Tylenchids (Nematoda) extracted from soil of Swiss vineyards north of the Alps(1)

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SUMMARY

Thirty-one plant-parasitic nematode species were extracted from 82 Swiss vineyards. *Criconemella xenoplax* was found to be the most frequent species, followed by *Zygotylenchus guevarai, Helicotylenchus digonicus, H. vulgaris* and *Paratylenchus baldaccii. Merlinius microdorus* was associated with *Rotylenchus fallorobustus* or with *Criconemella antipolitana* more frequently than expected. The vineyards could be divided in two groups according to the relative abundance of *C. xenoplax.* The group with the lowest relative abundances had large numbers of species and high diversity indices, the other group had low numbers of species and low diversity indices. The species distribution was analysed taking into account several vineyard characteristics like soil type, pH, weed cover, local precipitation and steepness of the terrain. Some of these characteristics seem to influence the abundance of the following species : *H. vulgaris, Z. guevarai, Paratylenchus peraticus, C. antipolitana* and *C. xenoplax.* Because of their relatively high abundance, only *C. xenoplax* was considered to be potentially harmful to vines.

RÉSUMÉ

Tylenchides (Nématoda) extraits du sol des vignobles suisses du nord des Alpes

Les échantillons de sol prélevés dans 82 vignobles ont révélé l'existence de 31 espèces de nématodes. *Criconemella xenoplax* était la plus fréquente, suivie de *Zygotylenchus guevarai, Helicotylenchus digonicus, H. vulgaris* et *Paratylenchus baldaccii.* Les espèces *Merlinius microdorus* et *Rotylenchus fallorobustus* étaient plus fréquemment associées que les calculs statistiques pouvaient le laisser supposer. Le même phénomène a été observé pour *M. microdorus* et *Criconemella antipolitana.* Les vignobles ont pu être divisés en deux groupes suivant l'abondance relative de *C. xenoplax;* dans les vignobles où cette abondance était réduite, les espèces du complexe étaient nombreuses et les indices de diversité élevés; en revanche, là où l'abondance de *C. xenoplax* était élevée, les espèces du complexe étaient moins nombreuses et les indices de diversité plus faibles. La répartition des espèces a été analysée en fonction de quelques caractéristiques des vignobles, à savoir : type de sol, pH, mauvaises herbes, précipitations locales et pente des vignobles. Quelques-unes de ces caractéristiques semblent avoir une influence sur la fréquence de *H. vulgaris, Z. guevarai, Paratylenchus peraticus, C. antipolitana* et *C. xenoplax.* Dû à son abondance, *C. xenoplax* est considéré comme le seul ravageur qui pourrait être dangereux pour les vignes suisses au nord des Alpes.

European records of tylenchids associated with vineyards are rather rare. The first list of fifteen species was published by Goodey, Franklin and Hooper (1965), who considered them as parasites of the vine. Other lists followed (Palmisano, 1970; Arias & Navacerrada, 1976; Mancini & Moretti, 1976; Mancini *et al.*, 1980; Liskova, 1978, 1980; Katalan-Gateva, 1980). Some authors, like Weischer (1961), did not identify their fauna beyond the genus level or, like Menzel (1941), referred to a single species.

The main purpose of this paper is to improve the knowledge on the tylenchids living in the soil of European vineyards. Emphasis is placed on their distribution and abundance. The influence of soil type, weather, agronomic practices and slope is also considered for the most common species.

Material and methods

ORIGIN OF THE MATERIAL AND SAMPLING

One soil sample was taken from each of the 82 vineyards considered (Fig. 1). A soil sample consisted of seven soil cores taken at random by means of an electric borer (« Humax », Lucerne) and mixed together. Each soil core had a length (depth) of 50 cm and a diameter of 5 cm. In stony soils, cores were taken by hand. Vineyards were at least ten years old.

EXTRACTION, PREPARATION AND COUNTING OF THE NEMATODES

The nematodes were extracted within four weeks. A subsample of 600 cm^3 was taken from each sample and

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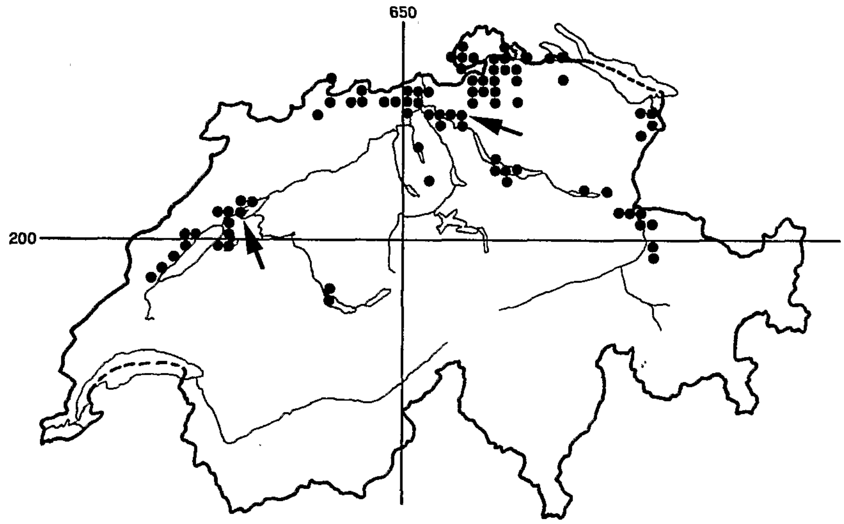

Fig. 1. Distribution of the investigated 82 vineyards. *Criconemella xenoplax* was found everywhere except for two places marked by an arrow.

suspended subsequently following a method by Bieri and Delucchi (1980). From the suspension, an equivalent of 200 cm^3 of soil was processed using the centrifugal method. For further concentration, the suspension was treated according to the method developed by Güntzel (1981). Then the nematodes were transferred to a 4 ml pill-glass before getting killed and fixed. For identification the nematodes were first resuspended in water and then poured into a round counting dish (Doncaster, 1962). Single nematodes were picked up under a microscope (with a prisma adapter to avoid side invertedness). Then they were transferred to glycerol and mounted on slides. After identification, the nematodes were counted under the mentioned microscope.

Characterization of sampling sites

The organic matter content of the soil was determined by wet oxidation with K-bichromate. The distribution of the soil particles was investigated by Dr. F. Jaeggli (Federal Research Station of Agronomy, Zuerich-Reckenholz) according to the sedimentation principle. Steepness of the vineyards slopes and the altitude of the locality was estimated from maps. Mean precipitations were obtained from the " Atlas der Schweiz " (Eidg. Landestopographie, Wabern, 1965-1978). The presence of weeds in the vineyards was estimated as follows : no weeds = 1, some patches of weeds = 2, soil nearly covered by weeds = 3. The soil pH values of all soils fell within a narrow range ($x \pm s.e.m. = 7.8 \pm 0.02$).

Data analysis

To characterize nematode communities, the total numbers of females and of collected species were used. The diversity index was calculated after Shannon-Wiener, from which the relative index of diversity was derived.

The relationship between pairs of species, i.e. the probability of their common occurrence or exclusion, was analysed by the χ^2 test of 2 × 2 contingency tables (Zar, 1974).

Because of the considerable variation in the data, only species occurring in at least ten vineyards were considered for statistical analysis. Data on abundance usually refer to adults only, as larvae could not be identified to species level. For bisexual species the total of males and females is given, except for *Paratylenchus baldacci* (the males of which cannot be separated from those of other congeneric species; only females counted) and for *Rotylenchulus borealis* (the females of which are sedentary; only males counted).

For analysis of variance (ANOVA) as well as for multiple regression analysis some of the data were transformed : the numbers of individuals were log-transformed (Noe, Barker & Smith, 1981; McSorley, 1982) and an angular transformation was applied to percentages (relative abundance, % of sand, etc.). For ANOVA, relative abundances were weighed ($w = \sqrt{n}$, n = number of individuals). Furthermore, if the dependent variable in a regression analysis was the relative abundance of a species, this variable was transformed according to the logit-prescription (Linder & Berchtold, 1976), and the sites weighed according to the number of adults (e.g. weight 10 = 10 adults at this particular site).

Results and discussion

FREQUENCY AND ABUNDANCE OF THE SPECIES

Thirty-one species of nematodes belonging to 15 genera were recorded in 82 vineyards. Eleven species occured in at least 10 vineyards; the frequency distribution of their abundance is shown in Figure 2. Species recorded in less than ten vineyards are listed in Table 1.

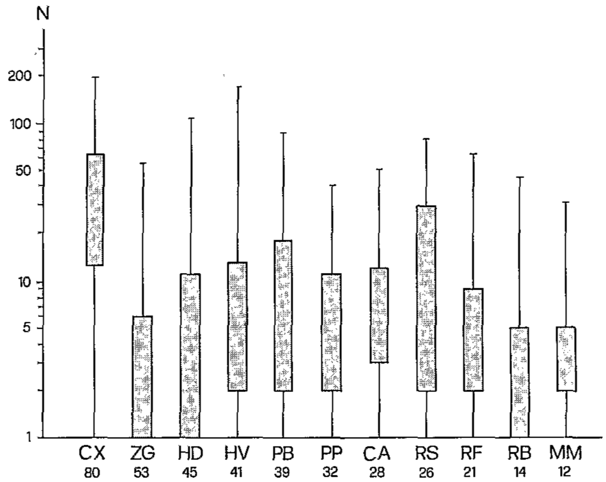

Fig. 2. Frequency distribution of the abundance of the most common species. Thick bars indicate the abundance of 50 % of the vineyards where the species were found (CX = *Criconemalla xenoplax;* ZG = *Zygotylenchus guevarai;* HG = *Helicotylenchus digonicus;* HV = *H. vulgaris;* PB = *Paratylenchus baldacii;* PP = *P. peraticus;* CA = *Criconemella antipolitana;* RS = *Rotylenchulus borealis;* RF = *Rotylenchus fallorobustus;* RB = *R. buxophilus;* MM = *Merlinius microdorus;* N = number of adults per 100 mm^3 soil; figures on abscissa = frequency).

In 50 % of the vineyards the numbers of adults per 100 cm^3 of soil ranged between 37 and 117, and the numbers of species between 4 and 7. The relative abundance of a particular species was generally low. Only in one third of the vineyards the relative abundance was above 7 % for the following species : *Zygotylenchus guevarai, Helicotylenchus vulgaris, Rotylenchulus borealis, Paratylenchus peraticus, Criconemella antipolitana* and *C. xenoplax.*

The geographical distribution of the species did not reveal any particular tendency. Some species were extremely rare or absent from the Canton Graubünden and the adjacent area of the Walensee (eastern part of Switzerland) : *H. vulgaris, R. borealis, Z. guevarai* and *P. peraticus* (Fig. 3). All these species exhibit some relationships to measured ecological factors (see below). *Rotylenchus buxophilus* was rarely observed in the Jura

Table 1

List of species, found in the soil of less than ten vineyards examined. The numbers on the right hand side indicate the frequency of the findings.

Tylenchorhynchus dubius (Bütschli, 1873) Filipjev, 1936	6
Nagelus " *leptus* " (Allen, 1955) Siddiqi, 1979	1
Amplimerlinius macrurus (Goodey, 1932) Siddiqi, 1976	5
Trophurus sculptus Loof, 1956	2
Macrotrophurus arbusticola Loof, 1958	5
Helicotylenchus pseudorobustus (Steiner, 1914) Golden, 1956	2
Rotylenchus pumilus (Perry, 1959) Sher, 1961	1
Rotylenchus sp.	4
Pratylenchus crenatus Loof, 1960	2
P. neglectus (Rensch, 1924) Filipjev & Sch. Stekh., 1941	2
P. pseudopratensis Seinhorst, 1968	1
P. thornei Sher & Allen, 1953	3
Paratylenchus projectus Jenkins, 1956	5
P. italiensis Raski, 1975	3
P. goodeyi Oostenbrink, 1953	1
P. macrodorus Brzeski, 1963	9
Criconemella rustica (Micoletzky, 1915) Luc & Raski, 1981	1
C. vadensis (Loof, 1964) De Grisse & Loof, 1965	5
C. informis (Micoletzky, 1922) Luc & Raski, 1981	6
Hemicycliophora thienemanni (Schneider, 1925) Loos, 1948	1

region were many samples were taken (Fig. 3, E). In Figure 4 the frequency distributions of the vineyards characteristics are summarized. The frequency distributions of the relative abundance of the most common species, *Criconemella xenoplax,* shows two distinct peaks (Fig. 5). This indicates the existence of two groups of vineyards with different characteristics. The vineyards where the relative abundance of the species is below 55 % are characterized by higher numbers of species as well as higher values of absolute and relative indices of diversity ($P \leqslant 0.001$). Moreover, in this group of vineyards the absolute and relative abundances of *C. antipolitana* and of *Helicotylenchus vulgaris* were found to be higher ($P \leqslant 0.001$) than in the other group. To a lesser degree the same holds true for *P. peraticus, Merlinius microdorus, H. digonicus* and *Z. guevarai* (all : $P \leqslant 0.05$). In some regions of the sampled area, the indices of diversity show that the vineyards of each of the above mentioned two groups are geographically connected. No significant coincidence of their distribution with measured ecological factors was observed.

RELATIONSHIPS BETWEEN PAIRS OF SPECIES

No interdependence of the abundances of any two species could be found. However, *Merlinius microdorus* was observed more frequently than expected in association with *Rotylenchus fallorobustus* as well as with *Cri-*

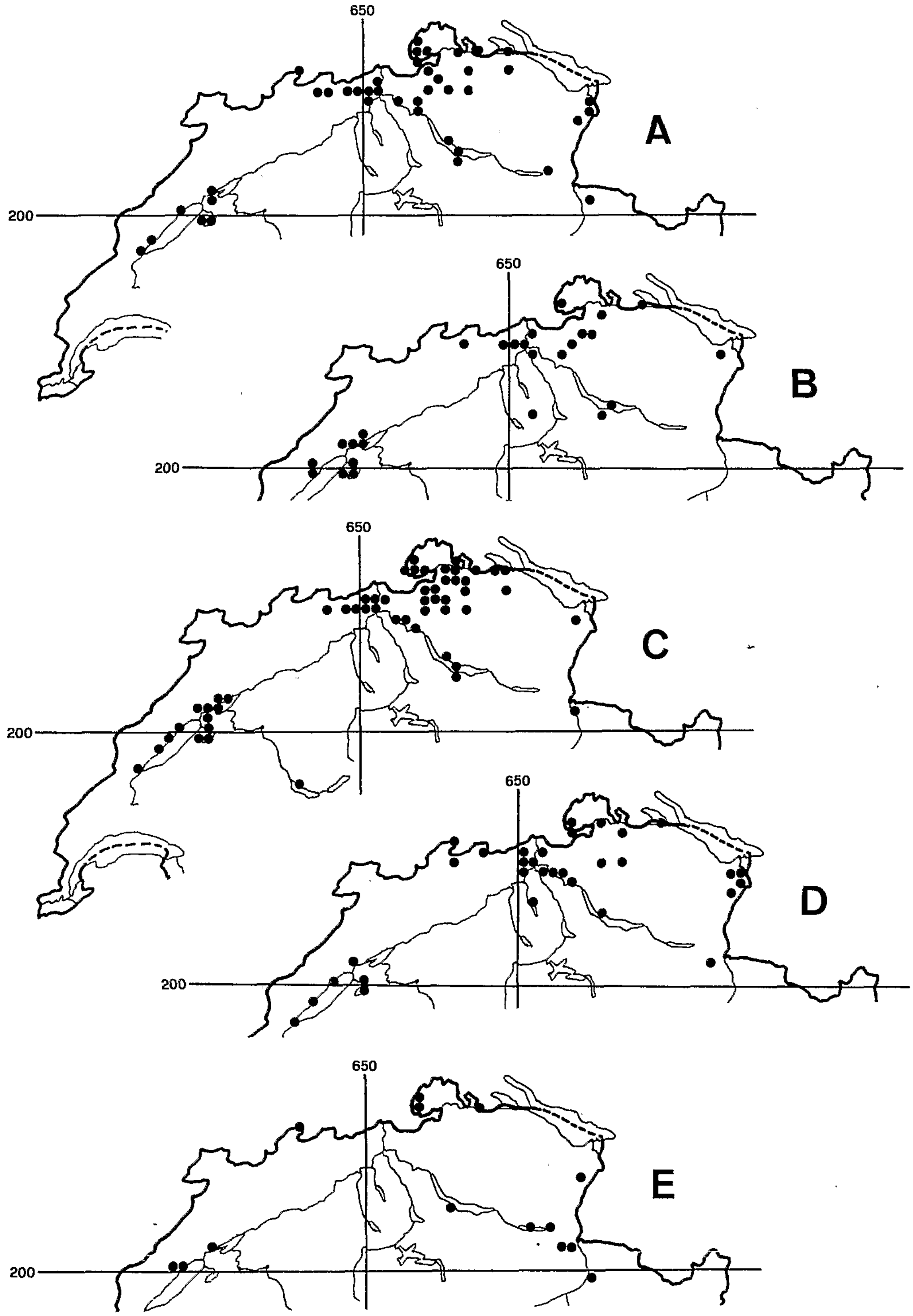

Fig. 3. Records of *Helicotylenchus vulgaris* (A), *Rotylenchulus borealis* (B), *Zygotylenchus guevarai* (C), *Paratylenchus peraticus* (D), and *Rotylenchus buxophilus* (E).

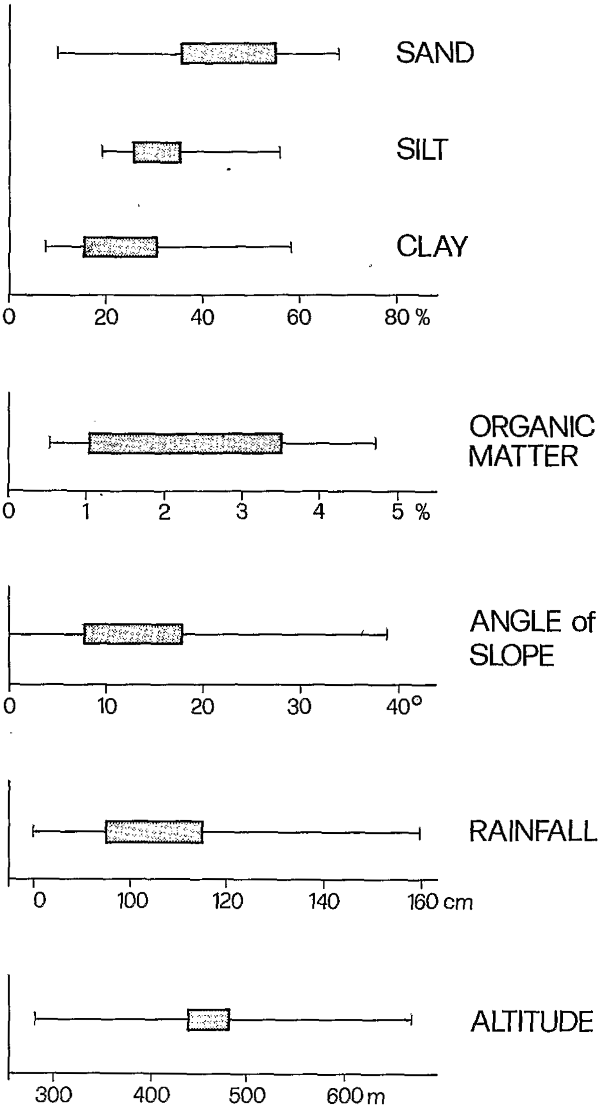

Fig. 4. Frequency distribution of the measured ecological factors. The thick bars indicate the values corresponding to 50 % of the vineyards around the mean.

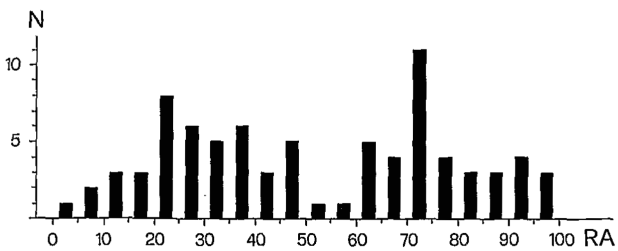

Fig. 5. Frequency distribution of the relative abundance (RA) of *Criconemella xenoplax* (N = number of findings).

conemella antipolitana (P ⩽ 0.001). These results do not indicate the nature of the association, which was tested by forming three classes of vineyards, i.e. two classes having one of the associated species alone and a third class of vineyards having two species present. The ANOVA did not reveal the existence of a measured ecological factor favoring the species. It is concluded that the association of the species might indicate differences in the preference for microhabitats and in feeding behaviour, thereby reducing competition for food supply. In fact, the morphology of the associated species is very different.

RELATIONSHIPS BETWEEN SPECIES AND MEASURED ECOLOGICAL FACTORS

Assuming normal distribution, the following relationships are all significant at the 5 % level or below. However, the correlation coefficients are not indicated because of the considerable variance in the data.

Helicotylenchus vulgaris : By considering the vineyards with no other species of the same genus, the numbers of the larvae could also be included in a multiple regression analysis. The results obtained indicate that highest numbers of adults and larvae are to be expected in vineyards with highest rainfall, highest organic matter content, highest altitude, and lowest inclination (in decreasing order of importance). Thus, 65 % of the total variance could be explained. All of the mentioned characteristics are somehow related to soil moisture : the higher the moisture content, the more abundant the species. This finding agrees well with the observation that *H. vulgaris* was mainly found in soils with higher contents of clay, i.e. in soils with a high capacity for water retention (P ⩽ 0.05).

Zygotylenchus guevarai : The number of adults and larvae, and the percentage of silt in the soil were positively correlated (Fig. 6). As the species is small, this correlation might also prove the existence of a relationship between available pore space and reproduction rate.

Paratylenchus peraticus and *Criconemella antipolitana* : The absolute and relative abundance of *P. peraticus* in vineyards free of weeds (class 1) was higher than in vineyards with some weeds (class 2) (Fig. 7 A for relative abundance). *C. antipolitana* was found to behave in the opposite way whereby only the relative abundance was concerned (Fig. 7 B).

Criconemella xenoplax : The total number of females and larvae decreased with increasing amount of clay (Fig. 8) in vineyards where no other congeneric species were present. In clay soils, where pores are small, this species seems to be hindered in its movements. This result is in agreement with Seshadri (1964) who found

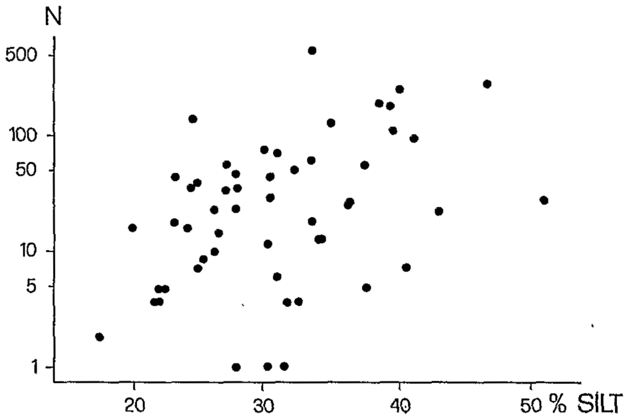

Fig. 6. Relationship between abundance of *Zygotylenchus guevarai* (N = adults + larvae, per 100 cm³ of soil) and amount of silt.

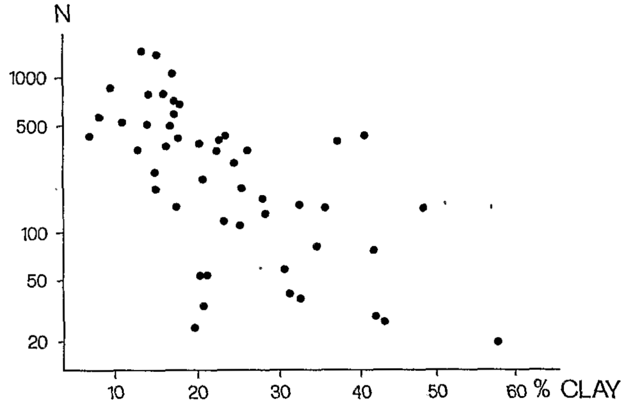

Fig. 8. Relationship between abundance of *Criconemella xenoplax* (N = adults + larvae, per 100 cm³ of soil) and amount of clay.

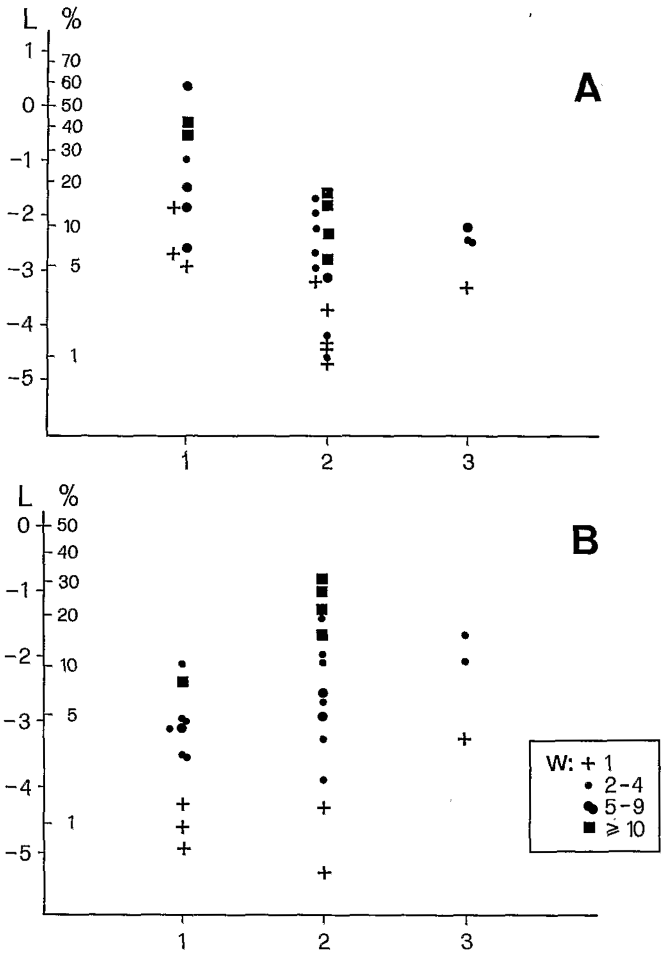

Fig. 7. Relationship between weed occurrence and relative abundance of *Paratylenchus peraticus* (A) (1 to 3 on abscissa = weed free (1), some patches of weed (2), surface nearly covered by weed (3), L = logits; W = weighting of the vineyards is indicated by different symbols).

a maximal reproduction rate in sandy soils. The species is highly sclerotized and quite sluggish.

Helicotylenchus digonicus mainly occurred in vineyards with higher contents of sand ($P \leqslant 0.05$). In contrast to this, Norton (1978) states that *H. digonicus* prefers heavy soils.

The absolute and relative abundance of *Rotylenchus fallorobustus* tended to increase at sites with high contents of silt and sand. Commonly, in such soils many big pores exist which might favor the propagation of this big species. The results are in contradiction with Norton (1978) who reported that *R. fallorobustus* does not prefer any particular soil type. With the data from vineyards where no other *Rotylenchus* species were found, a multiple regression analysis was carried out : in vineyards with high precipitation, situated on steep slopes and covered with weeds, highest numbers of adults and larvae were recorded (factors, in decreasing order of importance). With the equation obtained, 83 % of the total variance was explained.

Finally, the small species *Rotylenchulus borealis* was more abundant in soils containing more silt ($P \leqslant 0.05$).

Discussion of the damage potential

The distribution of the abundance of seven species is presented (Fig. 9). *Criconemella xenoplax* was the most abundant and was found in all vineyards except for 2. Its potential pathogenecity on vines is well known (for Europe : Weischer, 1961; Klingler & Gerber, 1972; Klinger, 1975; Ambrogioni, 1981). *Paratylenchus baldaccii* was found in 50 % of the vineyards; generally, its abundance was much lower than that of *C. xenoplax*. The species was first discovered in a vineyard in Sicily (Raski, 1975), but its pathogenicity remains unknown. It might be regarded as potentially harmful to the vine.

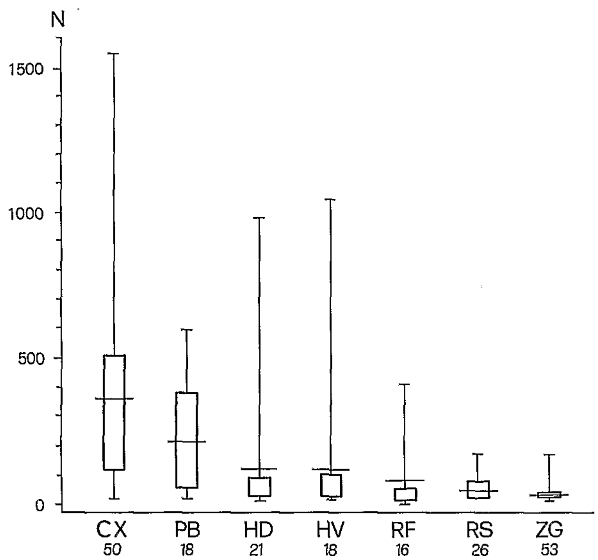

Fig. 9. Frequency distribution of the abundance of adults and larvae of seven species. Within the range of the thick bars half of the sites are located, and mean values are indicated by a crossline (CX = *Criconemella xenoplax;* PB = *Paratylenchus baldacii;* HD = *Helicotylenchus digonicus;* RF = *Rotylenchus fallorobustus;* RS = *Rotylenchulus borealis;* ZG = *Zygotylenchus guevarai* (N = number of adults and larvae per 100 cm^3 soil).

Both *H. digonicus* and *H. vularis* were rather rare except in one vineyard; together with *R. fallorobustus, R. borealis* and *Z. guevarai* they are in general not considered harmful. *Z. guevarai* was found in about two thirds of the vineyards. Its high frequency, together with its low abundance, could mean that his species is well adapted to the vine.

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