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Effects of agricultural practices on soil and microbial biomass carbon, nitrogen and phosphorus content: a preliminary case study

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Abstract. In this study we assessed the C : N : P ratios in soil and soil microbial biomass subject to conventional farming and three different organic farming practices. The results showed that microbial biomass was P-limited in soils subject to conventional farming and to organic farming with alfalfa green manure. Organic farming with compost amendment showed the best results in terms of microbial biomass carbon, nitrogen and phosphorus (CNP).

1 Introduction

The predominant agricultural trends in the past 50 years have been intensive production with increased use of commercial seeds, fertilizers, pesticides, fuel, etc. (Tomich et al., 2011). Consequences such as increased erosion, decreased soil fertility and biodiversity, water pollution and eutrophication, and alteration of atmospheric and climate processes lead to the urgency to develop new strategies that use the ecological interactions within the agricultural ecosystem (Matson et al., 1997). Soil microbial communities are extremely diverse, and the relation between their diversity and function influences soil stability, productivity and resilience; on the other hand, organic matter, water activity, soil fertility, physical and chemical properties influence microbial biomass in soils (Tomich et al., 2011). Because soil biota is influenced by land use and management techniques, changing management practices could have significant effects on the soil microbial properties and processes (Stark et al., 2007). Organic farming has been shown to favour soil biota in comparison with intensive farming (Kallenbach and Grandy, 2011; Santos et al., 2012). However, organic management may vary in its practices. The objective of this work was to determine soil and soil microbial carbon, nitrogen and phosphorus (CNP) in order to assess the effect of conventional and different organic farming practices on soil microbial biomass.

2 Methods

The study was conducted in central Portugal at the agricultural fields of Coimbra College of Agriculture, Polytechnic Institute of Coimbra. The conventional farming field (100 m × 150 m) is located at the right margin of the Mondego River (40°13′14″ N, 8°28′36″ W) whereas the organic farming field (OF), certified since 2010, is located at the left margin of the Mondego River (40°13′03″ N, 8°26′51″ W). The soils are similar (Table 1) and were cultivated with a month-old corn culture (*Zea mays* L.). At the organic farming field, three plots (100 m long × 50 m wide) with distinct previous cultures and organic management practices were sampled. Plot OF1 had been previously cultivated with alfalfa (*Medicago sativa* L.) and was fertilized with alfalfa green manure, plot OF2 had been previously cultivated with corn and was fertilized with organic compost, and plot OF3 had been previously cultivated with corn and was not fertilized (see the Table S1 in the Supplement).

Soils were sampled on 3 July 2013, after soil mobilization and fertilization and 1 month after seedling, when corn plants were circa 15 cm tall. Three replicate core samples

Table 1. Topsoil (0–20 cm) properties of the three plots under organic farming (OF) and of the plot under conventional farming (CF). Previous crop/fertilizer: alfalfa/alfalfa green manure for OF1, corn/organic compost for OF2; corn/no fertilizer for OF3; corn/chemical fertilizer for CF.

Variable	OF1	OF2	OF3	CF
Fine soil (< 2 mm) (%)	84	83	76	72
Gravimetric water content (%)	10.3	10.0	9.7	11.1
pH_{water}	5.5	5.6	5.8	6.6
Coarse sand (2–0.2 mm) (%)	37	42	54	46
Fine sand (0.2–0.02 mm) (%)	29	28	22	26
Silt (0.02–0.002 mm) (%)	24	18	16	20
Clay (< 0.002 mm) (%)	10	12	8	8
Organic matter ($g\,kg^{-1}$)	28.5	22.8	17.1	17.9
Soil organic carbon ($g\,kg^{-1}$)	16.5	13.2	9.9	10.4
Total Kjeldahl nitrogen ($g\,kg^{-1}$)	1.7	1.4	1.3	1.0
C : N	10	9	8	10
P_2O_5 ($mg\,kg^{-1}$)	319	312	181	279
K_2O ($mg\,kg^{1}$)	197	295	125	214
K^+ ($mg\,kg^{-1}$)	207	324	211	140
Na^+ ($mg\,kg^{-1}$)	32	35	14	28
Ca^{2+} ($mg\,kg^{-1}$)	129	101	97	161
Mg^{2+} ($mg\,kg^{-1}$)	9	8	7	5

($250\,cm^3$) were randomly collected at three places (along the margins and at the centre) of each of the four plots, at 0–5 cm and at 5–10 cm. The nine samples from each depth were pooled to provide a composite sample per depth and per plot, and four 25 g subsamples (two from each depth) were used to assess microbial biomass by the chloroform fumigation–extraction technique (Brookes et al., 1982, 1985; Vance et al., 1987). From each fumigated and non-fumigated sample, 2 g of soil was used to determine phosphorus and 23 g was used to determine carbon and nitrogen. Organic C, N and P content of the fumigated and non-fumigated samples were determined by standard methods with duplicate measurements per sample. Detailed information regarding the fumigation–extraction and the chemical analyses is provided in the Supplement.

Due to the non-replicated nature of the study, the effects of agricultural practice (plot) on soil and microbial C, N and P were analysed by resampling with permutation tests according to Bärlocher et al. (2005). The measurements for each plot were tabulated, and the differences between all six possible pairs were shuffled. The mean real difference between pairs was compared with the shuffled values using the Monte Carlo analysis (run 5000 times). The probability differences due to chance were given by the number of times the real difference was higher than the random assigned difference, divided by the number of runs (5000). These calculations were performed using PopTools for Excel 2010.

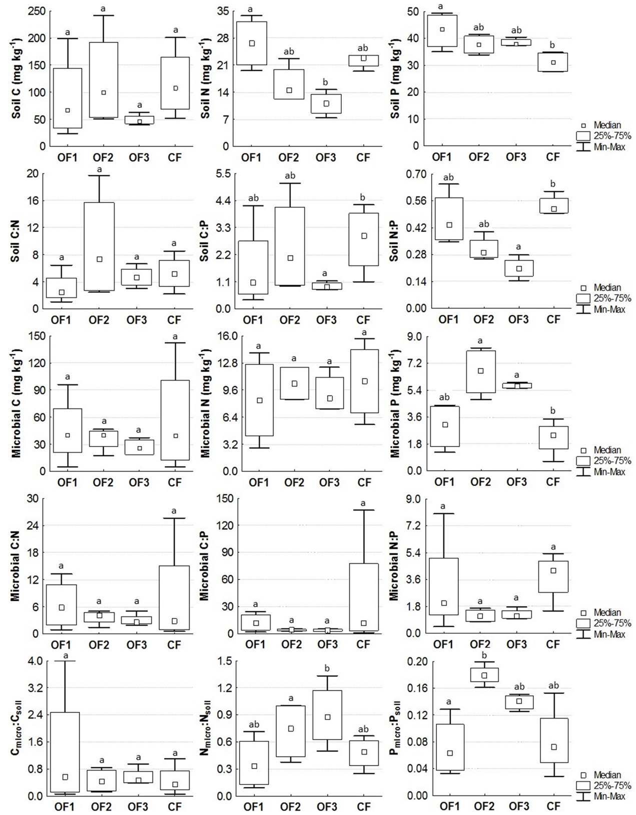

Figure 1. Carbon, nitrogen and phosphorus content of the soils and of the microbial biomass of the plots under organic (OF) and conventional farming (CF). Different letters indicate that differences between plots are not due to chance ($P < 0.05$).

3 Results

Soil carbon was similar in all plots, soil nitrogen was highest in OF1 and lowest in OF3 ($P = 0.008$; Fig. 1), and soil phosphorus was highest in OF1 and lowest in CF ($P = 0.001$; Fig. 1). Soil C : N attained highest values at OF2 with no significant differences among plots, and C : P ratios and N : P ratios were highest in CF and lowest in OF3 ($P = 0.013$ and $P = 0.009$, respectively; Fig. 1). Microbial carbon and nitrogen were similar in all plots, microbial phosphorus attained highest values in OF2 and lowest in CF and was significantly different between CF and OF2 or OF3 ($P = 0.002$; Fig. 1). C : N and C : P ratios attained highest values in CF while N : P ratios attained highest values in OF1 with no significant differences among plots. C microbial quotient ($C_{micro} : C_{soil}$) attained highest values in OF1, but there were no significant differences among plots. N microbial quotient ($N_{micro} : N_{soil}$) was significantly different between OF2 and OF3 ($P = 0.014$; Fig. 1) while P microbial quotient ($P_{micro} : P_{soil}$) was highest in OF2 and significantly different between OF1 and OF2 ($P = 0.015$; Fig. 1).

4 Discussion

Soil microorganisms have a C : N ratio of about 8.6 : 1 (Cleveland and Liptzin, 2007) and need a diet with a C : N ratio near 24 : 1 in order to acquire enough carbon and nitrogen (USDA, 2011). The C : N ratio of OF1 soil was low, which may be due to the amendment with alfalfa green manure. The low C : N ratio of green alfalfa (13 : 1; USDA, 2011) probably resulted in the microbial consumption of carbon leaving a temporary N surplus in the soil (USDA, 2011; Spohn, 2015). OF3 and CF soils also showed low C : N ratios, probably related to the non-amendment with organic matter in both fields. Despite the low soil C : N ratios, OF1 and CF attained relatively high microbial C : N ratios, which may indicate – as suggested by Cleveland et al. (2007) – a constrained C : N ratio in microbial biomass. The microbial quotients reflect the contribution of microbial biomass to soil nutrients and decrease with increasing organic matter availability (Moscatelli et al., 2005). The C microbial quotients obtained in the present study were low and attained values > 2.0 in OF1 only, suggesting that is was, of the four agricultural practices, the best management from the microbial carbon and nitrogen point of view. However, OF1, together with CF, also attained the highest N : P ratios and resulted in the lowest P microbial quotients showing that these soils were P-limited for microbial use. Soil P dynamics depends on the environmental factors affecting phosphate solubilizing microorganisms, which in turn contribute to soil acidification (Mahantesh and Patil, 2011). The highest clay content of OF2 together with the lowest pH may indicate a higher presence of phosphate solubilizing microorganisms in the organic farming soils, which could be the reason for the highest P microbial content observed in this plot. Thus, the management practice adopted in OF2 would be the best from the microbial phosphorus point of view.

In conclusion, the results obtained in this non-replicated small-scale experiment with soils sampled at the beginning of the growing season show that, of the four assessed farming practices, organic farming with amendment of organic matter via compost was the most suitable from the microbial point of view.

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