Population of nematodes in soils under banana, cv. Poyo, in the Ivory Coast. 3. Seasonal dynamics of populations in mineral soil

Patrick QUÉNÉHERVÉ

Laboratoire de Nématologie, Centre ORSTOM, BP V 51, Abidjan, Côte-d'Ivoire.

SUMMARY

The dynamics of nematode populations of bananas have been monitored during two vegetative cycles on two sites located on " mineral soil " (gravelly sandy clay soil and silty loam soil) in the banana producing area of the Ivory Coast. On this soil type the main endoparasitic nematodes which occur in the soil and in the roots are the burrowing nematode *Radopholus similis*, the spiral nematode *Helicotylenchus multicinctus* and on one site, *Pratylenchus coffeae*. In these conditions of soil type, fluctuations of *R. similis* in soil and roots or cortical part of the corm are a resultant of several factors such as the physiology of the renovation of the root system, the climate with respect to soil moisture, and the competition with the nematode species, making it the primary root invader. On this soil type, root infestation by *H. multicinctus* generally takes place after infestation by *R. similis*. This study also confirms that populations of both *R. similis* and *P. coffeae*, which occupy the same ecological niche, build up during the dry season and decrease with increasing rainfall, whereas *H. multicinctus*, *Hoplolaimus pararobustus* and *Cephalenchus emarginatus* show the reverse trend. In summary all the factors, endogenous or exogenous like the cultural practise of pruning, which favour new root emergence on banana plants contribute to the build up of *R. similis* population in the root system.

RÉSUMÉ

Populations de nématodes associés à la culture du bananier cv. Poyo en Côte-d'Ivoire. 3. Dynamiques de populations saisonnières sur sols minéraux

Les dynamiques de populations de nématodes associés au bananier ont été suivies sur deux sites en sols minéraux (sol gravillonnaire sablo-argileux et sol limono-sableux) de culture bananière en Côte-d'Ivoire. Sur ce type de sol, les principaux nématodes endoparasites présents aussi bien dans le sol que les racines sont *Radopholus similis*, *Helicotylenchus multicinctus* et, sur un site, *Pratylenchus coffeae*. Dans ces conditions de sol, la dynamique de population de *R. similis* dans le sol, les racines et la partie superficielle du rhizome est la résultante de plusieurs facteurs, tels la physiologie du renouvellement du système racinaire, la pluviométrie en relation avec la teneur en eau du sol et la compétition avec les autres espèces phytoparasitaires, qui font de *R. similis* l'espèce endoparasite pionnière. Dans ces conditions, l'infestation racinaire par 20 *H. multicinctus* apparaît secondairement. Cette étude confirme également que les populations de *R. similis* et de *P. coffeae*, qui occupent la même niche écologique, augmentent en saisons sèches et diminuent avec l'accroissement de la pluviosité; tandis que *H. multicinctus*, *Hoplolaimus pararobustus*, et *Cephalenchus emarginatus* suivent la tendance inverse. En fait, tous les facteurs endogènes ou exogènes, comme la pratique culturale de l'œilletonnage, qui favorisent l'émergence de nouvelles racines contribuent au développement de *R. similis* sur le système racinaire du bananier.

Several authors in differents parts of the world where banana is commercially grown have studied the nematode population dynamics and the related interdependent factors (Melin & Vilardebó, 1973; Jaramillo & Figueroa, 1974; Hugon, Ganry & Berthe, 1984). Most of these studies were conducted in order : *i)* to know the optimal time to control nematode populations by application of nematicides when populations are low but tending to build up, *ii)* to find some correlation between the nematodes parasitizing bananas in soil as well as in the roots and factors like rainfall and physiological stage of the banana plant which influence the fluctuations of the nematode populations.

Information on the seasonal behaviour of nematodes on bananas in different regions having various soil type would certainly contribute to a better understanding of the potential nematode problem and consequently to the use of appropriate control measures.

The objective of this study was to obtain improved results on the seasonal fluctuation of nematode populations on bananas in the Ivory Coast by using a new sampling method which gives a more accurate quantitative relationship between the nematode population and the different parts of the roots system than a blind random sampling of the roots.

The complete study was carried out between 1980 and

1985 in the banana producing areas during one vegetative cycle on five sites and during two consecutive vegetative cycles on eight sites. The structures of the nematode communities encountered were very different, mainly in relation with the soil type (Fargette & Quénéhervé, 1988; Quénéhervé, 1988). So we have chosen four different locations to follow the dynamics of nematode populations in the Ivory Coast conditions. Results given below concern the situation which occurs on soil generally named as « mineral soil » (less than 20 % organic matter; see Stover and Simmonds, 1987) and which are the most common soil condition in banana growing areas throughout the world.

Materials and methods

Commercial irrigated banana plantations were located on two sites, one near Azaguié on a ferrallitic soil (site 1), and the other near Aboisso on an alluvial soil (site 2). Chemical and granulometric characteristics of the two soils are given in Table 1. The trials were monitored during two vegetative cycles. Banana plants, cv. Poyo were planted with bullheads in June 5th, 1981, on site 1 and in April 19th, 1982 on site 2. Fluctuation of nematode populations were followed monthly (sampling every 28-32 days) in untreated plots. Roots and corms of banana rhizomes were sampled and analysed according to the method described by Quénéhervé and Cadet (1986) with six replicates per sampling date. Standardized extraction techniques were used for soil (Seinhorst, 1962) and roots (Seinhorst, 1950).

Table 1

Granulometric and chemical characteristics of soil of the two sites studied

	Site 1 (Azaguié)	*Site 2 (Aboisso)*
% Clay 0-2 µm	24.9	27.1
% Silt 2-20 µm	4.4	23.2
% Silt 20-50 µm	9.0	26.8
% Sand 50-200 µm	38.9	17.7
% Sand 200-2 000 µm	20.7	0.5
% H_2O	1.0	2.0
% Org. Matter	1.1	2.7
pH H_2O	5.5	5.1
pH KCl	4.5	4.1
‰ C	7.8	7.3
‰ N	0.8	0.8
C/N	10.4	9.8

Results of infestation are expressed as nematode densities per dm^3 of soil and per gram of roots or corms, belonging to the mother plant or bullhead (RPM, EPM), of the first principal sucker (R1Y, E1Y), of the second principal sucker (R2Y, E2Y), of the pruned suckers (R2YO, E2YO), etc. In order to have the level of infestation corresponding to the whole plant for each sampling, a « global root infestation » was calculated as a mean of the partial infestations on the different parts of the root system.

Rainfall records were collected daily on each site. A canopy level irrigation occurred in the dry season (about 24 mm of water per irrigation and per week). Three months after planting, the number of days of rainfall and the total rainfall (irrigation included) in a two, three, four, five, six-week period ending zero, one or two weeks before the monthly sampling dates were correlated with the nematode densities occuring in the soil and for the global root infestation for each species encountered. Correlations were calculated respectively on 18 and 19 sampling dates for sites 1 and 2.

Results

On site 1, one can notice that the great wet season in 1982 was very peculiar with a total rainfall superior to 1 400 mm between March and June 1982 (about 300 mm higher than the decennial average). Monthly amount of irrigation are illustrated on the same figure as the rainfall records.

Seasonal fluctuation of nematodes on site 1 (Azaguié)

On site 1 (ferrallitic clay-gravel soil) four main nematode species were found associated with bananas : three endoparasitic species, *Helicotylenchus multicinctus* (Cobb, 1893) Golden, 1956, *Radopholus similis* (Cobb; 1893) Thorne, 1949 and *Hoplolaimus pararobustus* (Sch. Stek. & Teun., 1938) Sher, 1963; one ectoparasitic species : *Cephalenchus emarginatus* (Cobb, 1893) Geraert, 1968.

Radopholus similis

The fluctuation of *R. similis* in the soil (Fig. 1, C) showed three peaks which coincided with the periods of dry seasons (Jan.-Feb. 82; Aug. 82 and March 83). In the roots (Fig. 2, A-D) infestation reached peaks just after the emergence of roots on unpruned and pruned suckers. For each sucker one can notice a peak of infestation in January. The Figure 1, D shows clearly the inverse trend of the global root infestation between *R. similis* and *H. multicinctus* in the dry season which coincided with the first flowering (Fig. 1, B).

During the second vegetative cycle after the heavy rainy season, the root infestations by *R. similis* became lower than those of *H. multicinctus* (Fig. 1, D). In the cortical part of the corm (Fig. 3, A-D), infestation levels increased on each successive sucker whatever the season but also during the rainy seasons. On this site *R. similis* was the only species constantly found in the corms.

There was no correlation between soil and root infestation, but there was a significant negative correlation between population levels of *R. similis* in the soil and the number of days of rainfall in the two week period ending one week before sampling (p = 0.023; r = 0.532).

Helicotylenchus multicinctus

H. multicinctus occurred constantly on site 1 and fluctuation in the number of nematodes from soil showed several major peaks coinciding with heavy rainfall periods (Fig. 1, A & C). In the roots (Fig. 2, A-D), high levels of infestation by the spiral nematode occurred always subsequently to infestation by *R. similis*. In the roots of the main sucker (Fig. 2, B), fluctuations showed three peaks (Nov. 81, July & Nov. 82) which coincided with heavy rainfall periods. Nematode seasonal fluctuations in the roots of the other suckers were similar and on Figure 1, D which shows the global root infestation reflecting the level of infestation of the entire root system of the banana tree, the same phenomenon of the narrow relation between rainfall and infestation level can be observed.

There was no correlation between soil and root infestation. There were significant positive correlation between : *i)* population levels of *H. multicinctus* in the soil and total rainfall in a three week period before sampling (P = 0.021; r = 0.536); *ii)* the global root infestation by *H. multicinctus* and the total rainfall in a three week period ending one week before sampling (p = 0.024; r = 0.529).

Hoplolaimus pararobustus

H. pararobustus infested roots at a low level by comparison with *H. multicinctus* and *R. similis* but occurred constantly in the soil at every sampling. Fluctuations in number of nematodes in the soil showed several major peaks coinciding with heavy rainfall period (Fig. 1, C & D). In the roots, except in those of the mother plant early after planting (Fig. 2, A), infestations remained at a low level in all suckers (below a mean of twenty nematodes per gram of root).

There was no correlation between soil and root infestation, but there was a significant positive correlation between the global root infestation by *H. pararobustus* and the number of days of rainfall in a two week period ending one week before sampling (p = 0.012; r = 0.575).

Cephalenchus emarginatus

Very high population of *C. emarginatus* occurred in the soil but seemed erratic (Fig. 1, C). There was no significant correlation found (p = 0.077), but results show a close positive relationship between the number of *C. emarginatus* in the soil and the number of days of rainfall in a four week period ending two weeks before sampling.

SEASONAL FLUCTUATION OF NEMATODES ON SITE 2 (Aboisso)

On site 2 (alluvial loamy-clay soil) the nematodes found were the same as noticed previously to which one can add, as endoparasitic species : *Pratylenchus coffeae* (Zimmerman, 1898) Filipjev & Sch. Stek., 1941; *Rotylenchulus reniformis* Lindford & Oliveira, 1940 and *Meloidogyne* spp.; and *Hemicycliophora oostenbrinki* Luc, 1958 as additional ectoparasitic species.

R. reniformis, H. oostenbrinki and *Meloidogyne* spp. were encountered very sporadically mostly in soil samples, so fluctuations in numbers are not exhibited below. For the sake of clarity, the dynamics of *H. pararobustus* in the roots are not illustrated in the figures.

One can notice the heavy rainy season from May to July of 1982 and in June of 1983. Monthly amounts of irrigation are illustrated on the same figure as the rainfall records.

Radopholus similis

Major soil infestation by *R. similis* took place in the dry season (Fig. 4, C) but in comparison to the first site was very abundant (often between 1 000 and 2 000 nematodes per liter of soil) during all the experiment.

In the roots of the differents suckers (Fig. 5, A-D), the peaks of infestation appeared early, two to three months, after the sucker emergence. This phenomenon was observed for all the suckers, pruned and unpruned.

The global root infestation (Fig. 4, D) showed that during the first vegetative cycle, *R. similis* was the main endoparasitic nematode. During the second vegetative cycle, populations of *H. multicinctus* and *P. coffeae* were similar to those of *R. similis*.

There was no correlation between root infestation by *R. similis* and soil or the number of days of rainfall or total rainfall.

Helicotylenchus multicinctus

Fluctuations in number of *H. multicinctus* from soil showed several peaks coinciding with heavy rainfall periods (Fig. 4, B-C). In the roots, low levels of infestation occurred and were only higher than *R. similis* in the roots of the first sucker later after flowering, at the moment of the bunch harvest (Fig. 4, B). On the different suckers as well as on the global root infestation (Fig. 4, D), levels of *H. multicinctus* remained lower than those of *R. similis*.

There was a close but not significant (p = 0.072) positive relationship between soil and root infestation and no correlation between population levels of *H. multicinctus* in soil or in roots and the number of days of rainfall or the total rainfall.

Pratylenchus coffeae

In soil *P. coffeae* was scarcely detected during the first vegetative cycle, levels of population increased only during the second vegetative cycle (Fig. 4, C). In the

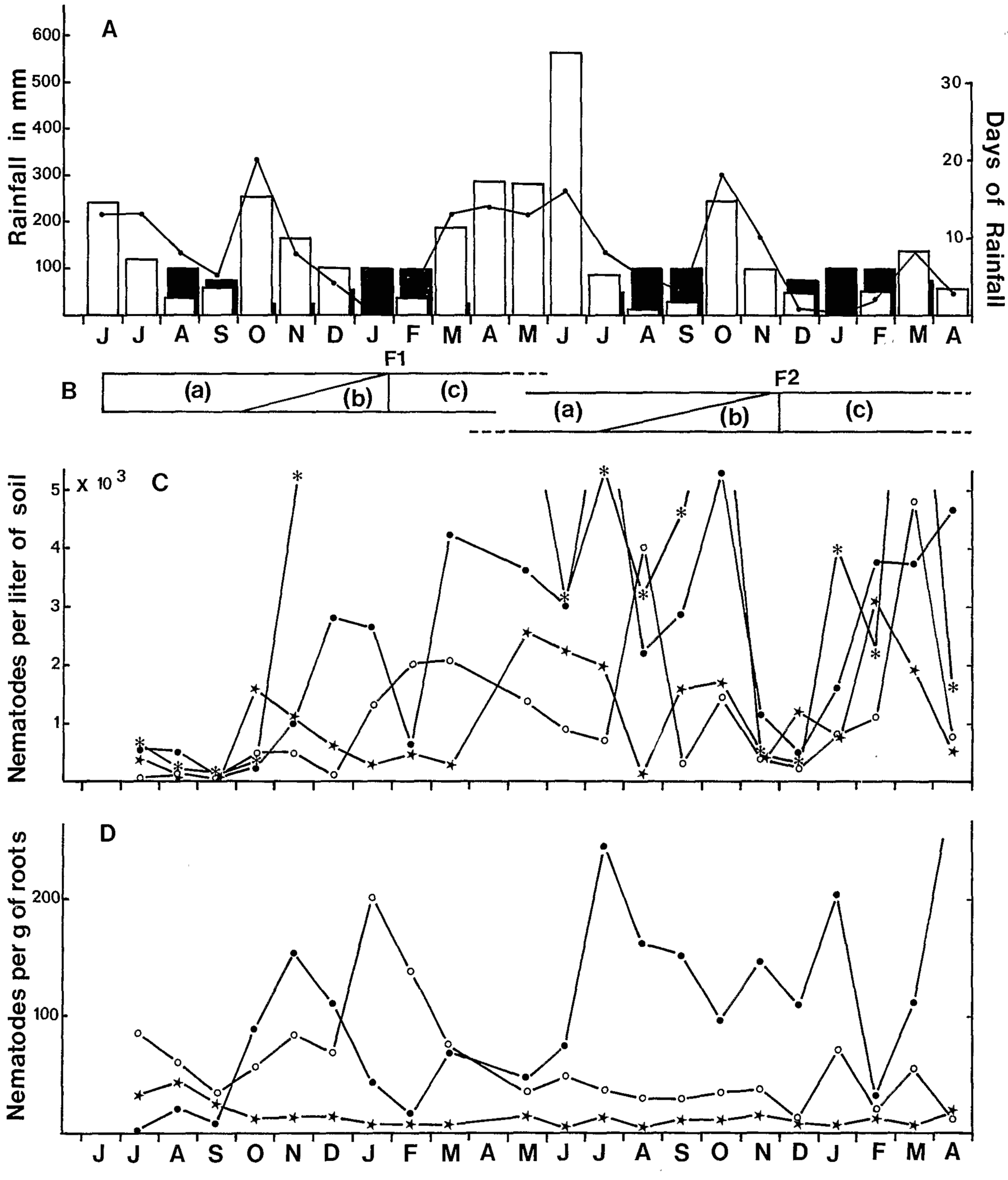

Fig. 1. Nematode population dynamics on site 1 (Azaguié). A : Rainfall and irrigation (white bar : monthly rainfall; black bar : monthly irrigation; black circles and plain line : number of days of rainfall per month). B : Schematic representation of physiological stages of banana plant : (a) vegetative phase; (b) fruiting phase; (c) ripening phase; F 1, shot fruit of the plant crop; F 2, shot fruit of the first ratoon. C : Seasonal fluctuation in the soil (white circle : *Radopholus similis;* black star : *Hoplolaimus pararobustus;* black circle : *Helicotylenchus multicinctus;* asterisk : *Cephalenchus emarginatus*). D : Seasonal fluctuation of the global root infestation.

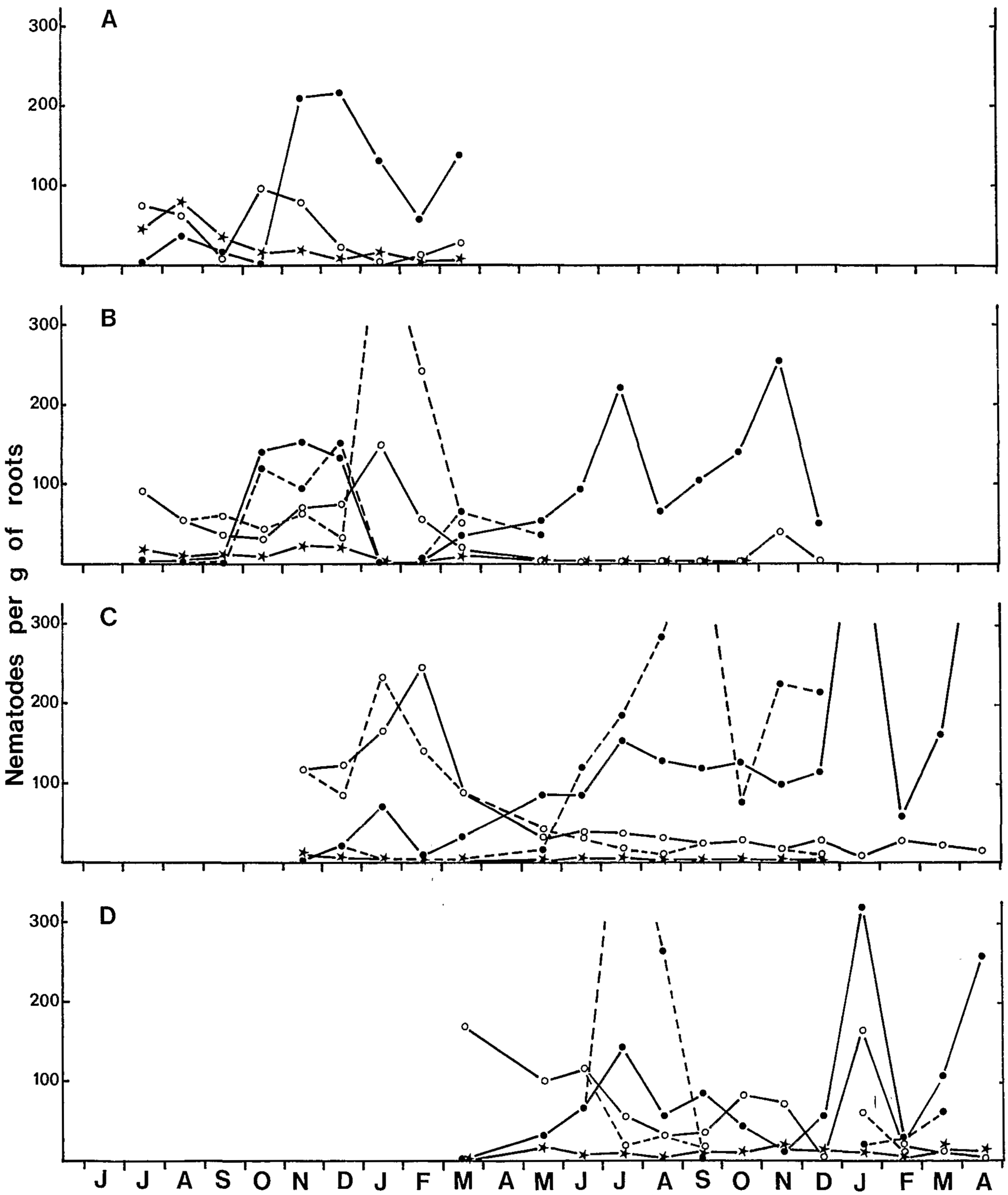

Fig. 2. Nematode population dynamics in the roots on site 1 (Azaguié) (white circle : *Radopholus similis;* black circle : *Helicotylenchus multicinctus;* black star : *Hoplolaimus pararobustus.* Plain lines : main suckers; dotted lines : pruned suckers). A : Seasonal fluctuation in the roots of the mother plant. B : Seasonal fluctuation in the roots of the first suckers. C : Seasonal fluctuation in the roots of the second suckers (first ratoon). D : Seasonal fluctuation in the roots of the third suckers (second ratoon).

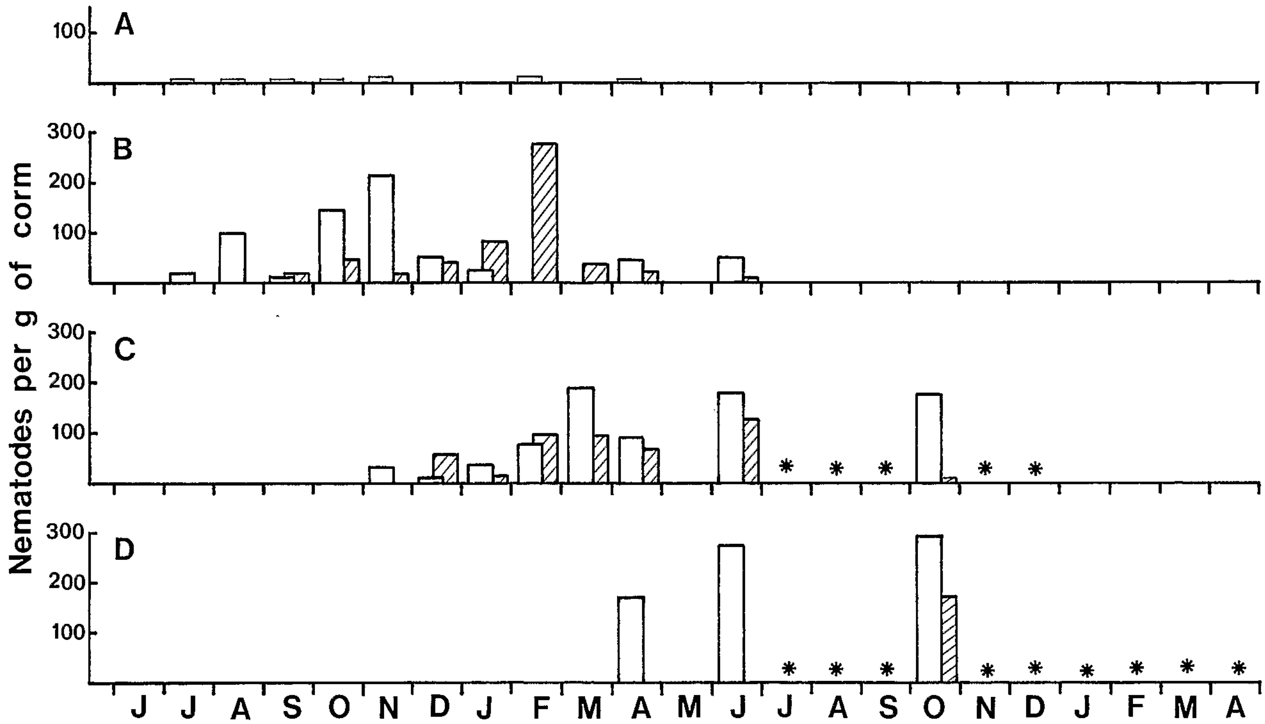

Fig. 3. Nematode population dynamics in the corn on site 1 (Azaguié) (white bar : main suckers; bar with diagonal lines : pruned suckers; asterisk : missing data). A : Seasonal fluctuation in the corm of the mother plant. B : Seasonal fluctuation in the corm of the first suckers. C : Seasonal fluctuation in the corm of the second suckers (first ratoon). D : Seasonal fluctuation in the corm of the third suckers (second ratoon).

roots, even during the first cycle, there was a regular level of infestation, without noticeable peaks, whatever the sucker considered. Levels of infestation were quite equal to those observed with *R. similis* during the second cycle (Fig. 4, D).

There was no correlation between soil and root infestation. There were close negative relationship (but not significant correlation) between population levels of *P. coffeae* in the roots (global root infestation) and the number of days of rainfall or the total rainfall.

Cephalenchus emarginatus

Soil infestation by *C. emarginatus* showed several peaks coinciding with heavy rainfall periods (Fig. 4, A-C). There were significant positive correlations between infestation levels and *(i)* the total rainfall in a two week period ending one week before sampling ($p = 0.020$; $r = 0.528$) and *(ii)* the number of days of rainfall for the same period ($p = 0.015$; $r = 0.620$).

Discussion

The climate in the south of the Ivory Coast where bananas are grown is defined as humid tropical with two rainy seasons, the main one which occurs from May to July with an average rainfall of 1 200 mm, and a short rainy season in October with 190 mm. Dry seasons are in fact wrongly termed because usually the relative atmospheric humidity does not decrease below 84 %, but the industrial plantations of bananas need some additional supplies of water by irrigation (most of them are made by canopy level irrigation). In this region, the mean temperature ranges between 24.4° (August) and 27.4° (March) with a maximal deviation of 6.5° (Eldin, 1971).

In such conditions the major environmental factors affecting population size of nematodes are soil type, soil moisture (with respect to rainfall and irrigation) and the plant growth stage. In subtropical or highland countries soil temperature is an additional and very important factor to consider. If soil type and rainfall are data easy to collect, knowledge of the plant growth stage, reflecting the life history of the root system, is valid for an annual plant but not sufficient for a semi-perennial plant like banana with successive waves of root emergence.

Numerous studies have been conducted on the population dynamics of different species of nematodes parasiting roots of bananas. All these studies were made after blind sampling of roots around the mat without knowledge of their origin on the underground rhizome, from the bullhead, the pruned or unpruned suckers, etc. So, most of the fluctuations observed were erratic and very difficult to explain. In this study a new sampling method was used (Quénéhervé & Cadet, 1986) to obtain specific fluctuations on every root system as soon as the suckers appeared.

Radopholus similis

In the literature, some authors have noticed a relation between successive annual peaks in the numbers of *R. similis* in the roots and the active growth of the plant (Jaramillo & Figueroa, 1974), coinciding with the emergence of the banana flower (Melin & Vilardebó, 1973). More recently Hugon, Ganry and Berthe (1984), observed in Guadeloupe the relation between the physiological stage of the banana plant and such climatic factors as temperature and rainfall.

The results of this study clearly show differences in the behaviour of the nematodes encountered. *R. similis* acts as the primary root invader; it is always the first parasite of the new roots and levels of infestation decrease as the root system ages or decays. It is also very important to notice that the cortical tissue of the different parts of the rhizome shelters a very high population of *R. similis*, perhaps still higher during the rainy season. In the soil, infestation levels of *R. similis* are always lower than those of other nematodes.

The biology of *R. similis*, the burrowing nematode, is well known since the work of Blake (1961) and Loos (1962) who first described « the black head disease » of bananas. These authors have shown that migratory activity and egg-layins are governed by nutritional factors, that the nematodes « do not move out of a root so long as they are able to invade healthy tissue » and that *R. similis* is able to complete its life cycle in the cortical tissue of the root or the rhizome without a soil phase. This may explain why the burrowing nematode is not affected by the soil type (Quénéhervé, 1988). Another factor to consider in understanding the population dynamics of *R. similis* is the biology of the host plant. After flowering there is little or no new root emergence on this part of the rhizome (Lavigne, 1987), but on the rhizomes of the suckers, strong root emergence occurs after they have achieved self-reliance (change of the lanceolated leaves to enlarged leaves). Pruning of suckers only by the removal of the aerial part as first stimulates root emergence for one to two months, but repetitive pruning can suppress this phenomenon and kill the suckers. In fact all the factors which favour root emergence on banana plants contribute to the build up of *R. similis* populations.

Besides *R. similis*, other parasites such as fungi, bacteria and other nematode species are present in the roots, in a complex of parasites which causes root decay. The subsequent increase of the infestation by other nematodes like *H. multicinctus*, *H. pararobustus* and *P. coffeae* may speed up root decay, thereby restricting the avaibility of healthy tissue to an over-particular parasite such as *R. similis*.

One important aspect of the biology of *R. similis* is its ability to infest the corm and to build up high level of infestation as a future source of inoculum, even when soil moisture conditions are extreme and affect its survival in the root system and in the soil.

Influence of climatic conditions have also been well studied and all the authors have observed a decline of population of *R. similis* during the wet season (Jimenez, 1972; Melin & Vilardebó, 1973; Jaramillo & Figueroa, 1974; Shafiee & Mendez, 1975; Mc Sorley & Parrado, 1981; Hugon, Ganry & Berthe, 1984). Hunt (in Ambrose, 1984) found a negative significant correlation between soil population of *R. similis* and a four week period of rainfall.

In this study we have also found on site 1 a negative significant correlation between soil population and the number of days of rainfall in a two week period ending one week before sampling. It is important to note this negative correlation, *R. similis* being suppressed by excess of water or lack of oxygen as discussed by Jimenez, 1972. This biological behavior is useful for such control method of *R. similis* in the soil as flooding (Loos, 1961; Sarah, Lassoudière & Guérout, 1983; Mateille, Foncelle & Ferrer, 1988).

In conclusion, fluctuations of *R. similis* in soil and roots or cortical part of the corm are a resultant of different factors such as the physiology of the renovation of the root system, the climate with respect to soil moisture, and the competition, in relation to its reproductive capabilities, with the other nematode species for the available virgin feeding sites at the cellular level.

Helicotylenchus multicinctus

H. multicinctus, is found in the outer layer of cortical cells, as reported by Luc and Vilardebó (1961). Zuckerman and Strich-Harari (1963) have shown that the spiral nematode is able to complete his life-cycle within the roots of banana.

In this study, *H. multicinctus* which was predominant in some sites in the Ivory Coast (Quénéhervé, 1988) showed its capacity to build up populations in the soil and in the roots.

On the mineral soil type of the Ivory Coast, root infestation by *H. multicinctus* generally takes place after infestation by *R. similis*.

Many studies have been conducted in order to find correlations between densities of *H. multicinctus* and rainfall. These studies gave variable results throughout the world. In Jamaica, Hutton (1978) found a significant negative correlation between soil population and the number of days of rainfall in a four-week period ending two weeks before sampling on one site and a significant positive correlation between root population and the total rainfall in the four week period ending four weeks

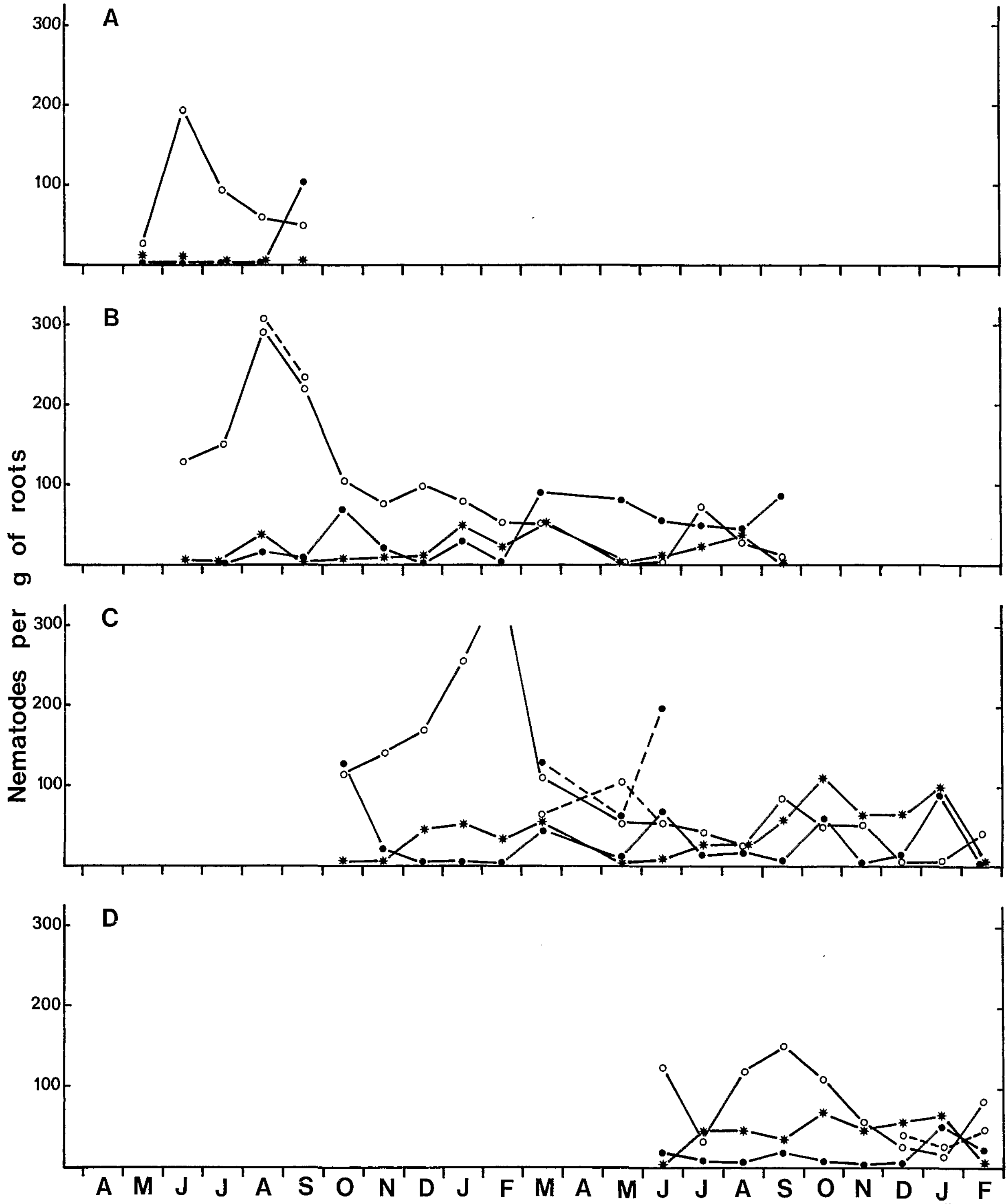

Fig. 5. Nematode population dynamics in the roots on site 2 (Aboisso). (white circle : *Radopholus similis;* black circle : *Helicotylenchus multicinctus;* black asterisk : *Pratylenchus coffeae;* plain lines : main suckers; dotted lines : pruned suckers). A : Seasonal fluctuation in the roots of the mother plant. B' : Seasonal fluctuation in the roots of the first suckers. C : Seasonal fluctuation in the roots of the second suckers (first ratoon). D : Seasonal fluctuation in the roots of the third suckers (second ratoon).

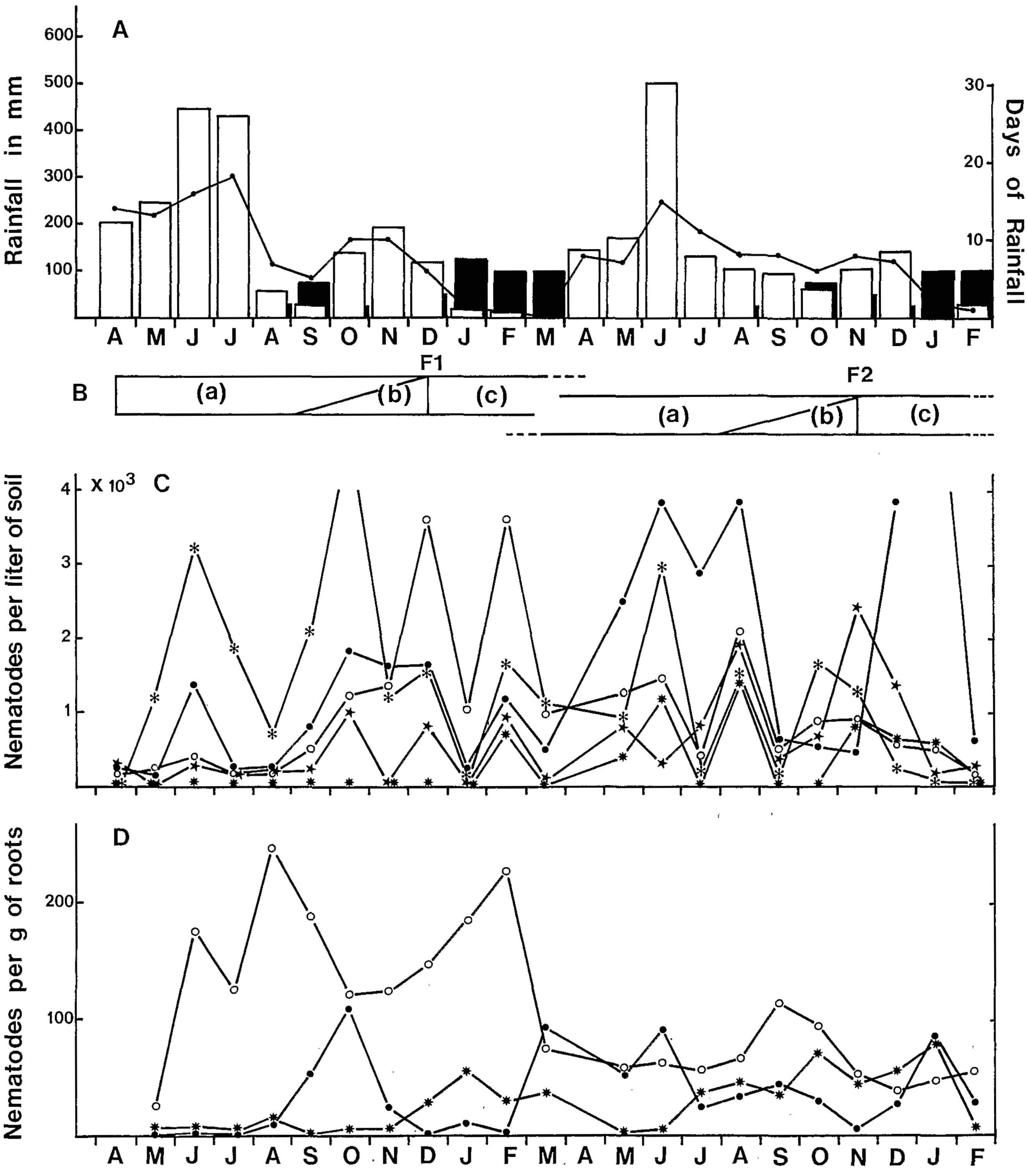

Fig. 4. Nematode population dynamics on site 2 (Aboisso). A : Rainfall and irrigation (white bar : monthly rainfall; black bar : monthly irrigation; black circles and plain line : number of days of rainfall per month). B : Schematic representation of physiological stages of banana plant : (a) vegetative phase; (b) fruiting phase; (c) ripening phase; F 1, shot fruit of the plant crop; F 2, shot fruit of the first ratoon. C : Seasonal fluctuation in the soil (white circle : *Radopholus similis;* black circle : *Helicotylenchus multicinctus;* black star : *Hoplolaimus pararobustus;* black asterisk : *Pratylenchus coffeae;* fine asterisk : *Cephalenchus emarginatus).* D : Seasonal fluctuation of the global root infestation.

before sampling. In Florida, McSorley and Parrado (1981) found a positive correlation between soil population and the number of days of rainfall of the previous month. In Nigeria, Badra and Caveness (1982), found no significant correlation with rainfall. In the Windward Islands, Hunt (in Ambrose, 1984) found no correlation between soil and root population but a significant positive correlation between soil population and total monthly rainfall.

In this study we have found on site 1 no correlation between soil and root infestation but significant positive correlations between population levels of *H. multicinctus : i)* in the soil and total rainfall in a three week period before sampling and *ii)* expressed as a global root infestation and the total rainfall in a three week period ending one week before sampling. On the second site, no significant correlation occurred.

It has been generally reported that *H. multicinctus* shows maximum populations in rainy seasons and minimum during the drier months and the discrepancies in the relationships between nematode population densities and rainfall reported in the literature may be attributed to differences in soil type, soil temperature and to incidence of heavy rainfall.

In conclusion, fluctuations of *H. multicinctus* are also a result of various factors, but here, more than for *R. similis* the soil type being the most predominant. In tropical and optimal conditions of soil type, climatic factors like rainfall and consequently soil moisture are quite sufficient to explain the annual fluctuations of population; while in sub-optimal conditions as outlined by McSorley and Parrado (1986), the description of seasonal population fluctuations requires further clarification, especially soil temperature.

Pratylenchus coffeae

P. coffeae, a " root lesion nematode ", occurs mainly in Central America. As mentioned by Wehunt and Edwards (1968), *P. coffeae* is occasionally found on bananas, but is widespread on abaca (*Musa textilis* Nees) and plantain. Recent surveys, found it as major parasite on bananas in Papua New Guinea (Bridge & Page, 1985). In Honduras, Pinochet (1978) described its life-cycle on plantain roots. It is interesting to notice that the destruction of the cortical parenchyma of plantain roots by *P. coffeae* is quite similar to that of *R. similis* described by Blake (1961, 1966) on banana.

In this study the fluctuation of *P. coffeae* shows that this nematode is able to build up high population in the banana roots like *R. similis*. We have found no correlation between soil and root infestation but a close negative relationship between population levels of *P. coffeae* in the roots (expressed as global root infestation) and the rainfall.

In fact the populations of both *P. coffeae* and *R. similis* do not increase during rainy season.

In optimal conditions of soil type and soil moisture, others factors such as reproductive capability and competition for the feeding sites takes place in the roots and *P. coffeae* could appear as a competitor of *R. similis* in infesting the roots. May be *P. coffeae* is less over-particular than *R. similis* in its nutritional relationship with the root tissue but this point needs further research. It is important to remark that, for the moment, *P. coffeae* has only been observed in the south-east of the Ivory Coast, both on bananas (Fargette & Quénéhervé, 1988) and plantains (Adiko, 1988). This nematode might become a more damaging parasite in other environmental condition, as in Papua New Guinea or like *P. goodeyi* in Canary Islands (de Guiran & Vilardebó, 1962) or on higland bananas in East Africa (Gichure & Ondieki, 1977; Bridge, pers. comm.). So it is now necessary to avoid transfer of infested planting material from this region.

Hoplolaimus pararobustus

H. pararobustus was observed for the first time in 1956 on banana in the Ivory coast (Luc & Vilardebó, 1961). Though it occurs in high densities mainly on sandy soil (Fargette & Quénéhervé, 1988; Quénéhervé, 1988), *H. pararobustus* is now widespread in the banana growing areas. There is only information on the pathogenicity of *H. pararobustus* on banana roots in Tanzania (Whitehead, 1959) and complete description of its life-cycle requires further work. In this study, this nematode was abundant in soil samples, but infestation of the roots generally occurred at low levels, below twenty nematodes per gram of root. In fact this nematode appears to build up in the roots only when other nematodes like *R. similis* is locally absent. This trend illustrates a competition for the feeding sites. Population densities observed on site 1 show a significant positive correlation between the global root infestation and the number of days of rainfall in a two week period ending one week before sampling.

As for *H. multicinctus*, fluctuations of *H. pararobustus* show a close positive relationship between densities in the soil or in the roots and the rainfall.

Cephalenchus emarginatus

It was the only ectoparasitic nematode species constantly observed in every sample and population densities in the soil were very high at both sites. There is no information on the host-parasite relationship of *C. emarginatus* and banana in the literature. In this study, seasonal fluctuations of *C. emarginatus* showed several peaks generally coinciding with period of heavy rainfall. In fact there is a close positive relationship between population densities in the soil and the rainfall (expressed as total rainfall or in number of days of rainfall).

Conclusion

Like the reports of numerous authors in different parts of the world these studies on the nematode population dynamics and the related interdependent factors are conducted in order *i)* to determine the optimal time to control nematode populations by application of nematicides when populations are low but tending to build up and *ii)* to find any correlation between the population levels of nematodes in soil as well as in the roots with factors like rainfall or the physiological stage of the banana tree influencing the trend of the nematode populations.

First of all, this study confirms the validity of the sampling method which has revealed the different quantitative and qualitative nematode populations infesting roots according to their origin on the rhizome.

These important results on the seasonal fluctuations of nematode populations on bananas growing on mineral soil in the Ivory Coast have shown that the root infestations of *R. similis* are more closely related to the successive root emergence on each sucker than to the physiological stage of banana plant such as flowering. This behaviour may be explained by the over-particular host-parasite relationship of *R. similis* with the healthy tissue, making it the primary root invader, and a very strict endoparasite. This study also confirmed that populations of both *R. similis* and *P. coffeae* build up during the dry season and decrease with increasing rainfall, whereas *H. multicinctus, H. pararobustus* and *C. emarginatus* show the reverse trend. In fact all the factors, endogenous or exogenous like the cultural practice of pruning, which favour new root emergence on banana plants contribute to the build up of *R. similis* population in the root system.

Therefore, the ideal application of nematicide should take into account soil type, nematode community structure encountered, physiological stage of the plant as reflected in the root development and climatic season.

ACKNOWLEDGEMENTS

The author thanks COFRUITEL (Ivory Coast) for its support of this investigation and gratefully acknowledges the growers MM. J. Eglin and J. B. Martin, for their technical assistance in the field trials. The author is also indebted to Dr. P. Cadet, and MM. T. Mateille, A. Adiko, P. Topart and all the technical staff of the Laboratory of Nematology, ORSTOM, Ivory Coast, for their helpful advices and technical assistance.

REFERENCES

ADIKO, A. (1988). Plant-parasitic nematodes associated with plantain, *Musa paradisiaca* (AAB) in the Ivory Coast. *Revue Nématol.*, 11 : 109-113.

AMBROSE, E. (1984). Research and development in banana crop protection (excluding Sigatoka) in the English speaking Caribbean. *Fruits*, 39 : 234-247.

BADRA, T. & CAVENESS, F. E. (1983). Effects of dosage sequence on the efficacy of nonfumigant nematicides on plantain yields, and nematode seasonal fluctuations as influenced by rainfall. *J. Nematol.*, 15 : 496-502.

BLAKE, C. D. (1961). Root rot of bananas caused by *Radopholus similis* (Cobb) and its control in New South Wales. *Nematologica*, 6 : 295-310.

BLAKE, C. D. (1966). The histological changes in banana roots caused by *Radopholus similis* and *Helicotylenchus multicinctus*. *Nematologica*, 12 : 129-137.

BRIDGE, J. & PAGE, S. L. J. (1985). Plant nematode pests of crops in Papua New Guinea. *J. Pl. Prot. Tropics*, 1 : 99-109.

ELDIN, M. (1971). Le climat. In : ORSTOM (Ed.). *Le milieu naturel de la Côte-d'Ivoire*, Paris, ORSTOM : 73-108.

FARGETTE, M. & QUÉNÉHERVÉ, P. (1988). Populations of nematodes in soils under banana, cv. Poyo, in the Ivory Coast. 1. The nematofauna occuring in the banana producing areas. *Revue Nématol.*, 11 : 239-244.

GICHURE, E. & ONDIEKI, J. J. (1977). A survey of banana nematodes in Kenya. *Z. PflKrankh. PflSchutz.*, 84 : 724-728.

DE GUIRAN, G. & VILARDEBÒ, A. (1962). Le bananier aux Iles Canaries. IV. Les nématodes parasites du bananier. *Fruits*, 17 : 263-277.

HUGON, R., GANRY, J. & BERTHE, G. (1984). Dynamique de population du nématode *Radopholus similis* en fonction du stade de développement du bananier et du climat. *Fruits*, 39 : 251-253.

HUTTON, D. G. (1978). Influence of rainfall on some plantain nematodes in Jamaica. *Nematropica*, 8 : 34-39.

JARAMILLO, R. & FIGUEROA, A. (1974). Analisis armònico de la densidad de poblaciòn de *Radopholus similis* (Cobb) Thorne en la zona bananeira de Guàpiles, Costa Rica. *Turrialba*, 24 : 402-407.

JIMÉNEZ, M. F. (1972). Fluctuationes anuales de la poblacion de *Radopholus similis* en la zona bananera de Potoci, Costa Rica. *Nematropica*, 2 : 33-40.

JONES, R. K. (1980). Population dynamics of *Helicotylenchus multicinctus* and other nematodes on bananas from a subtropical environment. *Nematologica*, 26 : 27-33.

LAVIGNE, C. (1987). Contribution à l'étude du système racinaire du bananier. Mise au point de rhizotrons et premiers résultats. *Fruits*, 42 : 265-271.

LOOS, C. A. (1961). Eradication of the burrowing nematode, *Radopholus similis*, from bananas. *Pl. Dis. Reptr*, 45 : 457-461.

LOOS, C. A. (1962). Studies on the life history and habits of the burrowing nematode, *Radopholus similis*, the cause of black-head disease of banana. *Proc. helminth. Soc. Wash.*, 29 : 43-52.

LUC, M. & VILARDEBÒ, A. (1961). Les nématodes associés aux bananiers cultivés dans l'Ouest Africain. *Fruits*, 16 : 205-219; 261-279.

MATEILLE, T., QUÉNÉHERVÉ, P. & TOPART, P. (1988). Nematicidal treatment of banana AAA cv. Poyo planting material by corm coating. *Revue Nématol.*, 11 : 89-92.

MATEILLE, T., FONCELLE, B. & FERRER, H. (1988). Lutte contre les nématodes du bananier par submersion du sol. *Revue Nématol.*, 11 : 235-238.

MCSORLEY, R. & PARRADO, J. (1981). Population fluctuations of plant-parasitic nematodes on bananas in Florida. *Proc. Fl. State hort. Soc.*, 94 : 321-323.

MCSORLEY, R. & PARRADO, J. L. (1986). Nematological review : *Helicotylenchus multicinctus* on bananas : an international problem. *Nematropica*, 16 : 73-91.

MELIN, P. & VILARDEBÓ, A. (1973). Efficacité de quelques nématicides en bananeraie dans les sols volcaniques de la région du Mungo (Cameroun). *Fruits*, 28 : 3-17.

PINOCHET, J. (1978). Histopathology of the root lesion nematode, *Pratylenchus coffeae* on plantains, *Musa* AAB. *Nematologica*, 24 : 337-340.

QUÉNÉHERVÉ, P. & CADET, P. (1986). Une nouvelle technique d'échantillonnage pour l'étude des nématodes endoparasites du bananier. *Revue Nématol.*, 9 : 95-97.

QUÉNÉHERVÉ, P. (1988). Populations of nematodes in soils under banana, cv. Poyo, in the Ivory Coast. 2. Influence of soil texture, pH and organic matter on nematode populations. *Revue Nématol.*, 11 : 245-251.

SARAH, J.-L., LASSOUDIÈRE, A. & GUÉROUT, R. (1983). La jachère nue et l'immersion du sol : deux méthodes intéressantes de lutte intégrée contre *Radopholus similis* (Cobb) dans les bananeraies de sols tourbeux de Côte-d'Ivoire. *Fruits*, 38 : 35-42.

SEINHORST, J. W. (1950). De betekenis van de toestand van de grond voor het optreden van aantasting door het stengelaatje (*Ditylenchus dipsaci* (Kühn) Filipjev). *Tijdschr. Pl. Ziekt.*, 56 : 291-349.

SEINHORST, J. W. (1962). Modifications of the elutriation method for extracting nematodes from soil. *Nematologica*, 8 : 117-128.

SHAFIEE, M. F. & MENDEZ, J. M. (1975). Estudios sobre tres problaciones y fluctuaciones estacionales de *Radopholus similis* en platano, *Musa* sp. *Ciencias, Univ. Habana, Ser. II, Sanidad veg. (1975)*, 12 : 12 p.

STOVER, R. H. & SIMMONDS, N. W. (1987). Soils. In : Wrigley G. (Ed.). *Bananas*, 3rd ed., London, Longman : 212-222.

WEHUNT, E. J. & EDWARDS, D. I. (1968). *Radopholus similis* and other nematodes species on bananas. In : Smart G. C. & Perry J. G. (Eds). *Tropical Nematology*, Gainesville, USA, Univ. Fl. Press : 1-19.

WHITEHEAD, A. G. (1959). *Hoplolaimus angustalatus* n. sp. (Hoplolaiminae : Tylenchida). *Nematologica*, 4 : 99-105.

ZUCKERMANN, B. M. & STRICH-HARARI, D. (1963). The life stages of *Helicotylenchus multicinctus* (Cobb) in banana roots. *Nematologica*, 9 : 347-353.

Accepté pour publication le 16 mai 1988.