Soil fertility comparison among organic and conventional managed citrus orchards in Sicily

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Abstract

In recent years, organic farming is expanding in Southern Italy and in the Mediterranean area, due to interests of consumers and EU agricultural policies.

Evaluation of organic farming system introduction on soil quality and fertility status should be taken into account in order to define medium-long term environmental and agricultural strategies, on both local and national scale. Soil physical, chemical and biological parameters represent effective tools to evaluate soil quality and changes in soil fertility status, as a consequence of different agronomic management (i.e. organic *vs*. conventional).

The aim of this work was to compare soil fertility status of conventional and organic managed citrus orchards, using specific soil system descriptors.

The research was carried out in a Mediterranean environment (Sicily region, Southern Italy), on Navelina and Tarocco orchards. 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. For each soil, total organic carbon, total nitrogen, mineral NO_3-N and NH_4-N were determined. In addition, in order to evaluate biological fertility status of considered soils, carbon mineralisation and nitrogen mineralisation in anaerobic conditions were studied. Soils humic fraction was at least characterised qualitatively by isoelectric focusing technique, to obtain information on soil organic matter stability.

Potentially mineralisable carbon and cumulative mineralised carbon 21 days of experimental trials differed significantly in organic and conventional soils. Since this significance was detected also for cumulative mineralised carbon after 7 days, probably C-mineralisation represents the more reliable and prompter indicator to be able to discriminate soil biological fertility in with respect to the other tested ones. Moreover, it should be remarked that some parameters (as total nitrogen content, mineralised carbon after 1 day and the more humified organic matter fraction), even if not yet significantly different, revealed a strong tendency to increase in organic managed soils, attesting that the organic citrus orchards can be considered systems able to conserve energy and store nutrients more than the conventional ones.

Keywords: organic farming, soil fertility, citrus orchards, mineralisation, isoelectric focusing

Introduction

Nowadays, consumers' interest in healty and safe food and in environmental concerns have been increasing (Carboni *et al.,* 2000; Saba, personal communication). The definition of product quality has been changing and, in addition to the nutritional and health characteristics, aspects linked to the environmental protection have been taken into account, 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" increase by preserving 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 2000, the Italian organic and in conversion land area was 1 million ha, corresponding to about 5% of the national total agricultural surface 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 the 70% of organic farms is localised in Southern Italy and the 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, respect to the conventional one, induced only slight differences on main soil physical and chemical characteristics in citrus orchards of Southern Italy. Since it is well known (Nannipieri and Grego, 1990) that biochemical parameters are suitable indicators to be able to detect changes on soil properties, the aim of our work was to verify if organic farming system introduction could induce differences in soil biochemical characteristics, by using some specific soil system descriptors in a field survey approach.

Materials 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, the requested three years conversion period foreseen by the low in force (E.E.C. Regulation 91/2092) was completed for all organic citrus orchards.

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 (%)	33.90	31.70
Silt (%)	21.60	20.70
Sand (%)	44.50	47.60
pH	8.00	7.90
$EC_{1:2}$ (mScm^{-1})	0.34	0.39
Active lime (g kg^{-1})	57.00	46.00

From: Intrigliolo *et al*., 2000

Organic carbon amount and turnover

Total organic carbon (TOC, mg kg^{-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}] by soil in closed environment (Isermeyer method, 1952), on 1st, 2nd, 4th, 7th, 10th, 14th, 17th and 21st days. Cumulative C-CO$_2$ mineralised after 1 (C$_1$), after 7 (C$_7$) and 21 (C$_{21}$) days were 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 the 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$_4$P$_2$O$_7$ (0.1 M) 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, precipitate was re-solubilised with NaOH 0.1 M. Ten milliliters of this solution was dialyzed 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 (2 h; 1,200 V; 1°C) was performed and the pH gradient formed in the slab was checked by a specific surface electrode. The electrophoretic run (2 h 30'; 1,200 V; 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}, mg×kg^{-1}) was measured by Kjeldahl's procedure. Soil inorganic N (mg×kg^{-1}) in 1:10 soil-KCl (2 M) 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 (mg kg^{-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 2 N and 40 mL KCl 4 N was added to the suspension in order to keep the soil:solution ratio to 1:5. The samples were shaked 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 oxidized 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 kg^{-1}$_{soil}$)	10776	13322	0.15	ns
C_1 (mg kg^{-1}$_{soil}$)	102	120	0.30	ns
C_7 (mg kg^{-1}$_{soil}$)	347	514	**0.01**	*
C_{21} (mg kg^{-1}$_{soil}$)	552	827	**0.03**	*
C_0 (mg 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 kg^{-1}$_{soil}$)	1083	1289	0.20	ns
NO_3^--N (mg kg^{-1}$_{soil}$)	2.44	2.22	0.85	ns
NH_4^+-N (mg kg^{-1}$_{soil}$)	7.19	8.0	0.32	ns
NPM (mg 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, were higher in organic managed soils (13,322 mg kg^{-1}) than to conventional ones (10,776 mg kg^{-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 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 (Fließbach and Mäder, 1997).
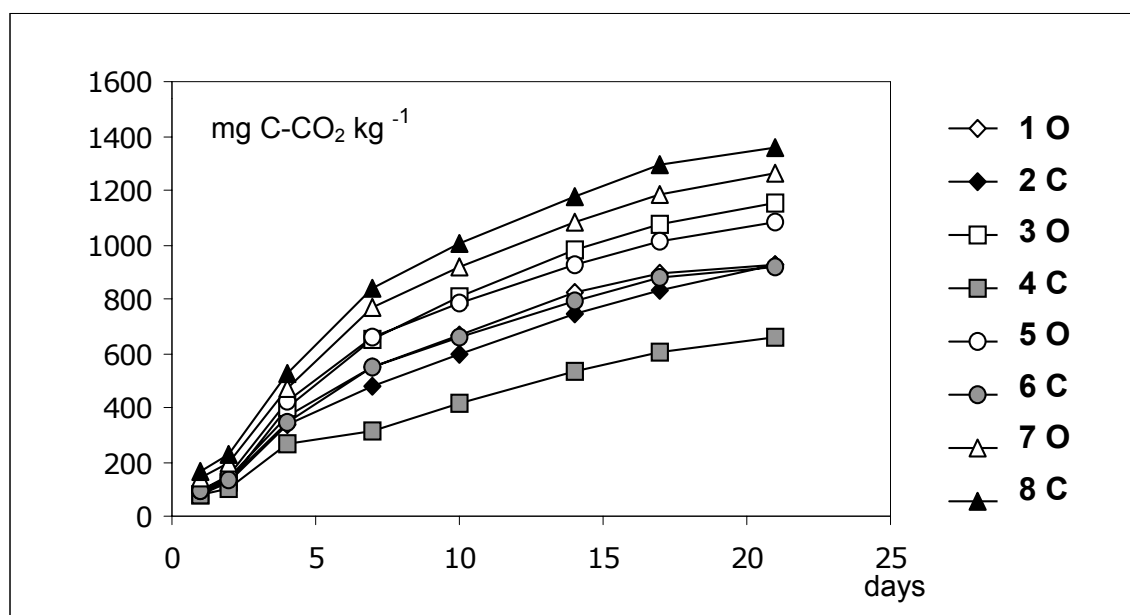

Figure 1 Some cumulative curves of C-mineralisation for organic (O) and conventional (C) soils.

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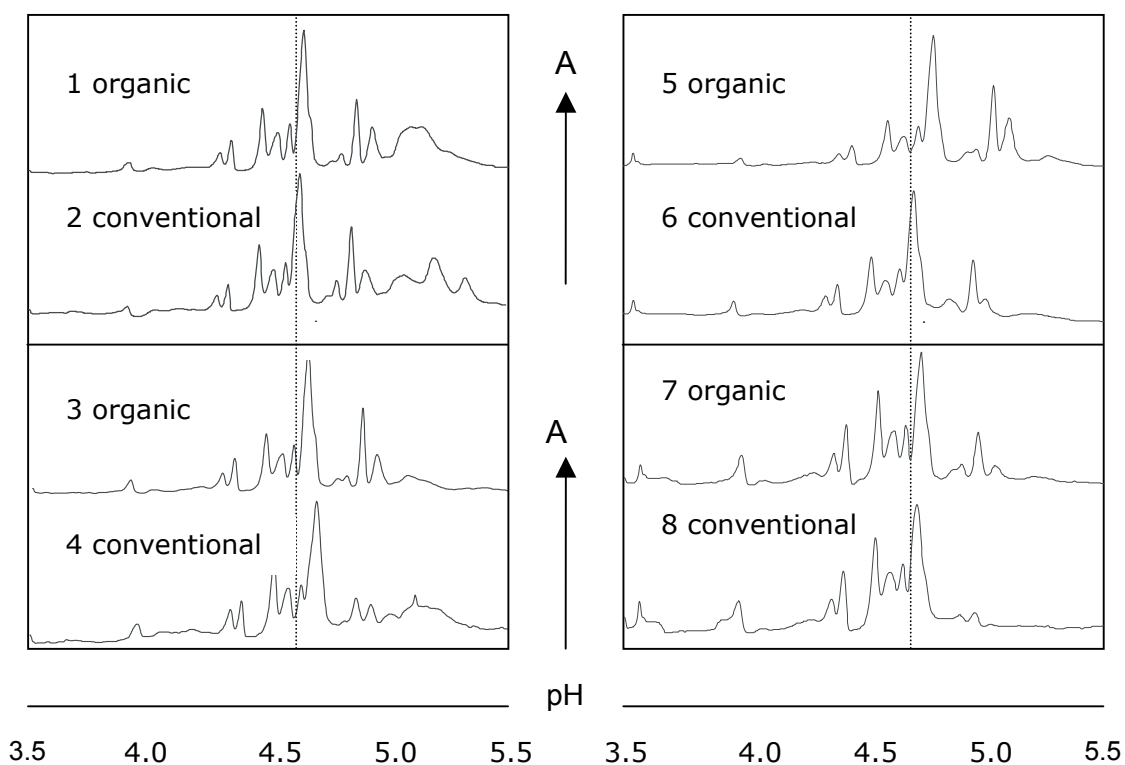
Figure 2 IEF profiles of humic matter extracted from some organic and conventional soils.

Isoelectric focusing is an electrophoretic technique, which is commonly used to investigate humic matter extracted from soils (Ciavatta and 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 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 the pH values higher than 4.5, were noticed. In order to quantitatively evaluate these differences, we calculated the areas sum 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 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 (1,289 mg kg^{-1}) respect to conventional ones (1,083 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 results above reported, referred to cumulative mineralised carbon, higher in organic managed soils, together with the lower values of mineralisation coefficients, suggesting 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 to be able to evidence changes on soil biological fertility, due to the different farming management.

Conclusion

The chemical and biochemical parameters considered in this work furnished information on differences in soil quality and fertility 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), a 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, have 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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