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CHANGES IN NEMATODE COMMUNITIES OF FOREST SOIL IN RELATION TO CLEAR-CUTTING

by

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Summary. The nematode community of a forest soil on the volcano Etna (Italy) was studied from a faunistic and ecological point of view in order to verify how and to what extent its structure is affected from moderate clear-cutting due to the forest management. Sampling was made in three contiguous areas of the forest, one in almost natural conditions, another subject to clear-cutting and a third one completely cleared. A qualitative and quantitative analysis of the nematode communities of the three stations was undertaken, including diversity index, maturity index, trophic groups and the frequencies of some taxa. The data obtained showed that moderate clear-cutting caused some remarkable variations in the nematode community structure: decrease of the biodiversity, disturbance of the dominance relationships between species, decrease or disappearance of the most fragile taxa, appearance or increase of taxa typical of open environment, increase of plant feeders, demographic outburst of a single species, *Tylencholaimus mirabilis*, which might be considered as an indicator of forest soil disturbance.

In the last three decades an increasing number of papers on nematode community structure analyses in relation to environmental changes or disturbance has shown that nematodes can be used as indicators of changes in soil quality (Freckman, 1988; Bongers, 1990; Wasilewska, 1991; Linden *et al.*, 1994), both because they increase nutrient turnover and indirectly influence decomposition through their feeding on microbial decomposers and because some species may be very sensitive to disturbances of various type. Moreover, they occur everywhere, are easily isolated, counted and identified (Bassus, 1968; Sohlenius and Wasilewska, 1984; Wasilewska, 1989; Freckman and Ettema, 1993; Ettema and Bongers, 1993; de Goede and Decker, 1993; Yeates and Bird, 1994; Yeates, 1995). The analyses of the communities are based on numbers or biomass, diversity, trophic groups, species composition and life histories and refer to several kinds of environmental modifications due either to human intervention or to natural changes as ecosystems dynamics, successions, etc. The aim of the research described here was to test whether ecosystem parameters based on the nematode community are influenced by different degrees of clear-cutting due to forest management.

Sohlenius (1997) studied the dynamics of a nematode population of a pine forest by yearly sampling during two periods after the clear-cutting, obtaining contradictory results. In our study two contiguous areas of the same forest, one of which had undergone periodical clear-cutting while the other was in an almost natural condition, were compared simultaneously with a completely cleared area.

Materials and methods

The selected site was a mixed forest with pine, oak, beech and birch trees (*Pinus laricio* Poiret, *Quercus cerris* L., *Fagus sylvatica* L., *Betula aetnensis* Raf.) on the eastern slopes of the volcano Etna (Italy), at about 1500 m above sea level. The ground vegetation included *Festuca circummediterranea* Patzke, *Segale strictum* (Presle) Stroble, *Vicia cassubica* L. Sampling was made in three contiguous areas of the forest, one where the tree covering was thicker, another where some clear-cutting had thinned the forest, reducing the soil protection from the erosion caused by flooding, and a third one completely cleared. The soil mineral component was volcanic sand, pH 6.10-6.30. Sampling was undertaken in the uncut forest among oak trees (soil with deep litter and gramineae), in the cut forest among oak and birch trees (soil with sparse litter and gramineae) and in the cleared area near a low tuft of *Vicia cassubica* (soil covered with transported oak litter). In each of the three stations two samples (in order to reduce casualness effect in sampling) of organic layer (litter, F, H) where taken on July 1996 by means of a steel square soil corer (side 4.5 cm) to a depth of 8 cm, after removing loose leaves. The two samples were not contiguous, but taken in comparable sites. Each sample was divided into four sub-samples 2 cm thick.

After the sub-samples were washed and centrifugated, up to 100 nematodes were extracted at random from each sub-sample using a steel needle; subsequently, the sub-sample was diluted in 400 ml of water and mechanically shaken; from this suspension three aliquots of 8 ml were separated and all the specimens were extracted, fixed in 4% formalin, processed to anhydrous glycerol and mounted on slides for identification to species level. The three aliquots also allowed the estimation of the total number of nematodes in each sub-sample. The numbers of the two equivalent sub-samples of each station were summed and the ecological analysis was conducted on the total.

The nematode community was studied from a faunal and ecological point of view. A qualitative and quantitative analysis was made and some ecological indexes were calculated, such as Shannon and Weaver (1949) diversity index (DI), evennes (E), species richness (SR), maturity index (MI) and plant parasites index (PPI), the last two according to Bongers, 1990. The relative frequencies of the nematode trophic groups (according to Yeates *et al.*, 1993) and of some taxa were also analysed.

Results

In Table I the species composition per subsample (A-D from the soil surface) in each station is shown. In Table II total numbers of species and specimens, DI, E, SR, MI (calculated both with and without plant parasites nematodes), PPI and PPI/MI ratio in the three stations are given: the species number decreased from the uncut to the cut forest and, more markedly, in the clearing, while the total abundance was much lower in the uncut forest than in the two other stations. The diversity index had the highest value in the uncut forest and the minimum value in the cut one. This very low value was partly due to the decrease in the species number but also to the uneven distribution of the specimens per species of this station, as shown also by the evenness values. Otherwise, the specific richness, which was related only to the total number of species and specimens of each station, reached its maximum in the uncut forest and the lowest value in the clearing. Thus, the uncut forest had both the highest number of species and the most regular dominance relationship between species.

The MI, calculated with the inclusion of plant parasites according to the views of Yeates (1994) and Wasilewska (1994), showed much higher values in both forest stations than in the cleared area. Otherwise, when the MI was calculated without plant parasites according to the views of Bongers (1990) and Bongers *et al.*, 1997, and the PPI was calculated separately, there were no significant differences between the three stations.

The analysis of the trophic groups (Fig. 1), limited to the four most frequently represented feeding types (bacterial feeders, hyphal feeders, predators and plant feeders), showed that they had a balanced distribution in the uncut forest, with a high percentage of bacterial feeders (related to the high rate of organic matter decomposition processes) and of predators (K strategists at the top of the alimentary net needing highly stable environmental conditions). There were low percentages of plant feeders, which are rarely dominant under semi-natural conditions (Bongers, 1985, Freckman and Ettema, 1993, Yeates and Bird, 1994); the percentage of hyphal feeders was rather lower than those of predators and bacterial feeders. In the cut forest and in the clearing the relative frequencies of the trophic groups had similar trends, but different from those of the uncut forest: predators decreased markedly (from 33 to 7%); bacterial feeders also decreased although to a lesser extent, while plant feeders and mainly hyphal feeders largely increased in numbers. Since it was difficult to understand this abnormal increase of hyphal feeders, the relative frequencies of the trophic groups based on species instead of specimens numbers was also calculated in the two forest stations. It was noted that while for the other trophic groups the number of species followed the same trend as the number of specimens, in the case of hyphal feeders the number of species showed an opposite trend, being lower in the cut than in the uncut forest. In this case, however, the high increase of hyphal feeders was only due to the demographic explosion of a single species, *Tylencholaimus mirabilis* (Bütschli, 1873), which represented the 94% of the whole feeding group. This species increased from 17% of the whole nematode population in the uncut forest to 53% in the cut forest.

Examination of the relative frequencies of Dorylaimida in the forest stations showed that there were 52.4% in the uncut forest, which increased to 62.4% in the cut forest. Otherwise, when *T. mirabilis* was not considered, their percentage decreased from 35.2% in the uncut forest to 9.4% in the cut forest.

The presence-absence and the relative abundance of the most significant species of nematodes in the two forest stations were also analysed. In the uncut forest there were eight species (Table III), most of which were present with several specimens, which were completely lacking in the cut forest. *Bastiania gracilis* de Man, 1876 is a rare species always found with very few individuals, *Bunonema richtersi* Jägerskiöld, 1905 and *Odontolaimus chlorurus* de Man, 1880 are also rather uncommon species and *Plectus cirratus* Bastian, 1865 is typical of forest soil. In the cut forest there were two species not found in the uncut one, *Filenchus* sp. 2 and *Trichodorus sparsus* Szczygiel, 1968, which were also present in large numbers in the clearing. Some other species, such as *Coomansus parvus* (de Man, 1880) and *Aporcelaimellus efficiens* (Cobb in Thorne et Swanger, 1936), both predators, were more abundant in the uncut forest. On the contrary, *Filenchus* sp. 1 and *Cervidellus serratus* (Thorne, 1925), typical colonisers with low c-p values, were more abundant in the cut forest; they were also well represented in the clearing.

Discussion

In comparing the three sites, which were natural environments where the disturbance factor was not an increase in nutrients, the MI gave better results when plant parasites were included: in this case there were much higher values in both forest stations than in the clearing, as was to be expected since forest is a more stable ecosystem, nearer to climax condition than the clearing. Moreover, comparison between uncut

TABLE I - *List of the species and percent of specimens in the three stations per layer* (A = 0-2 cm; B = 2-4 cm; C = 4-6 cm; D = 6-8 cm).

Species	Uncut forest				Cut forest				Clearing			
	A	B	C	D	A	B	C	D	A	B	C	D
Achromadora terricola (de Man, 1880)	1.2	3.9	1.3	1.0	0.4			0.9				
Acrobeles ciliatus Linstow, 1877		6.7	4.8	2.0		0.7	1.0	0.3	1.2		3.8	0.9
Alaimus sp.	4.8	6.1	4.4	7.0								
Alaimus mucronatus Altherr, 1950	0.6	1.1	0.4		0.8	1.8	0.6	1.2		2.2	3.2	0.9
Aphelenchoides parietinus Bastian, 1865	7.7				0.4	0.4			5.0	0.9	0.9	0.4
Aporcelaimellus amylovorus (Thorne et Swanger, 1936)		7.3	0.4									
Aporcelaimellus efficiens (Cobb in Thorne et Swanger, 1936)	25.6	9.5	20.1	17.6	2.3		2.3	6.9	3.1	4.0	3.7	1.3
Aporcelaimellus obtusicaudatus (Bastian, 1865)		0.6	1.3	0.5	1.0	0.4	0.3				1.0	
Bastiania gracilis de Man, 1876				1.0								
Bunonema richtersi Jägerskiöld, 1905	8.3	1.7										
Cephalobus thermophilus Meyl, 1953	0.6	1.1	0.9	1.5	1.5	2.9	0.3	0.9	2.8	1.3	0.6	1.7
Ceratoplectus armatus (Bütschli, 1873)								0.3				
Cervidellus serratus (Thorne, 1925)	3.0	12.8	7.0	4.0	1.2	17.9	12.7	12.7	4.1	4.0	4.6	7.3
Coomansus parvus (de Man, 1880)	13.7	8.4	8.3	10.0	1.5	0.7	1.3	0.9				
Cylindrolaimus communis de Man, 1880	0.6					0.4		0.3				
Discolaimoides symmetricus Das *et al.*, 1969										2.2	2.6	3.4
Discolaimus paramajor Coomans, 1966					0.8	0.7	0.6			0.9		
Ditylenchus sp. 1									1.9	10.3	11.0	3.9
Ditylenchus sp. 2		0.6							0.3			
Domorganus sp.											0.3	
Drilocephalobus moldavicus Lisetzkaya, 1968			0.4									
Epidorylaimus sp.		1.1		0.5								
Eudorylaimus brevis (Altherr, 1952)		0.6								0.4		
Eumonhystera simplex de Man, 1880	0.6					0.4						
Filenchus sp. 1	7.7			1.0	15.8	6.4	3.9	11.2	16.3	12.0	7.2	6.9
Filenchus sp. 2					1.5	0.4		3.6	5.6	3.1	4.3	2.6
Filenchus sp. 3						0.4						
Geomonhystera villosa (Bütschli, 1873)			0.4		5.4	0.7	0.3					
Haliplectus leptocephalus Vinciguerra et Zullini, 1980									0.3	0.4		
Helicotylenchus sp.										0.4	0.3	
Lelenchus sp.							2.6					
Longidorella frontiniani (Dalmasso, 1966)	0.6	3.4	2.2	4.0	1.2		0.6		0.3	0.4	0.3	0.4
Longidorus sp.						0.4	0.3	1.2				

TABLE I - *Continued.*

Species	Uncut forest				Cut forest				Clearing			
	A	B	C	D	A	B	C	D	A	B	C	D
Metateratocephalus crassidens (de Man, 1880)	4.8		1.7									
Microdorylaimus longicollis (Brzeski, 1964)				0.5	0.4	1.1	1.3	2.4	1.2	1.3	1.4	1.3
Neopsilenchus sp.								1.5				
Nygolaimus sp. 1	0.6	1.1	0.9		0.4	0.4	1.3	7.1		0.4	1.4	3.4
Nygolaimus sp. 2						1.8						
Odontolaimus chlorurus de Man, 1880		3.3	3.1	10.0								
Ogma sp.			2.6	4.0								
Panagrolaimus sp.	1.8											
Paramphidelus sp.						0.4	0.6	0.3				
Paratylenchus sp.									0.3		0.9	7.3
Paraxonchium loofi Hodda *et al.*, 1994								1.0				
Plectus acuminatus Bastian, 1865	3.6				2.3	0.4	0.3					
Plectus cirratus Bastian, 1865	7.1		0.4									
Plectus parietinus Bastian, 1865					0.4							
Plectus parvus Bastian, 1865	0.6	0.6	0.4	2.5								
Plectus rhizophilus de Man, 1880			0.4									
Pratylenchus sp.								0.3		0.9		
Prismatolaimus intermedius (Bütschli, 1873)	1.8	3.3	0.9	3.0	6.6	2.1	1.3	3.3	26.0	17.0	7.5	3.4
Steinernema bibionis (Bovien, 1937)			2.2	1.5				0.3				
Takamangai circulifera (Loof, 1961)	0.6											
Teratocephalus terrestris (Bütschli, 1873)		0.6		3.0	1.2	2.1		0.6				
Trichodorus sparsus Szczygiel, 1968							2.6	0.3	0.6	1.8	1.2	0.4
Tylencholaimus ibericus Peña Santiago et Coomans, 1994											0.3	
Tylencholaimus minutus Vinciguerra, 1986			0.4	2.0								5.15
Tylencholaimus mirabilis (Bütschli, 1873)	1.2	21.2	30.1	12.1	52.5	54.1	59.3	46.5	29.8	22.8	28.1	29.2
Tylocephalus cephalatus (Cobb, 1893)	0.6							0.3				
Tylolaimophorus minor (Thorne, 1939)	2.4	3.9	4.4	10.5	3.1	1.1	6.2	1.2	0.9	12.9	15.9	20.2
Wilsonema capitatum Cobb, 1913		1.1	0.4	0.5		1.8						
Wilsonema sp.						0.4						
Total number of specimens identified	168	179	229	199	259	279	307	331	319	224	345	233
Total number of specimens	762	797	1198	814	1861	2198	1427	797	2708	978	1057	849
Total number of species	24	23	26	23	21	26	21	25	17	21	22	19

TABLE II - *Number of specimens and species and ecological indices in the three stations* (DI = diversity index; E = evenness; SR = species richness; MI = maturity index; PPI= plant parasites index).

	Uncut Forest	Cut Forest	Clearing
Number of specimens	3571	6283	5592
Number of species	41	38	28
DI	2.87	1.96	2.42
E	0.77	0.54	0.73
SR	6.01	5.23	3.84
MI (with plant parasites)	3.51	3.41	3.12
MI (without plant parasites)	3.57	3.59	3.47
PPI	2.0	2.2	2.1
PPI/MI	0.56	0.44	0.60

and cut forest showed that clear-cutting introduced some disturbance factors that reduced soil stability. On the contrary, when plant parasites were excluded and PPI was calculated separately, there were no significant differences between the three stations and the highest values, both of MI and PPI, were found in the disturbed forest. When the number of species of plant parasites in the three sites is considered, in the uncut forest there were only three of them, with few individuals, while in the cut forest and in the clearing they were eight with many individuals. Since almost all these species are colonisers with low c-p value, their increased presence in the latter sites, which might reasonably be the consequence of the disturbance, contributed to lower the MI in these two environments. Excluding them from the MI therefore leads to a loss of information. Otherwise, the slightly higher PPI value in the cut forest and in the clearing was only due to the presence of a few individuals of plant parasites with c-p value higher than 2, belonging to *Trichodorus sparsus*, *Longidorus* sp., *Paratylenchus* sp. and *Helicotylenchus* sp., all absent in the uncut forest.

Rather puzzling was the demographic explosion of *T. mirabilis* in the cut forest and in the clearing, where it became the dominant species. A similar increase of this species in cut plots was regularly observed by Sohlenius (1997). Such high demographic consistency is not typical of K strategist species; moreover, the hyphal feeding habit is not widespread in most dorylaim families, which are mainly predators or algae feeders. In our opinion *T. mirabilis* is a coloniser species and deserves a lower c-p value. This opinion is confirmed by the comparative analysis of the dorylaims frequencies in the cut and uncut forest sites: when *T. mirabilis* was included in the former more disturbed site, the percent of dorylaims was higher than in the lat-

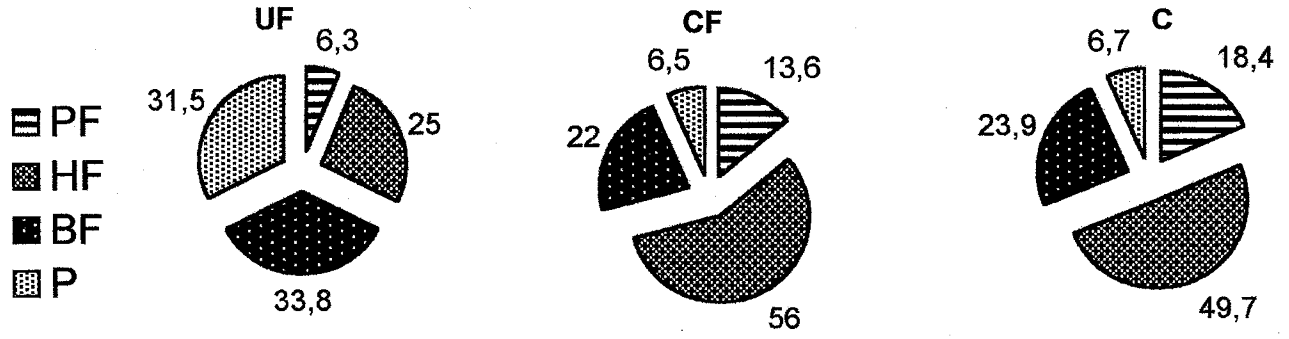

Fig. 1 - Percent frequencies of trophic groups in the three stations (UF = uncut forest; CF = cut forest; CL = clearing; PF = plant feeders; HF = hyphal feeders; BF = bacterial feeders; P = predators).

TABLE III - *Number of specimens of some species in the uncut and cut forest.*

	Uncut Forest	Cut Forest
Alaimus sp.	43	0
Aporcelaimellus amylovorous	14	0
Bastiania gracilis	2	0
Bunonema richtersi	17	0
Metateratocephalus crassidens	12	0
Odontolaimus chlorurus	33	0
Ogma sp.	14	0
Plectus cirratus	13	0
Coomansus parvus	77	13
Aporcelaimellus efficiens	141	36
Cervidellus serratus	52	134
Filenchus sp. 1	15	108
Filenchus sp. 2	0	17
Trichodorus sparsus	0	9

ter, contradicting the usual trend, while the relation was reversed if *T. mirabilis* was excluded. The dorylaim frequency analysis is a useful indicator of soil disturbance just because these nematodes are mainly K strategists, but it seems not to be true for *T. mirabilis* which did not follow the general trend. The demographic explosion of this species might be related to its being an opportunistic species with a wide ecological range for which the cut sites represent better living conditions and possibly to the absence of predators. Since this demographic trend was also evident in other cases, *T. mirabilis* might be considered as an indicator of forest soil disturbance related to clear-cutting.

Conclusions

This study, although based on relatively few samples and related to a single temporal testing, has shown that even a non-disruptive modification of the forest structure, like that caused by partial clear-cutting due to forest management, induced remarkable variations in the nematode community structure: a) biodiversity decreased; b) the dominance relationships between species was disturbed; c) the most fragile species, as well as the rare ones, the predators and the K strategists in general, decreased in number or disappeared; d) species typical of open environments appeared; e) the plant feeders, in natural conditions controlled by predators, increased; f) a eurytope species, *Tylencholaimus mirabilis*, had a true demographic explosion and also having shown a similar trend in other cases of forest clear-cutting, it may be considered as an indicator of forest soil disturbance related to clear-cutting.

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