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Organic agriculture and soil quality

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ABSTRACT: Organic agriculture, avoiding the use of synthetic fertilizers and pesticides, has attracted considerable attention the last decade. Its value is not only limited for the production of organic crops but also for the enhancement of soil quality. Soil quality is defined by numerous physical, chemical and biological indicators. The latter are more sensitive to environmental changes and provide signals of degradation or restoration of soils. Among biological indicators nematodes offer a great potential for assessing the impacts of land use. In four Asparagus fields, managed since 5, 3.5, 2 and 1.5 years organically, the soil quality was assessed and compared to a conventional Asparagus field and hedgerows. The studied areas were differentiated mainly due to their biological indicators. The organic fields had intermediate characteristics between the conventional field and the hedgerows. Carbon mineralization rate, Microbial Biomass and bacterial feeding nematode numbers increased with duration of organic management, while hyphal feeding and plant parasitic nematode numbers decreased. This is indicative of the decrease of mineral fertilizers in the soil and the increase of the biological activity.

1 INTRODUCTION

Soil quality has been defined by Doran and Parkin (1994) as the capacity of a soil to function within ecosystem boundaries to sustain biological productivity, maintain environmental quality and promote plant and animal health. Physical and chemical indicators have been proposed as potential soil quality indicators (Karlen et al. 1994). Because nutrient cycling is mainly controlled by biological processes, biological indicators are more sensitive to changes and may therefore give signals of soil degradation or restoration of agricultural soils, according to Panhurst et al. (1997). Bongers and Ferris (1999) stated that nematodes offer great potential for use as indicators for assessing the impacts of land use on soil conditions. Soil nematodes are heterotrophs, primary consumers (plant parasites), secondary consumers (predators) and consumers of decomposers (bacterial and hyphal feeders). They are involved in soil ecological processes such as decomposition, mineralization and nutrient cycling and they vary in sensitivity to pollutants and environmental disturbance (Bongers 1990, Wasilewska 1997).

Organic agriculture, avoiding the use of synthetic fertilizers and pesticides, has attracted considerable attention the last decade. Products from fields managed organically for three years, are certified as organic. But how does the soil quality of organic fields develop in relation to the duration of organic management? Are there any differences to conventional managed soils? Are there similarities to more "natural" ecosystems, like hedgerows? The objective of our study was to assess the soil quality, with respect to a number of physical, chemical and biological parameters, of organic Asparagus fields in relation to the duration of their organic management. A further aim was to compare soil quality of organic to conventional Asparagus fields and to adjacent hedgerows of both field categories.

2 MATERIAL AND METHODS

The study site is located in Kria Vrisi-Gianitsa about 80 Km northwest of Thessaloniki (Greece). The site is an agricultural area with Asparagus cultivations. The soil is silty clay with pH 7.8. The climate is Mediterranean. The study areas comprised 4 fields managed by organic practices over the last 5, 3.5, 2 and 1.5 years respectively (O_5, $O_{3.5}$, O_2, $O_{1.5}$) and their hedgerow (Ho), and one field managed by conventional practices over the last 8 years (C) and its hedgerow (Hc). The conventional field was examined as control and the hedgerows were considered the closest to the cultivations "natural" ecosystems.

Soil samples were collected on October 2002, when no agricultural activities took place since the previous summer. Physical, chemical and biological indicators of soil quality were measured such as: water content, organic carbon and nitrogen, pH, P, K, Mg, Ca, inorganic nitrogen (NO_3^- and NH_4^+), microbial activity and biomass, microbial nitrogen, carbon mineralization rate, and nematodes. All data were analyzed by PCA. Nematode genera were classified to feeding groups (Yeates, 1993) and Maturity Indexes and Plant Parasitic Indexes were calculated (Bongers, 1990).

3 RESULTS

In Table 1 average values of the measured physical, chemical and biological indicators for the soils of the four organic fields (O_5, $O_{3.5}$, O_2, $O_{1.5}$), the conventional field (C) and the hedgerows (Ho, Hc) are presented. Highest values of Microbial biomass (Cmic) and Carbon mineralization rate (C min rate) were observed in the hedgerows (Ho, Hc), followed by the organic fields (O_5, $O_{3.5}$, O_2, $O_{1.5}$), while the lowest values were observed in the conventional field (C). The highest and the lowest values of the Maturity Index (MI) were observed in the hedgerow of the conventional field (Hc) and in the two years old organic field (O_2) respectively. The highest value of the Plant Parasitic Index (PPI), as well as the ratio PPI/MI was observed in the Conventional field (C).

Table 1. Mean values of physical, chemical and biological indicators of soil quality in the Organic and Conventional fields and Hedgerows

	O_5	$O_{3.5}$	O_2	$O_{1.5}$	Ho	Hc	C
Water content [% DW]	18.14	23.04	19.96	20.39	19.61	20.56	17.09
pH	7.51	7.83	7.90	7.94	7.92	8.23	7.99
NH_4 [μg/ g DW]	24.82	16.98	17.81	19.01	20.02	22.24	23.53
NO_3 [μg/ g DW]	34.79	36.12	37.32	34.74	32.16	24.36	27.22
C/N	12.32	14.27	14.00	12.11	19.72	9.31	8.21
Mg [μg/ g DW]	0.20	0.44	0.37	0.38	0.66	0.36	0.18
K [μg/ g DW]	0.18	0.46	0.84	1.07	0.85	0.57	0.59
Ca [μg/ g DW]	0.22	0.25	0.21	0.23	0.19	0.24	0.17
P [μg/100 g DW]	2.06	2.95	6.18	2.30	3.62	2.12	3.41
Mic. activity [μgCO_2/g DWh^{-1}]	3.20	2.54	1.62	1.81	4.36	2.45	1.70
Cmic [mg/g DW]	1.94	1.97	1.73	1.72	2.23	2.27	1.17
Nmic [mg/g DW]	0.10	0.10	0.09	0.09	0.13	0.14	0.09
C min rate [μgCO_2/g DW day^{-1}]	5.63	5.14	5.03	5.63	6.91	7.11	3.56
Nematode MI	1.90	2.27	1.88	2.18	2.14	2.36	2.11
Nematode PPI	2.21	2.15	2.00	0.00	2.23	2.50	2.89
Nematode PPI/MI	1.16	0.95	1.06	0.00	1.04	1.06	1.37

In Fig. 1, the results of PCA for physical, chemical and biological parameters are presented in two axes plane. The conventional field (C) is ordinated at the left end of the first axis, all the organic fields (O_5, $O_{3.5}$, O_2 and $O_{1.5}$) as well as the hedgerow of the conventional field (Hc) are at the center and the hedgerow of the organic field (Ho) is at the right end. Microbial biomass (Cmic), Carbon Mineralization rate (C Min R) and Mg had the highest positive first axis scores, while Hyphal feeding nematode richness (Hy fe R) had the lowest negative one. Bacterial feeding nematode abundance (Ba fe A) and Plant feeding nematode abundance (Pl fe A) had the highest positive and the lowest negative second axis scores respectively.

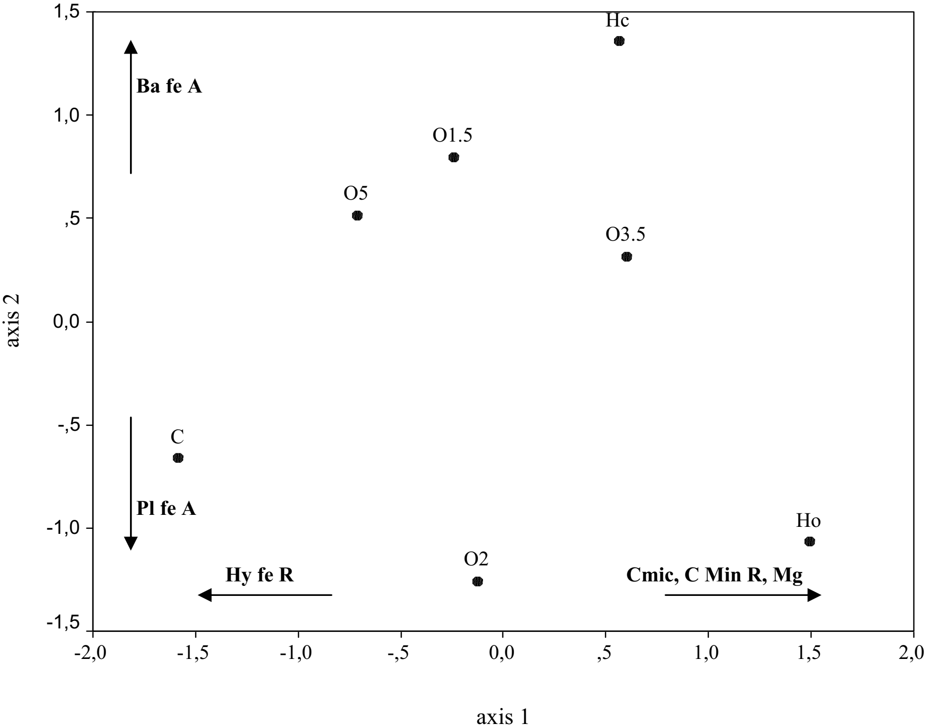

Figure 1. Factor analysis (two axes plane) applied to physical, chemical and biological parameters

Fig. 2 presents the proportion of each feeding group in the nematode assemblages for the soils of the four organic fields (O_5, $O_{3.5}$, O_2, $O_{1.5}$), the conventional field (C) and the hedgerows (Ho, Hc). In all fields and hedgerows (except in Hc) the highest proportion was observed for the Bacterial feeders (Ba fe). Plant parasites (Pl pa) comprise a relative high proportion of the nematode assemblages in the conventional fields (C), the hedgerow of the organic fields (Ho) and in the 2 years old organic field (O_2), while they are totally absent in the 1.5 years old organic field ($O_{1.5}$). Animal predators (An pr) as well as omnivorous (Omn) nematodes comprise a very low proportion of the nematode assemblages. Both groups are absent of the 5 years old conventional field (O_5), while omnivorous nematodes are present in both hedgerows (Hc, Ho) and in the conventional field (C).

Acrobeloides (Cephalobidae, Bacterial feeder) was the dominant genus in all the Organic fields (O5, O3.5, O2, O1.5) and the Hedgerow of the Conventional field (Hc). In the hedgerow of the Organic fields (Ho) the dominant genus was Neopsilenchus (Tylenchidae, Plant parasite), while in the Conventional field the dominant genus was Helicotylenchus (Hoplolaimidae, Plant parasite), followed closely by Acrobeloides.

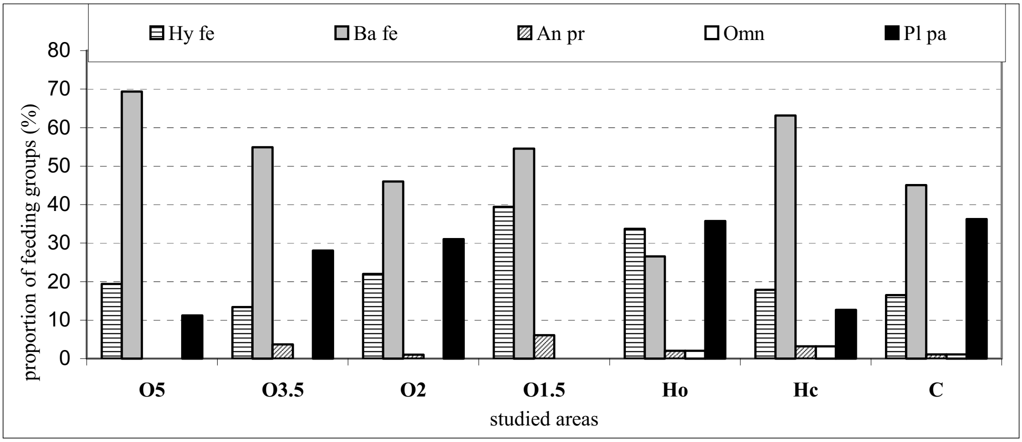

Figure 2. Proportion of feeding groups in nematode assemblages in the studied areas

4 DISCUSSION

Regarding soil quality, organic and conventional fields and hedgerows were differentiated by the combination of their chemical and biological characteristics. Microbial biomass and Carbon mineralization rate but more specifically nematode feeding groups reinforced this differentiation. The microbial biomass is a very sensitive indicator of changes resulting from agronomic practices. Microbial biomass and activity as well as C mineralization rate are regularly higher in organically managed soils than in conventionally ones (Hassink 1994, Gunapala and Scow 1997). In this aspect the organic fields seem to have intermediate characteristics between the conventional fields and the hedgerows.

The Maturity index itself seems not to provide sufficient information about the soil quality of the studied areas, at least fur the studied period. The relative high values of the index in the conventional filed (C) is related to the presence of even the few individuals of predators and omnivores, which are K-strategist and indicative of later successional or less-disturbed environments (Bongers, 1990). The bioindication potential of these groups though, is limited due to their low abundance especially in the cultivated soils (Yeates and Bird 1994). In this sense their presence in the conventional field (C) must not be directly related to environmental conditions. The absence of one or even both groups in the organic fields could be due to competitive exclusion by other representatives of the soil fauna (Wasilewska 1997). It has to be mentioned that the use of organic fertilizers on soil lead to a decline in the MI values (Ettema and Bongers 1993), thus explaining their relatively low values of the MI in the organic fields. The PPI/MI index showed a more accurate situation regarding soil quality. The higher PPI and PPI/MI value in the conventional field (C) than in the organic fields and hedgerows, due to the high abundance of plant parasitic nematode, is associated with the processes of environmental degradation resulting from the over-use of mineral fertilizers (Sohlenius and Wasilewska 1984).

The high abundance of bacterial feeding nematodes in the organic fields was expected because they are related to readily decomposing organic material of plant origin (Wasilewska 1995), which in our case was Asparagus litter. Their relative high abundance also in the conventional field has to be related to the same reason. In agreement with our results, Acrobeloides, which was the dominant genera in the organic fields, is positively correlated with bacterial phospholipid fatty acids (PLFA) (Yeates et al. 1997) and Cephalobidae are known to be predominant under organic management (Yeates 2003).

The characteristics of the nematode assemblages seemed not to display a specific pattern in relation to the duration of organic management at least for the studies period. MI values fluctuated, while PPI values increased with duration of organic management. The most indicative parameter of soil quality is the increase of bacterial feeding nematodes with duration of organic management along with the increase of Carbon mineralization rates, which denote biologically-active soils (Griffiths et al, 1994). This assumption is supported also by the decrease of hyphal feeding and plant parasitic nematodes, which indicates the decrease of mineral fertilizers (Sohlenius and Wasilewska 1994).

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