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SOIL FERTILITY STATUS OF CONVENTIONAL AND ORGANIC MANAGED CITRUS ORCHARDS IN MEDITERRANEAN AREA

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Introduction

Consumer's interest in healthy and safe food and in environmental concerns has been increasing recently (Carboni *et al*. 2000; Saba, personal communication). The definition of quality product has been changing and, in addition to the nutritional and health characteristics of food products, environmental protection has been emphasised, giving to the product itself a new attribution of a so called "environmental quality" (Cornevale, 2000).

In addition, agricultural policies at National and European level have been supporting sustainable agricultural production systems (i.e. organic farming) able to guarantee the "environmental quality" and increase or preserve air, water and soil quality.

Consequently, in these last years, the percentage of organic farms in European countries increased notably and the organic and in-conversion land area went up to about 4 million hectares (Organic EU website).

In the year 2000, the Italian organic and in conversion land area was about 1 million hectares, corresponding to about 5% of the national total agricultural surface area and 25% of the European organic managed cultivated area (Italian Ministry of Agricultural Policies website). The distribution of Italian organic surface is not homogeneous, since 70% of organic farms is localised in Southern Italy. Citrus (186,000 ha) can be considered the most important organically managed crop, widespread in Calabria, Arco Ionico Metapontino and Sicily (Lunati, 2001).

In order to verify if the organic farming cultivation system could determine an increase in the quality of environment, complying with the consumers expectation and political targets, we wanted to evaluate the effects of the organic farming management on soil quality and fertility status of Mediterranean citrus orchards.

In a previous paper, Intrigliolo *et al*. (2000) demonstrated that organic management, in respect to the conventional one, induced only slight differences on main soil physical and chemical characteristics in citrus orchards of Southern Italy. It is well known (Nannipieri, Grego, 1990) that biochemical parameters are suitable indicators able to detect changes on soil properties therefore, the aim of our work was to verify if organic farming system could induce differences in soil biochemical characteristics. To achieve this some specific soil system descriptors in a field survey approach was used.

Material and Methods

The research was carried out on citrus orchards (Navelina and Tarocco orange), localised in the Eastern Sicily (Italy). Soil characteristics were analysed in 54 farms under both organic and conventional management. Farms were selected to obtain similar pairs (27) in the same environmental conditions. Moreover, orchard pairs were homogeneous for age, cultivar and rootstock to reduce effects not linked to soil management.

At soil sampling was completed for all organic citrus orchards and for the requested three years conversion period foreseen by the Law in force (E.E.C. Regulation 91/2092). Soils were sampled in January and February and analysed, according to official guidelines (Intrigliolo *et al*., 1999). In Table 1, main physical and chemical parameters of considered soils are reported.

Table 1. Main physical and chemical parameters (mean values).

Parameter	Organic	Conventional
Clay (%)	33.9	31.7
Silt (%)	21.6	20.7
Sand (%)	44.5	47.6
pH	8.0	7.9
$EC_{1:2}$ (mS cm^{-1})	0.34	0.39
Active lime (g kg^{-1})	57	46

From: Intrigliolo *et al*., 2000.

Organic carbon amount and turnover

Total organic carbon (TOC, mgkg^{-1}) was determined by Walkley-Black's method. Estimation of organic carbon mineralisation was performed by measuring C-CO_2 production [mg(C-CO_2)kg^{-1}_{soil} d^{-1}] of the soil in closed environment (Isermeyer method, 1952), on 1^{st}, 2^{nd}, 4^{th}, 7^{th}, 10^{th}, 14^{th}, 17^{th} and 21^{st} days.

Cumulative C-CO_2 mineralised after 1 (C_1), 7 (C_7) and 21 (C_{21}) days was calculated for each soil. The kinetic study of organic carbon dynamic was performed by fitting the cumulated data to experimental curves by first order exponential equations $C_t = C_0(1-e^{-kt})$. This elaboration allowed to calculate the potentially mineralisable carbon C_0 [mg(C)kg^{-1}_{soil}] and the kinetic constant k ($days^{-1}$) for each investigated soil. Mineralisation coefficients (C_1/TOC % and C_{21}/TOC%) were determined to obtain information on mineralisation activity related to a different farming management.

In order to evaluate the level of stability reached by the soil organic matter, humic fraction extracted from soils was characterised by isoelectric focusing technique (IEF). Humic acids were extracted by 1:20 soil-NaOH/$Na_4P_2O_7$ (0.1M) solution at 65°C for 48 hours, and

25 mL of this solution was precipitated by acidification with HCl 1 M until reaching pH<2.0.

After centrifugation, the precipitate was re-solubilised with NaOH 0.1 M. Ten milliliters of this solution was dialysed in 6.000-8.000 Dalton membranes and then lyophilised to obtain purified soil humic matter (Ciavatta *et al.,* 1990).

This fraction, obtained from each soil, was analysed by isoelectric focusing technique (IEF) in a pH range 3.5-8.0, on a polyacrylamide slab gel (Ciavatta and Govi, 1993), using a defined mixture of carrier ampholytes (Pharmacia Biotech): 25 units of Ampholine pH 3.5-5.0; 10 units of Ampholine pH 5.0-7.0; 5 units of Ampholine pH 6.0-8.0. A prerun (2h; 1200V; 1°C) was performed and the pH gradient formed in the slab was checked by a specific surface electrode. The electrophoretic run (2h 30'; 1200V; 1°C) was carried out loading the water-resolubilised extracts (5 mg C 100 μL^{-1} sample^{-1}).

The electrophoretic bands were stained with an aqueous solution of Basic Blue 3 (30%) and then scanned by an Ultrascan-XL Densitometer, obtaining a typical IEF profile for each investigated soil. Peaks were numbered and the peaks' area was determined for each soil IEF profile, assuming as 100% the area under the entire IEF profiles. The sum of peaks' areas focused at pH>4.5 (corresponding to more humified organic matter) was calculated and named A_s%.

N content and mineralisation

Total nitrogen (N_{tot}, mgkg^{-1}) was measured by Kjeldahl's procedure. Soil inorganic N (mgkg^{-1}) in 1:10 soil-KCl (2M) extracts were estimated by continual flow colorimetry (Autoanalyzer Technicon II), as suggested by Wall et al. (1975) for NH_4^+-N, by Kampshake et al. (1967) for NO_3^--N and using adapted method according to Griess-Ilosvay (Griess, 1879; Ilosvay, 1889) for NO_2^--N (Keeney and Nelson, 1982).

Potentially mineralisable N (NPM) was estimated from the NH_4-N (mgkg^{-1}) accumulated after 7 days of anaerobic incubation at 40°C, according to Sahrawat and Ponnamperuma (1978), slightly modified by Canali et al. (2000). In particular, soil samples (16 g) were air dried and ground to pass through a 2-mm sieve.

The samples were placed in 50 ml test tubes containing 40 ml distilled water, covered and incubated at 40 °C for 8 days. The test tubes were agitated for a few seconds each day, in order to mix the water and soil suspension. After incubation, soil was extracted with KCl 2N and 40 ml KCl 4N was added to the suspension in order to keep the soil:solution ratio to 1:5.

The samples were shaken for 1 h and then filtered through paper filters. Determinations were performed in triplicate and difference between the N-NH_4^+ amount released by the sample after incubation and the amount released by the non-incubated sample was taken as mineralized nitrogen (NPM). Anaerobiosis was controlled by determining nitric (N-NO_3^-) and nitrous (N-NO_2^-) nitrogen concentrations at the end of incubation. Only negligible traces of oxidised forms of N were observed.

Statistical analyses

Obtained results were elaborated by ANOVA (organic *vs.* conventional management).

Results and Discussion

In table 2, mean values of all investigated parameters measured in conventional and organic managed soils are reported.

Table 2 Farming management effect on tested soil chemical and biochemical parameters.

Parameter	Conventional	Organic	*p*-level	Significance
TOC ($mg \times kg^{-1}{}_{soil}$)	10776	13322	0.15	ns
C_1 ($mg \times kg^{-1}{}_{soil}$)	102	120	0.30	ns
C_7 ($mg \times kg^{-1}{}_{soil}$)	347	514	0.01	*
C_{21} ($mg \times kg^{-1}{}_{soil}$)	552	827	0.03	*
C_0 ($mg \times kg^{-1}{}_{soil}$)	575	894	0.01	*
C_1/TOC (%)	1.01	0.89	0.28	ns
C_{21}/TOC (%)	6.69	6.14	0.64	ns
A_s (%)	54.70	59.30	0.27	ns
N_{tot} ($mg \times kg^{-1}{}_{soil}$)	1083	1289	0.20	ns
NO_3^--N ($mg \times kg^{-1}{}_{soil}$)	2.44	2.22	0.85	ns
NH_4^+-N ($mg \times kg^{-1}{}_{soil}$)	7.19	8.0	0.32	ns
NPM ($mg \times kg^{-1}{}_{soil}$)	34.10	39.0	0.76	ns

Mean values, *p*-level and relative significance are reported

Organic carbon amount and turnover

TOC values, representing one of the main parameters used to define soil fertility, resulted higher in organic managed soils (13322 $mgkg^{-1}$) in respect to conventional ones (10776 $mgkg^{-1}$), even if the differences showed no statistical significance (p = 0.15). Some examples of obtained cumulative curves for C mineralisation, related to organic and conventional managed citrus orchard soils, are reported in figure 1.

Carbon mineralisation has been considered a reliable property to evaluate soil microbial activity (Anderson and Domsch, 1985), being able to inform on soil metabolic status and organic matter turnover (Trinchera *et al*., 2001).

For all investigated soils, first order exponential equation that was able to fit experimental data and basal respiration was reached after 21 days of incubation. Mean values of mineralised C after 1, 7, 21 days of incubation, C_0, k, and the mineralisation coefficients (C_1/TOC, C_{21}/TOC) are presented in Table 2.

C_1, C_7, C_{21} and C_0 were higher in organic than in conventional soils, being highly statistically significant in the case of C_7, C_{21} and C_0 (p = 0.01, 0.03 and 0.01, respectively). On the other hand, mineralisation coefficients, lower in organic soils, suggested a decreased energy demand and a reduction of organic matter consumption in these soil systems compared to the conventional ones (Fliebach and Mäder, 1997).

In figure 2, some isoelectric focusing profiles from humic matter purified from 4 pairs of organic and conventional soils are reported.

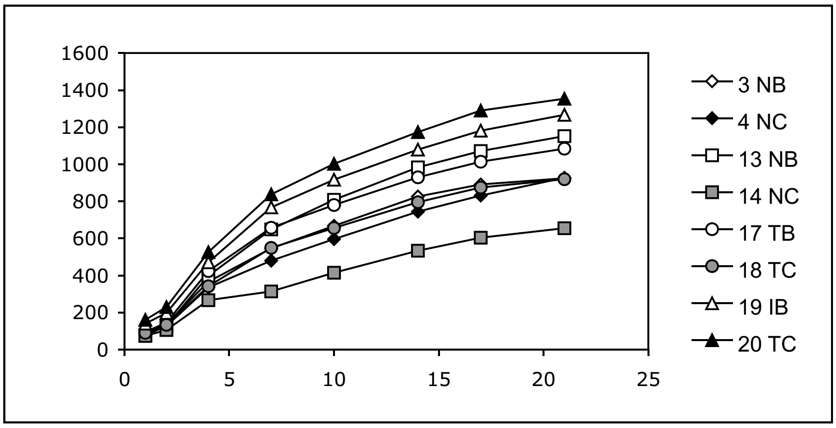

Figure 1. Some cumulative curves of C-mineralisation for organic (O) and conventional (C) soils

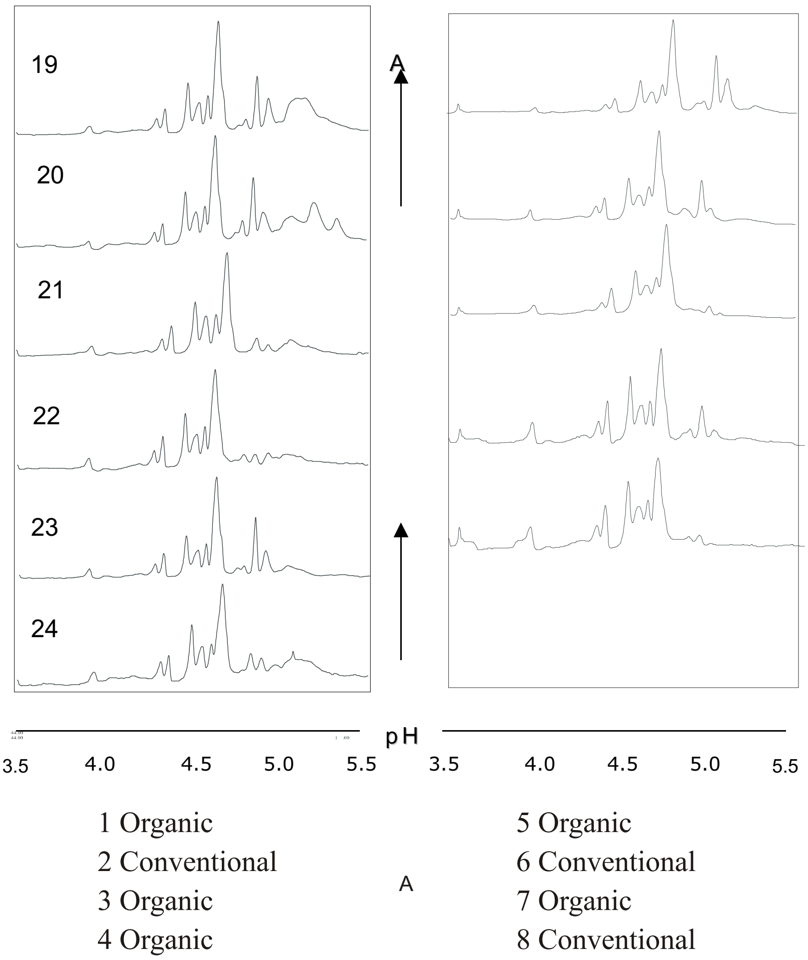

Figure 2. IEF profiles of humic matter extracted from some organic and conventional soils.

Isoelectric focusing is an electrophoretic technique, which is commonly used to investigate humic matter extracted from soils (Ciavatta e Govi, 1993) and fertilisers (Govi *et al.,* 1991; Canali *et al.,* 1998). It is based on the separation of different humic substances on the basis of their isoelectric point and their molecular weight. It is well known that the more is humified the organic matter, the higher is its isoelectric point, so that the organic molecules focus at higher pH values (Govi *et al.,* 1994).

Comparing the IEF patterns of each soils pair, differences in the less acidic part of the profiles, corresponding to pH values higher than 4.5, were noticed. In order to quantitatively evaluate these differences, we calculated the sum areas of the peaks focused at pH>4.5 (A_s %).

A_s parameter was higher in organic soils respect to the conventional ones (Table 2) and, even if this difference was not statistically significant, it was verified in the 75 % of the total cases. Since more humified organic compounds focus in correspondence of higher values of pH, this finding indicated that organic matter extracted from organic soils was characterised by higher level of humification.

N content and mineralisation

Results obtained for total N content, mineral N and NPM are reported in Table 2. N_{tot} was higher in organic managed soils (1289 mg×kg^{-1}) in respect to conventional ones (1083 mg×kg^{-1}), even if the differences showed no statistical significance. Although, for this parameter, a strong tendency to an increase of N content in organic soils was revealed by the low p values (0.20), very close to the significance. This finding seemed to indicate an increase of the long-term storage of this nutritive element in organically managed systems. No significant differences were also detected about the other tested parameter describing N turnover in soil.

All above results reported, referred to cumulative mineralised carbon, higher in organic managed soils, together with the lower values of mineralisation coefficients, suggested an increased metabolic efficiency in organic citrus orchards, which corresponded to a better ability to conserve energy (higher C content) and to storage nutrient (higher N content).

Moreover, the higher values of A_s % in organic managed soils could be due to i) the tendency to prevent more humified organic matter fraction from mineralisation or ii) the presence of humic matter of neo-formation. In any case, obtained data confirmed a positive humic balance in organic managed systems.

Obtained results allowed us to affirm that C-mineralisation could represent the most prompt indicator available to evidence changes on soil biological fertility, due to the different farming management.

Conclusion

The chemical and biochemical parameters considered in this work provided information on differences in soil quality and fertility level between organic and conventional managed systems. In fact, organic soils were characterised by a higher C-mineralisation (higher C_7, C_{21}, C_0), a higher humification level (higher values of A_s), an increase in soil nutrient (N) and energy (C) pools (higher TOC and N), and better efficiency in organic matter turnover (lower C-mineralisation coefficients). These findings suggested that organic managed soils could be considered as more conservative systems.

Generally, as theorised in Odun'hypothesis (1969), natural ecosystems show a balance in energy and nutrients economy, being characterised by an equilibrium between the organic matter input and the residual organic matter amount (Pinzari et al., 1999). Thus, organic managed soils seemed to be ecosystems in which transformations toward a new status, more similar to that of natural self-regulating systems, has been started.

On the basis of these results, the fertility status of studied soils will be monitored on long term, to verify if the revealed tendencies will be confirmed and better describe soil properties changes, by using a wider range of parameters and soil system descriptors.

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