequent (Mukherjee *et al.*, 1994).

H. multicinctus is considered to be an endoparasite which is able to complete its life cycle within the cortex of the roots where both sexes, all juvenile stages, and eggs can be found (Zuckerman & Strich-Harari, 1963). A good knowledge of the biology, host-parasite relationships, population dynamics of a target nematode species and its interactions with the environment is necessary for planning nematode management strategies (Jones & Kempton, 1978; Barker & Campbell, 1981; Noe & Sikora, 1990; Chawla & Mittal, 1995). As little information is available on the population dynamics of *H. multicinctus* on the Indian subcontinent, the seasonal changes in the populations of this nematode species in roots and soil around banana plants in relation to some environmental factors were studied.

Material and methods

Tripura is a small hilly state in north-eastern India. It lies between 22°56′ and 24°32′ North and between 90°10′ and 90°21′ East, at an altitude varying from

15 to 780 m above sea level (Biswas *et al.*, 1989). The state is characterized by a humid tropical climate with an average annual rainfall of 2400 mm. The mean minimum and maximum temperatures range from 8 to 35.6°C, and the relative humidity varies from 70 to 85%. Bananas (*Musa* spp.) are intensively grown in the state on approximately 3600 ha. The average yield is 24.5 tons/ha (Anon., 1995).

Composite soil and root samples were collected on the 25th day of every month at three sites over a period of 12 months, from February 1994 to January 1995: Jogendranagar (site 1), Malaynagar (site 2), and Nagichhara Horticultural Research Complex (site 3) around Agartala. The soil texture was sandy-clay at all sites. Sites 1 and 3 were planted with 5- and 9-year old bananas, respectively (cv. Champa, AAB genome). Site 2 was planted with cv. Dwarf Cavendish (AAA genome) and the plantation was one year old at the time of the first sampling.

At each site, three banana mats consisting of a mother plant and seven to ten daughter suckers were selected at random and three composite samples of soil and roots were collected. The sampling was confined from the same mats each time which were in preflowering condition. As a consequence, root samples contained roots of different ages and developmental stages (including primary and secondary roots). Four soil samples were taken per banana mat, at four different points, all equally distant (40-50 cm) from the pseudostem (Geetha & Koshy, 1984). The samples were taken with a 2.5 cm diameter iron tube at a depth of up to 30 cm (Cabrales, 1995).

The four soil samples were thoroughly mixed and a 250 cm^3 soil sub-sample was processed by a modified Baermann funnel technique (Whitehead & Hemming, 1965) within 24 h of sampling. Roots were washed in running tap water and sliced into 2 cm pieces which were thoroughly mixed. Subsamples (5 g) were blended in 100 ml tap water for 30 s and the resulting suspensions incubated in 1-3% hydrogen peroxide (Gowen & Edmunds, 1973) for up to 3 days. The nematodes extracted from soil and root samples were collected separately, heat-relaxed and killed in a hot water bath, and fixed in TAF or FAA. After concentration of the suspensions to 5 ml, nematodes were counted in a Hawksley 1 ml counting slide. Males, females, and juveniles were counted separately.

The climatological data (daily temperature, rainfall, and number of rainy days per month) were obtained from the meteorological observatory at Agartala Airport, which is very close to site 1. Sites 2 and 3 are 2 km away east and north of site 1, respectively.

The physico-chemical properties of the soil collected were also analysed (Jackson, 1967). The nematode population data were transformed to $log_{10}(x+1)$ and subjected to an analysis of variance. Correlations between nematode population data and environmental factors were assessed.

Results

Climatic conditions

The climatic conditions at the sites were dominated by higher pre-monsoon (March) and monsoon (May-August) rainfall and comparatively little rainfall during post-monsoon and winter months. Rainfall was negligible or nil during the winter months (December-January). The temperature increased from March (25.5°C) to September (28.3°C), then declined from October (26.5°C) to January (16.6°C). The coldest month was January with a minimum temperature of 8.3°C (Fig. 1).

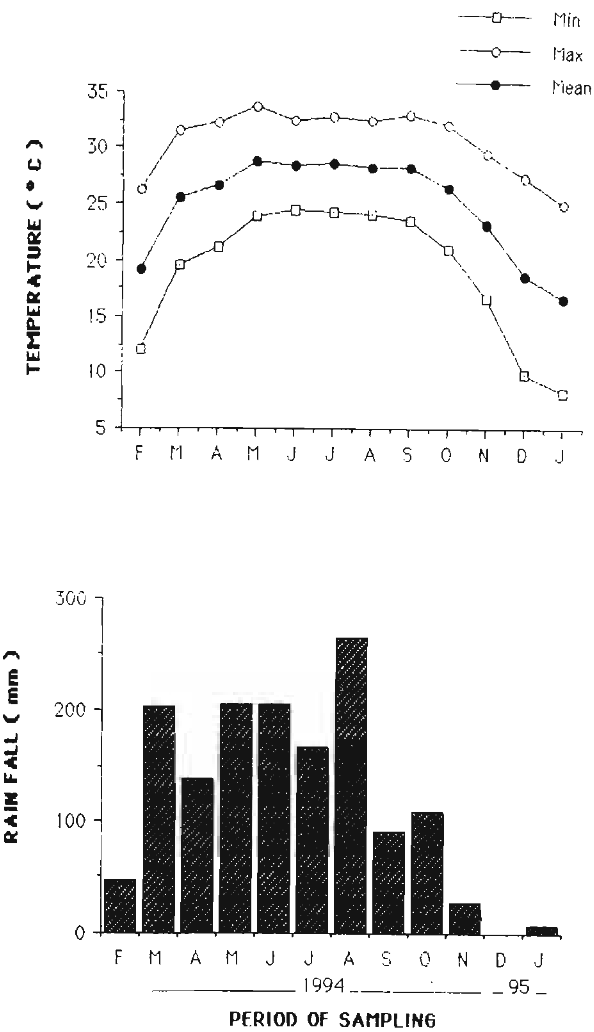

Fig. 1. Monthly rainfall and temperatures during the sampling period (February 1994-January 1995).

Soil conditions

All three sites had sandy-clay, acid (pH 4.5-6.7) soils, with high sand (45-50%), low silt (15-17%), and moderate clay (33-38%) contents. Organic carbon varied from 0.5 to 0.7 % and there was wide variation in NPK status (Table 1).

Nematode species

The same plant-parasitic nematode species were present at all three sites, *H. multicinctus* being the most abundant. Other nematode species present included *Meloidogyne incognita, Pratylenchus coffeae,* and *H. dihystera* at all sites. In addition, a few *Hoplolaimus seinhorsti* were present at site 3.

Seasonal fluctuations of the nematode populations

H. multicinctus occurred in large numbers in both soil and root samples throughout the year at all sites. Soil populations reached three peaks: during March, June, and October at sites 1 and 2; during March, July, and November at site 3 (Fig. 2). The peak levels were of decreasing magnitude. The lowest soil populations were recorded in December at all sites. The population levels differed significantly from each other (LSD at 1% = 0.037) at every sites and they also significantly differed during months (LSD at 1% = 0.075). The interaction effect between months and sites also was significant (LSD at 1% = 0.129).

Root populations also reached three peaks during March, June, and December at all sites (Fig. 3). The peak levels decreased from June to March to December at sites 1 and 2 and from March to June to December at site 3. The populations differed significantly in all three sites (LSD at 1% = 0.023) and in different months (LSD at 1% = 0.047). The interaction effect between months and sites also was significant (LSD at 1% = 0.081). At all three sites, root populations started increasing in September and reached a peak in December, then declined in January. The lowest root populations were found in August at sites 1 and 2, and in May at site 3.

In this study, rainfall, number of rainy days, and mean monthly temperature were not significantly correlated with root populations of *H. multicinctus.* Significant positive correlations were observed only between soil population and monthly total rainfall at site 1 ($r = 0.498$) and 2 ($r = 0.527$) (Table 2).

Relative abundance of males, females, and juveniles

The relative abundance of males, females, and juveniles in soil showed that population peaks were caused by proportionate increases in the numbers of individuals of all stages whereas the June-July increase was due to an increase in the number of adult nematodes. Female nematodes became more abundant in April following peaks in March, at a time when the total population was declining (Fig. 2). In roots, population peaks were due to an increase in both juveniles

Table 1. *Type and physicochemical properties of banana soil in Tripura.*

Sites	Soil type	Sand (%)	Silt (%)	Clay (%)	Organic carbon	Nitrogen	Phosphorus	Potassium	pH
Site 1	Sandy-clay	50	17	33	0.6	0.06	0.3	18.0	6.5
Site 2	Sandy-clay	48	15	37	0.7	0.07	0.3	16.0	6.7
Site 3	Sandy-clay	45	17	38	0.5	0.06	0.2	12.0	4.5

Table 2. *Correlation coefficient (r) between populations of* Helicotylenchus multicinctus *in soil and roots and mean monthly temperature, total rainfall, and number of rainy days in each site.*

Sites	Population	Temperature (°C)	Rainfall (mm)	Number of rainy days
Site 1	Soil	0.398	0.498*	0.139
	Roots	-0.248	-0.041	-0.372
Site 2	Soil	0.417	0.527*	0.174
	Roots	-0.021	-0.018	-0.197
Site 3	Soil	0.378	0.456	0.156
	Roots	-0.202	-0.065	-0.308

* Significant at $P \leq 0.05$.

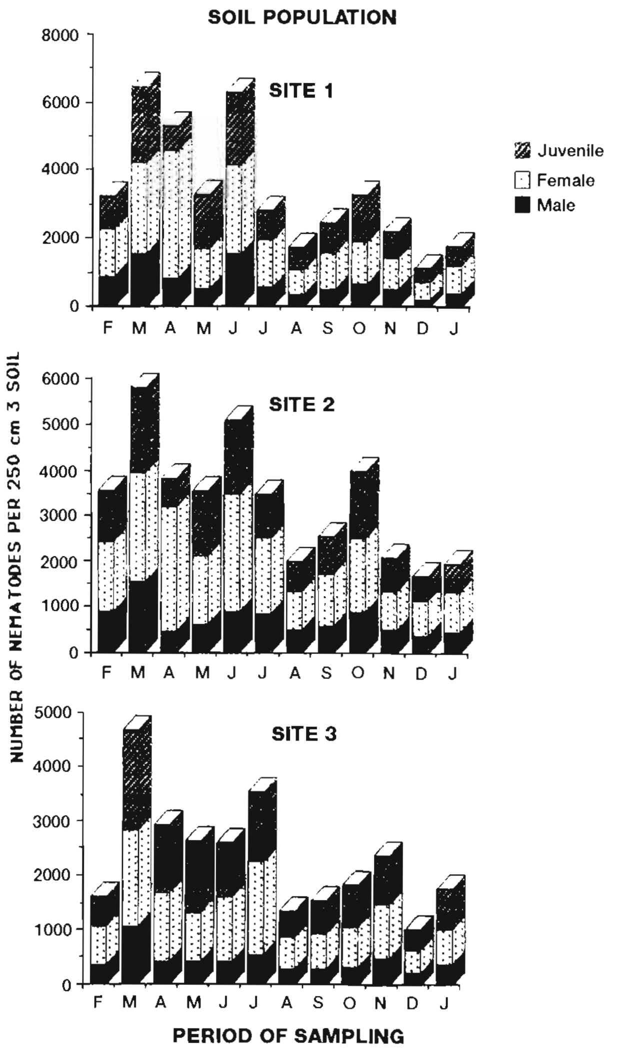

Fig. 2. Seasonal fluctuations of soil populations and relative abundance of three life stages of Helicotylenchus multicinctus *on banana at three sites (February 1994-January 1995).*

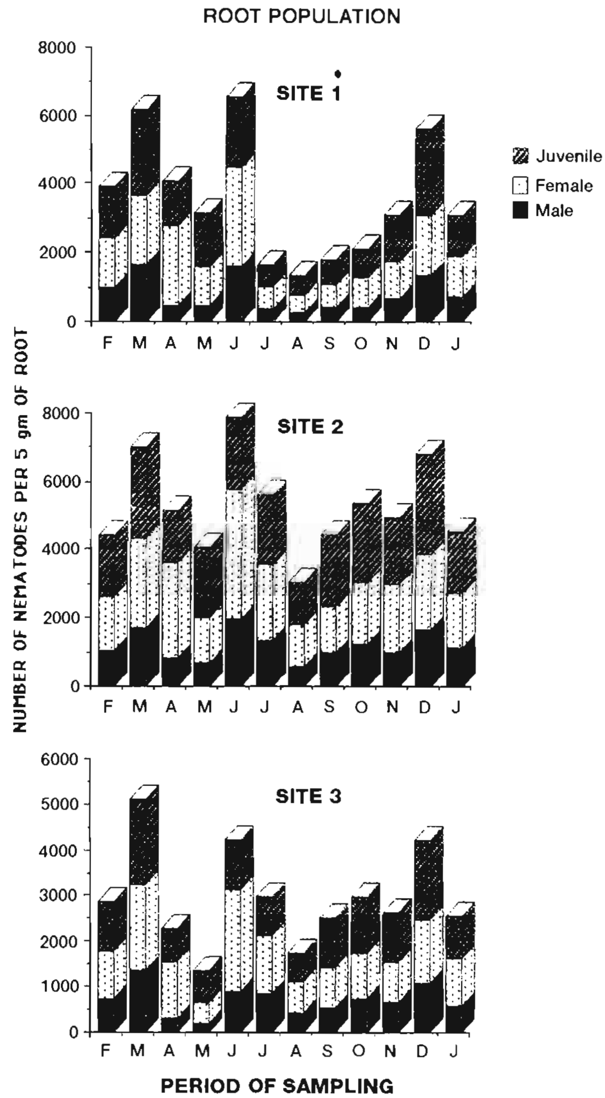

Fig. 3. Seasonal fluctuations of root populations and relative abundance of three life stages of Helicotylenchus multicinctus *on banana at three sites (February 1994-January 1995).*

and adults in March, June, and December, and an increase of juveniles was observed in root populations during March and December (Fig. 3). Adult nematodes were more abundant than juveniles in both soil and roots throughout the year. The increase in the adult population was followed by a marked increase in the juvenile population. The ratio of males to females varied; when there was an increase or decrease in the numbers of males, there was a variable increase or decrease in the numbers of females (Fig. 2). In soil, sex ratio was about one male to two females, but this ratio was lower in the roots.

Discussion

Increases in both soil and root nematode populations were observed in March, June-July, and October-November. Seasonal fluctuation data suggest that the species has at least three generations per year and that each generation takes 3-4 months to complete its development under natural conditions. Apparently, reproduction was somewhat lower during winter, and it took about 3 months for populations to reach a peak. High peaks were reached faster during pre-monsoon and monsoon months. Males of *H. multicinctus* were more abundant in root than in soil, which indicated that the females of the species were more migratory than the males. This is the opposite of a previous finding by Jones (1980).

The results indicate that soil populations were the lowest in December at all sites and that both soil and root populations decreased sharply in August following heavy rainfall (265.7 mm). This confirms the findings of Hutton (1978) on the influence of rainfall on plantain nematodes in Jamaica. High soil moisture content with continuous high rainfall for 25 days was found optimal for the population growth of *Meloidogyne incognita* in a banana field at Bhubaneswar, India (Mohanty *et al.*, 1993). An abrupt increase in root populations occurred at all sites in December when soil populations were the lowest due to very low temperatures and dry soil conditions. This indicates that the variation in soil and root populations was caused by the migration of the almost entire soil population into the roots. This is a common behaviour for migratory endoparasitic species like *H. multicinctus* confirmed in this study. Population density of *H. multicinctus* at site 2 was always much higher than at the other two sites (above 3000 nematodes/5 g of roots), which suggests that this species may have a preference for the cv. Dwarf Cavendish.

In this study, the occurrence of population peaks of *H. multicinctus* in March, June-July, and October-November may be due to the fact that pre-monsoon and post-monsoon rainfall (Fig. 1) during these months favour the root flush of banana: this increase in feeding sites may have caused an increase in nematode population density. The tendency of endoparasitic nematodes to increase in roots during post-monsoon months is common in the sub-tropical climate of India for other plantation crops. For example, *R. similis* in roots of coconut (Koshy & Sosamma, 1978) and black pepper (Mohandas & Ramana, 1988), *Pratylenchus coffeae* in coffee roots (Kumar, 1991), and *Meloidogyne* spp. in cardamom roots (Eapen, 1993) show similar behaviour. According to Choudhury and Phukan (1990), maximum population build-up of *H. dihystera* was recorded in March and minimum build-up in December in soil around banana roots in Assam, which agrees with our results obtained in an almost similar environment in the adjoining State of Tripura. On the basis of such evidence, Mukherjee and Dasgupta (1993) and Rama and Dasgupta (1987) postulated that the production of more juveniles during the root flush of a host plant is a sign of parasitic adaptation to the host plant, by enhancing the survival capacity of the nematodes.

CORRELATION OF POPULATION WITH CLIMATIC FACTORS

H. multicinctus survived at high population levels in dry soil, and rainfall was negatively correlated with soil populations but positively correlated with root populations (Hutton, 1978). McSorley and Parrado (1986) concluded that seasonal population cycles of *H. multicinctus* are strongly influenced by soil types and by quantity and quality of rainfall. By contrast, in a study of mixed nematode populations consisting of seven different species (including *H. dihystera)* around banana plants in Assam, it was claimed that temperature and monthly rainfall had no influence on nematode populations (Choudhury & Phukan, 1990).

In the present study, population peaks of *H. multicinctus* were observed when mean monthly temperature was between 25.5 and 28.6°C. In controlled conditions, the life cycle from egg to adult of *H. abunaamai* was completed in 28-35 days at 25 ± 6.5°C (Padhi & Das, 1986). Khan *et al.* (1971) also reported that temperatures of 20, 25, and 30°C were apparently favourable for nematode (*H. erythrinae, Hoplolaimus indicus,* and *Hemicriconemoides mangiferae)* population build-up, 25°C being the optimum temperature.

According to McSorley and Parrado (1981), population fluctuations of *H. multicinctus, H. dihystera,* and *M. incognita* on banana in Florida were rainfall-dependent and the highest nematode populations were found at the time of the year when the banana plants were under the greatest climatic stress, *i.e.,* in the coldest season. A larger increase of root populations during a period of great climatic stress (absence of rainfall, low soil moisture, and very low temperature inducing dry and chilly conditions of the soil) in December agrees with previous findings in Florida. Here, the pre-monsoon and post-monsoon rainfall were limiting the population size of *H. multicinctus.* Temperature did not have the same effect. Any chemical control programme should be applied preferably prior to March, June-July, and October-November to prevent the occurrence of the population peaks.

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