Population of nematodes in soils under banana cv. Poyo in the Ivory Coast. 2. Influence of soil texture, pH and organic matter on nematode populations

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SUMMARY

During the nematicide tests carried out between 1980 and 1985 in the banana producing areas of the Ivory Coast, the relative percentage of some nematode species extracted from soil and roots in control plots (where no nematicides had been used) were compared in relation to some soil variables using the multivariate analysis. This study showed, on one hand, a marked difference between the polyspecific communities encountered in organic soil and those in mineral soil. In organic soil, *Helicotylenchus multicinctus* proves to be predominant in the soil as well as in the roots; whereas *Radopholus similis* remains the main root parasite in the roots but also is barely present in the soil whatever its texture. On the other hand, soil variables observed (texture, pH, organic matter content) seem to have no effect on *Radopholus similis* populations while they affect the other genera encountered. Clay content appears to be the most determining factor in the equilibrium of the nematode community structure in the soil.

RÉSUMÉ

Populations de nématodes associés à la culture du bananier cv. Poyo en Côte d'Ivoire.
2. Influence de la texture du sol, du pH *et du contenu en matière organique sur les populations de nématodes*

Au cours des essais conduits en Côte d'Ivoire en culture bananière de 1980 à 1985, les pourcentages relatifs des différentes populations de nématodes phytoparasites extraits du sol et des racines de bananiers dans les parcelles non traitées ont été comparés à l'aide de l'analyse statistique multivariée en relation avec certaines variables du sol. Il ressort de cette étude, d'une part une différence très nette entre les communautés polyspécifiques rencontrées sur sol organique et sur sol minéral; *Helicotylenchus multicinctus* est en effet capable, sur sol organique, d'être prépondérant aussi bien dans le sol que dans les racines. Sur sol minéral, *Radopholus similis*, s'il est faiblement représenté dans le sol, demeure le parasite majeur des racines quelle que soit la texture de ce type de sol. D'autre part, les variables du sol prises en compte (texture, pH, quantité de matière organique) ne semblent pas avoir d'effets sur les populations de *Radopholus similis* tandis qu'elles auraient une influence diverse sur les autres genres rencontrés. La teneur en argile apparaît être la composante la plus déterminante de l'équilibre des populations de nématodes dans le sol.

Nematode populations change in response to the pressures and challenges imposed by external factors, and so they develop a structure and show properties of dynamic equilibrium. It is difficult to relate population growth to such factors as rainfall, temperature, soil type or host plant and to show precisely how each factor affects biological processes.

In general, most of the information in the literature deals with the relation between soil type and densities of nematode species on banana (Stover & Fielding, 1958; Ayala & Romàn, 1963; Varghèse & Nair, 1968; Guérout, Lassoudière & Vilardebó, 1976; Davide, 1980; Mc Sorley & Parrado, 1981). But it is a rare study that correlates soil variables to the nematode community structure.

In the Ivory Coast, banana cv. Poyo is grown industrially in very different types of soil, and the species of nematodes encountered in the different localities varied considerably in their relative distribution (Fargette & Quénéhervé, 1988). During five years, from 1980 to 1985 a survey was undertaken in the banana producing areas and nematode populations were monitored monthly on thirteen sites for at least one vegetative cycle (five sites), and for two consecutive vegetative cycles on the others. The complete results of the fluctuation in nematode populations in relation with the rainfall and the physiology of the host plant will be published and discussed later. The purpose of this study is first to determine the influence of the type of soil on the field distribution of the nematode communities.

Materials and methods

Natural fluctuation in nematode populations has been monitored monthly on the control plots without applications of nematicide during the time of the experiment. Six banana trees were uprooted and the root system was sampled and analysed separately as previously described (Quénéhervé & Cadet, 1986). Standardized extraction techniques were used for soil (Seinhorst, 1962) and roots (Seinhorst, 1950). Samples of soil collected between 20 and 40 cm depth were sent to the ORSTOM Central Laboratory for analysis of chemical and physical properties.

The statistical methods used were the principal component analysis and the stepwise multiple regression analysis by the NDMS program from the ORSTOM library. The objective of a principal components analysis is to find few linearly independent combinations (principal components) that keep the maximum information of the original variables. The results can be expressed graphically. The total variation is expressed by a few components without any great loss of information : the first principal component is that which accounts for most of the information (variability) and corresponds to the longest axis of the total cluster of individuals; the second component is orthogonal to it (uncorrelated) and takes a maximum of the residual variability (Foucart, 1982).

Code numbers of the different sites refer to the name of the plantation and location of the trial plots as described in Table 1.

Table 1

Location of the different sites of sampling.

Site	*Region*	*Plantation*	*Trial plot*
1	III	Elima	C 66
2	II	Elevie	C 1
3	II	Marcel	C 3
4	II	2 The	C 8
5	II	Cotivor	C 21
6	II	Kilcher	C 17
7	III	Elima	C 77
8	II	Dominique	C 1
9	II	Monet	C 12
10	II	Tohante	C 10
11	I	Agbo	C 115
12	I	Yace	C 25
13	I	Dagbe	C 10

Results

Results of soil analysis are reported in Table 2 in the order of the regions previously defined (Fargette & Quénéhervé, 1988). Cumulative results of the different nematode populations extracted from soil and roots during the survey are expressed by a percentage of the whole plant parasitic nematode fauna and reflect some dynamic equilibrium (Tab. 3). This is a way of minimizing the influence of such factors as rainfall or the physiological state of the host plant in order to know the influence of the type of soil on the nematode populations.

First, one can notice that the three sites belonging to the region I are very different from the others in soil texture and organic matter content; they are located in the lagoon valley of Nieky or its surroundings which was previously occupied by a primary forest of *Mitragyna ciliata*, *Symphonia globulifera* and *Raphia* spp. on peat-moor. So, in this region, one can find all the stages from pure clay soil found in Agbo 115, to pure peaty soil found in Yace 25 or Dagbe 10.

As shown in Table 3, on these sites *Helicotylenchus multicinctus* predominates both in the soil and in the roots and it is the only region where *Radopholus similis* is rare in the roots. For homogeneity in the data, very peculiar results from these three sites, located on « organic soil », are not taken for the multivariate analysis.

On the other sites from region II and III, located on « mineral soil », *R. similis* remains rare in the soil but abundant in the roots, whatever the type of soil.

Principal component analysis was done with soil texture, pH and organic matter content data, and the percentage contribution of nematodes in the soil as supplementary variables for the ten sites located on « mineral soil ». Only the five most frequent nematode species encountered on these ten sites are taken; there are *H. multicinctus*, *Hoplolaimus pararobustus*, *R. similis*, *Cephalenchus emarginatus* and *Meloidogyne incognita*. There is no correlation between the percentage of nematodes in the soil and those obtained in the roots so only the percentage contribution of nematodes in the soil are taken here as supplementary variables. All percentages are being substituted by angular transformation (arcsine $\sqrt{x}$) for calculations.

The first four factors obtained with the principal component analysis accounted respectively for 52.2 %, 26.5 %, 16.2 % and 3.6 % of the variability for a total of 98.5 %.

Factor 1, as shown in Table 4, is negatively correlated with the content in sand and coarse sand, and positively with the silt content. Factor 2 is positively correlated with the clay content and pH. Factor 3 is negatively correlated with organic matter content and pH Diagrams 1 and 2 from Figure 1 show positions of the ten sites according to these factors and correlation of the nematodes (as supplementary variables) with these factors (Tab. 5) figured as arrows of a correlation circle (of radius 1) to have the trend of nematode population considered.

These diagrams show different trends between the population of *H. multicinctus* and those of *M. incognita*, *H. pararobustus* and, *C. emarginatus*. There is no correlation between the population of *R. similis* and these factors.

Table 2

Results of soils analysis on the thirteen sites.

Locality *Sites no.*	*Reg. I* *11*	*Reg. I* *12*	*Reg. I* *13*	*Reg. II* *2*	*Reg. II* *3*	*Reg. II* *4*	*Reg. II* *5*	*Reg. II* *6*	*Reg. II* *8*	*Reg. II* *9*	*Reg. II* *10*	*Reg. III* *1*	*Reg. III* *7*
% Clay-0-2 μm	61.2	0	12.6	7.3	15.2	12.3	9	13	24.9	14	8.6	21.7	27.1
% Silt 2-20 μm	20.3	0	9.2	10.5	8	14.2	9	16.4	4.4	6.2	7.4	26.8	23.2
% Silt 20-50 μm	0.2	0	1.2	26.3	11.8	23.1	16.6	18.7	9	10.2	20.5	23.2	26.8
% Sand 50-200 μm	0.2	0	2.9	37.2	44.6	30.8	41.5	31.3	38.9	46.2	46.7	17.5	17.7
% Sand 200-2 000 μm	0.2	0	3.1	15.5	17.5	15.4	19.4	16.6	20.7	18.5	15.7	5.5	0.5
% H2O	3	*	*	0.9	1	1.1	1.1	1.4	1	2	0.7	2.2	2
% Org. Matter	14.2	*	17.4	2.5	1.8	1.9	2.4	2.5	1.1	2.9	1.2	2.5	2.7
pF 4.2	*	*	*	4.8	8	5.7	6.3	9.8	*	*	5.1	12.2	*
pH H_2O	4	3.4	5.3	4.6	6.3	4.7	6	6	5.5	6.3	4.9	5.9	5.1
pH KCl	3.5	3	4.7	3.8	5	4.3	5.1	5.1	4.5	5.1	4.5	5.4	4.1
% Org. Matter	14.2	*	17.4	2.5	1.8	1.9	2.4	2.5	1.1	2.9	1.2	2.5	2.7
‰ C	109.5	397.3	*	14.9	10.9	14.9	14	13.6	7.8	9.5	6.6	14.9	7.3
‰ N	5.5	15.5	*	0.7	0.8	0.7	1.0	1.0	0.8	0.9	0.5	1.4	0.8
C/N	20.1	25.6	*	20.0	14.4	15.5	15.0	14.6	10.4	10.5	12.8	10.9	9.8

* Missing data

Table 3

Percentage of the whole plant parasitic nematofauna occurring in the soil and in the roots.

Locality *Sites no.*	*Reg. I* *11*	*Reg. I* *12*	*Reg. I* *13*	*Reg. II* *2*	*Reg. II* *3*	*Reg. II* *4*	*Reg. II* *5*	*Reg. II* *6*	*Reg. II* *8*	*Reg. II* *9*	*Reg. II* *10*	*Reg. III* *1*	*Reg. II* *7*
Percent in soil													
H. multicinctus	82.9	53.1	56.1	4.4	2.8	26.8	1.8	18.2	27.3	8.9	10.6	38.5	24
H. pararobustus	0.5	3.2	1.3	28.5	30.1	14.7	52.7	23.3	13.9	19.7	23.5	22.6	9.5
R. similis	2.5	2.4	2.1	9.3	4.6	7.1	12.3	11.2	12.4	7.7	8.4	7.1	17.3
C. emarginatus	14.1	39.8	27.1	51.9	61.2	38.5	27.6	35.3	46.3	58.9	42.4	30.1	23.3
P. coffeae												1.2	4.3
M. incognita				3.9	1.3	10.4	5.6	3.8		4.2	3.7		0.8
Others		1.5	11.7	2.1		2.4				0.6	11.4	0.4	20.8
Percent in roots													
H. multicinctus	87.6	92.1	90.3	1	4.5	3.7	7.4	0.2	50.7	18.2	15.1	2.2	18.1
H. pararobustus	0.5	1.7	1	32.1	18	6.8	27.1	12.7	9.6	23	16.5	16.9	5.8
R. similis	10.8	5.8	7.4	52.6	71	79.4	55.5	65.8	38.9	52	62.1	77.2	57.8
C. emarginatus	1	0.3	1.3	2.9	2.3	1.9	1.9	1.6	0.8	1.1	2.8	0.9	2.3
P. coffeae												2.8	15.5
M. incognita				11.3	4.3	8.3	8.1	19.6		5.7	3.5		0.5

Results of the stepwise multiple regression analysis are presented on Fig. 2 which shows in decreasing order of importance the percentage of variance explained by the soil variables for each nematode genus.

H. multicinctus : 87 % from the observed variance is explained by the silt content and the level of pH. Contribution of all other soil variables increased the variance up to 97.5 %.

H. pararobustus : 40.8 % from the observed variance is explained by the clay content. The other soil variables increase regularly the variance up to 85.5 %.

R. similis : In the case of *R. similis,* there is also a regular increase of the observed variance from 12.9 % to 67.9 % but it reveals no evident relation between soil factors and soil population.

Table 4

Table of correlations between soils variables and factors.

Variables	*Factor 1*	*Factor 2*	*Factor 3*	*Factor 4*
Clay	0,484	0,819	0,242	0,151
Silt 1	0,960	— 0,051	— 0,066	— 0,249
Silt 2	0,745	— 0,633	0,167	— 0,009
Sand 1	— 0,951	— 0,150	— 0,161	— 0,178
Sand 2	— 0,933	— 0,115	— 0,029	— 0,315
pH	0,081	0,725	— 0,659	— 0,118
Org. Matter	0,400	— 0,463	— 0,763	0,144

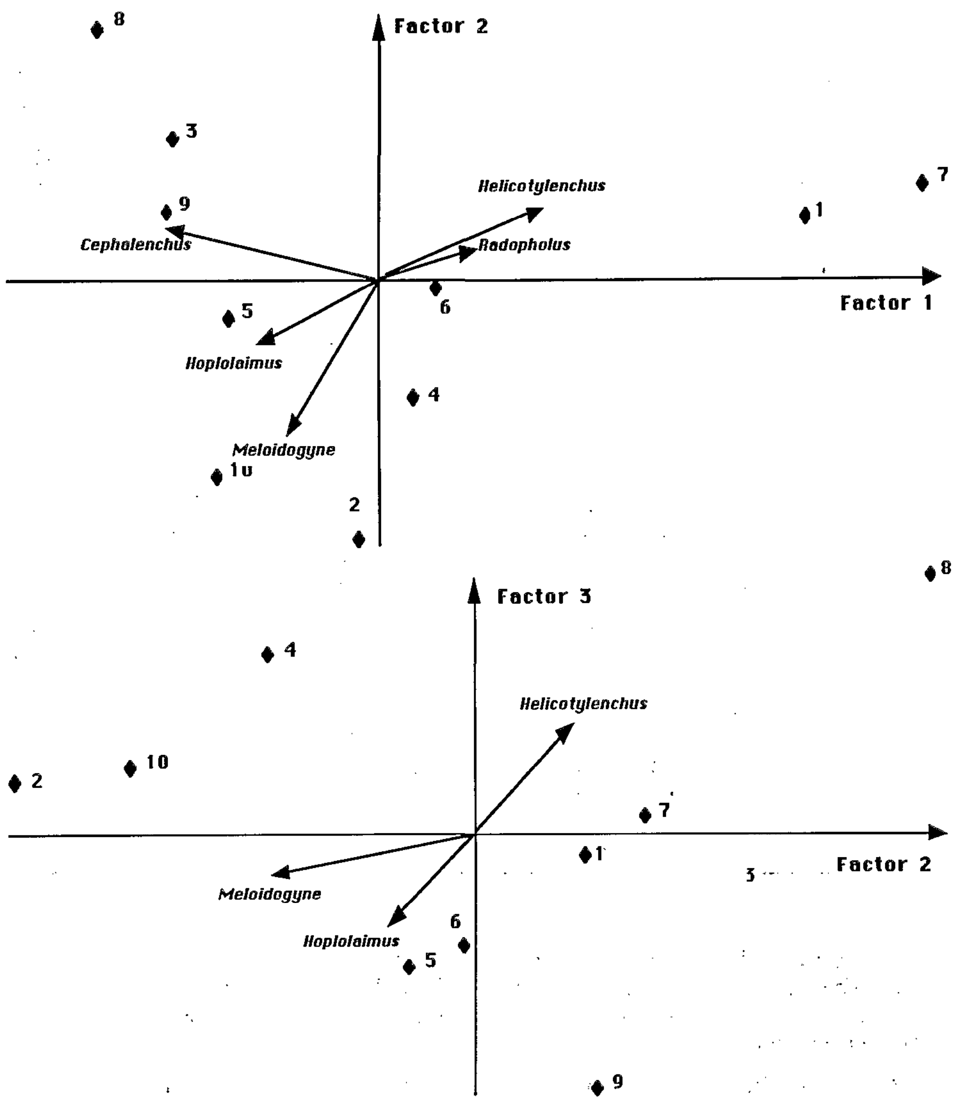

Fig. 1. Diagrams 1 & 2. Two dimensional diagrams showing the first three factors of a principal component analysis done on the results of the soil variables. Trends of the nematode genera are figured as arrow of a correlation circle of radius 1. The key for the code numbers of the sites is given in the text.

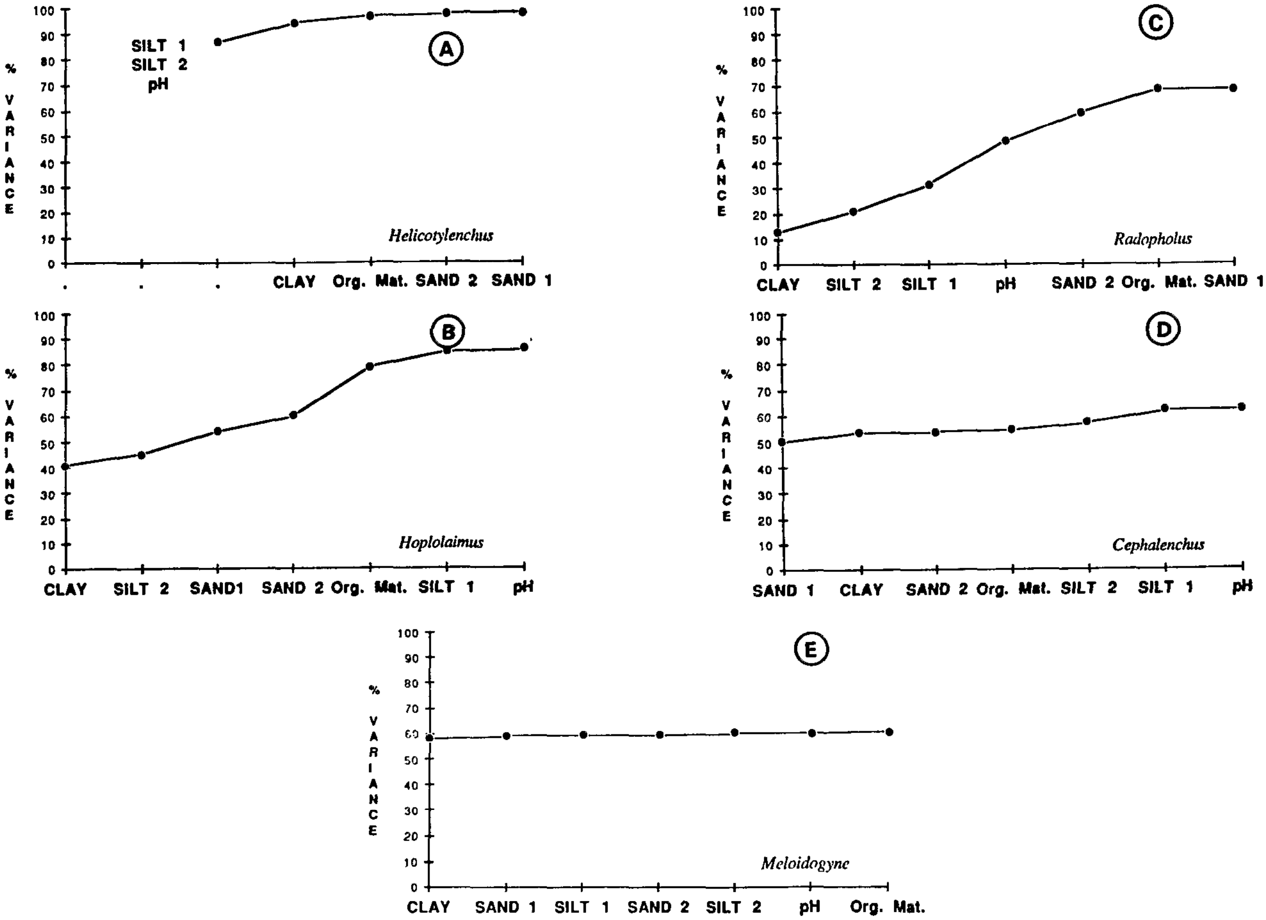

Fig. 2. (A-E). Percentage of variance explained by the soil variable for each nematode species : A-*Helicotylenchus multicinctus;* B-*Hoplolaimus pararobustus;* C-*Radopholus similis;* D-*Cephalenchus emarginatus;* E-*Meloidogyne incognita.*

C. emarginatus : The only real ectoparasite shows 50.1 % from the observed variance explained by the sand content. Contribution of all other soil variables increased the variance to 62.1 %.

M. incognita : In this case, one can notice that 58.1 % from the observed variance is explained by the clay content when the contribution of the other soil variables only increase from 58.1 % to 60.8 %.

Discussion

In the Ivory Coast, up to now the industrial plantations of banana are grown in intensive monoculture and there are no fallow or any kind of crop rotation so the nematode community structure in the soil reaches an internal equilibrium which is barely modified by uprooting and replanting banana trees.

Thus soil type may be very important for determining community composition of nematodes in the soil and roots of banana plants, though as reviewed by Ferris & Ferris (1974) and Vrain (1986), the effect of soil type on the nematode population may result from a combination of soil factors related to moisture.

The first and most important result of this study is the difference between the sites located in « organic soil » and those in « mineral soil »; in « organic soil » *H. multicinctus* is predominant in the soil and in the roots while on « mineral soil » *R. similis* remains the main endoparasitic nematode in the roots whatever the soil texture. Differences in the nematode community structure occur only in the soil; *R. similis* is the only nematode not affected by the soil variables, possibly because it is a strict endoparasite with a very restricted temporary soil phase.

H. multicinctus, unlike *M. incognita*, shows some affinities with soil with a high level of clay, silt, organic matter and low pH. These results from the multivariate analysis, confirm the observations made in the « organic soil » (Tab. 3) where *H. multicinctus* is predominant.

Table 5

Table of correlations between supplementary variables (percentage of the different nematode species in soil) and factors.

Variables	*Factor 1*	*Factor 2*	*Factor 3*	*Factor 4*
H. multicinctus	0,574	0,312	0,454	— 0,149
H. pararobustus	— 0,380	— 0,291	— 0,452	— 0,361
R. similis	0,358	0,141	0,115	0,290
C. emarginatus	— 0,698	— 0,040	— 0,085	0,164
M. incognita	— 0,272	— 0,677	— 0,202	— 0,115

H. pararobustus and mostly *M. incognita* prefer sandy soils with a low level of clay. *C. emarginatus*, a strict ectoparasite which feeds on the root system without entering them, shows affinities with sandy clay soils.

In the soil texture the clay content, which can affect the levels of soil moisture, appears here as the most important and determining factor acting upon the nematode community structure.

Soil pH seems here to have a slight effect on *H. multicinctus* and *M. incognita,* though as reported by Norton (1979), numerous data suggest that soil pH unless at an extreme low or high levels has no adverse effect on nematodes.

The structure of nematode communities in organic soil is determined not only by the organic matter content but also by the activities of other microorganisms. These activities may result in the production of toxins and/or other unknown by-products which are detrimental to some plant parasitic nematodes (Hollis & Rodriguez-Kabana, 1966; Norton, 1979; Vrain, 1986).

That subject merits further investigation to explain the biological equilibrium and to attempt to control nematodes in that type of soil.

As well reviewed by McSorley and Parrado (1986), *H. multicinctus* and *R. similis* often occur together on bananas and plantains in tropical regions offering the best conditions of growth for the production of these crops. Vilardebó and Guérout (1976) say that high population of *H. multicinctus* tend to build up when *R. similis* is locally absent. In our survey, on « organic soil », even if *H. multicinctus* act as secondary parasites in the roots behind *R. similis,* this nematode is able to build up a higher population and to become exclusive parasites, may be for reasons previously discussed.

The knowledge of the soil type appears essential, not only for its close relationship with the nematode fauna but also for the control of the parasites, many nematicides and particularly organophosphates are less effective on organic soils than on mineral soil (Whitehead *et al.,* 1973*a,b).* But another problem appears in the Ivory Coast where on old plantations located on « organic soil » frequent and regular applications of systemic nematicide are not followed by a significant increase of the bunch harvest as on mineral soil, in spite of the apparent control of the infestation of the roots by *R. similis.* Indeed the pressure of *H. multicinctus* inoculum in soil is so strong that only flooding or a long fallow break which does not allow for an increase of *H. multicinctus* or a fumigation of the soil before new banana planting, may have an effect on the nematode fauna and correlatively on the bunch harvest.

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