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Short Communication

Variation of the chemical and biological properties of a Technosol during seven years after a single application of compost

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ABSTRACT

Technosols are composed of natural soils mixed with artificial materials and can be an inhospitable environment for the soil microbial community. The main goal of the current research was to evaluate temporal variations of Technosol quality through an integrated approach, considering all of the evaluated chemical, physical and biological characteristics for a period of seven years after a single application of compost. The soil samples were evaluated using the following parameters: pH; water content; water holding capacity; bulk density; porosity; organic matter and N contents; C/N ratio; fungal biomass; microbial biomass; respiration; metabolic quotient (qCO_2); and endogenous mineralisation coefficient (CEM). The overall evaluation showed that a single application of compost improved the soil quality in the short term. A decrease in Technosol quality over the long term appears to be due to deterioration of the physical and chemical properties, rather than a change in biological properties.

1. Introduction

Technosols are constituted by artefacts and technic hard material derived from human activities for which decomposition is difficult (FAO, 2008). Technosols generally exhibit poor structure, have a low content of organic matter and nutrients, exhibit extreme pH values, and show low levels of biological activity (Santorufo et al., 2014). The addition of compost can improve Technosol quality by increasing soil water holding capacity (Termorshuizen et al., 2004) and the content organic matter and essential nutrients while favouring soil microorganism activity (Odlare et al., 2008). Long-term effects of repeated applications of compost have been widely investigated, but research addressing a single application is scarce (Memoli et al., 2017). Nevertheless, a single application of compost may help the stability and evolution of Technosols and thus decrease management costs. The main goal of the current research was to evaluate temporal variations of Technosol quality through an integrated index, considering all evaluated chemical, physical and biological characteristics, for a seven-year period after a single compost application.

2. Materials and methods

2.1. Study area, experimental planning, and soil sampling

The sampling site is located at the University Campus of Monte Sant'Angelo Federico II of Naples and consists of cement vessels built during the construction of the Department of Biology. In 2006, at the end of construction of Department, 12 vessels (each with area: 16 m^2, depth: 2 m) were filled with Andosols (FAO, 2008). The soils studied are classified as Ekranik Technosols (FAO, 2008), as they contain high amounts of artefacts (> 20%) derived from cracked building rubble and mixed with pyroclastic materials. In 2010, five subsamples of substrate (0–10 cm) were collected from each vessel and mixed together to provide a more representative soil sample. In the laboratory, the subsamples were sieved (< 2 mm) and analysed for physical-chemical and biological characteristics to evaluate soil properties before the addition of compost. After that step, dry compost was added (2 kg/m^2) to the soil, equivalent to approximately 0.28 kg/m^2 of organic carbon, to a depth of approximately 20–30 cm and was manually moved with by use of tools for tilling and levelling. The compost used for the experiments was produced by GESENU S.p.A. (Perugia, Italy) from the green refuse resulting from tree pruning and was analysed by the Experimental Institute for Plant Nutrition (salinity = 53.2 meq 100 g^{-1} d.w.; pH = 7.9; water content = 35.0% d.w.; organic matter = 28.0% d.w.; N = 2.1%

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d.w.; C/N 13.3; $P = 0.8\%$ P_2O_5 d.w.; $K = 1.8\%$ K_2O d.w.; total Cu = 67.2 mg/kg^{-1} d.w.; total Zn = 146 mg/kg^{-1} d.w.) and was certified by the "Consorzio Italiano Compostatori". To avoid stress conditions resulting from the addition of compost to the soils (Maisto et al., 2010), in 2011, the vessels were irrigated twice a week for 40 min over a two month period (the average amount of water added to each vessel was approximately 17 l/ m^2); however, until 2017, the vessels were left undisturbed. From each vessel and at each sampling time, i.e. 2011 and 2017 (after one and seven years from the time of compost addition) five subsamples of substrate were collected from the surface layer (0–10 cm) and mixed into a representative sample, providing 12 samples at each sampling time. In the laboratory, the soil samples were sieved (< 2 mm) and analysed for physicochemical and biological parameters.

2.2. Soil physical-chemical and biological analyses

Soil pH was measured with a pH meter on aqueous extracts obtained by adding distilled water to the samples (2.5:1 = *w/v*); bulk density (BD) was assayed on undisturbed soil cores of known volume after drying for 48 h at 105 °C. Soil porosity was calculated according to Danielson and Sutherland (1986). The water content (WC) was determined by drying fresh soil at 105 °C until a constant weight was reached, and the water holding capacity was determined (WHC) by the gravimetric method according to Aceves et al. (1994). To calculate organic matter (OM) content, organic carbon (C_{org}) was evaluated using gas chromatography (Thermo Finnigan, CNS Analyzer) on soil samples previously treated with HCl (10%). The OM content was obtained by multiplying the C_{org} by 1.724 (Pribyl, 2010). Total C and N concentrations were evaluated on oven-dried (105 °C until constant weight was reached) and ground (Fritsch Analysette Spartan 3 Pulverisette 0) soil samples employing gas chromatography and used to calculate C/N ratios. Soil microbial biomass (MB) and potential respiration were evaluated according to methods described by Anderson and Domsch (1978) and Froment (1972), respectively. The metabolic quotient (qCO_2), i.e., the degree of microbial biomass activity, and the coefficient of endogenous mineralisation (CEM), i.e., the rate of organic carbon mineralisation (Anderson and Domsch, 1993) were calculated. Total fungal biomass (FB) was assayed by a membrane filter technique (Sundman and Sivelä, 1978) after staining with aniline blue and determining hypha length by the intersection method (Olson, 1950) with an optical microscope (Optika, B-252). All analyses were carried out in triplicate.

2.3. Soil quality index (SQI)

An integrated soil quality index was calculated considering all the physicochemical and biological parameters and were ranked by a linear scoring technique according to Liebig et al. (2001). More details are reported in Panico et al. (2018).

2.4. Statistical analysis

The normality of the data distribution was assessed by the Shapiro-Wilk test. The one-way analysis of variance (ANOVA) followed by Tukey's post hoc test was performed to evaluate the differences between the three years of sampling. Spearman's correlations were performed to evaluate the relationships between physicochemical and biological parameters of Technosols during the entire experimental period. The statistical assays, performed by Systat_SigmaPlot_12.2 software (Jandel Scientific, USA), were considered to be statistically significant for $P < 0.05$.

3. Results

At the beginning of the experiment (2010) and before compost addition, the mean pH value was 7.47 and then significantly increased to 8.10 in 2017 (Table 1). WHC was statistically higher in 2017 (47.4% d.w.); conversely, WC was statistically lower (7.62% d.w.) when compared to other sampling times (Table 1). BD and porosity showed similar mean values between the first (2010) and the last (2017) sampling times when compared to 2011 (Table 1). OM content showed the statistically highest values in 2010 (7.99% d.w.) before compost addition (Table 1). Additionally, a statistically significant decrease (from 7.99% to 3.36%) in the OM content in 2017 was observed (Table 1). A statistically significant increase was observed for N content between 2011 and 2017 (0.11 and 0.36% d.w.) and for the C/N ratio between 2010 and 2011 (11.3 and 20.5). MB, FB and respiration (Fig. 1) showed wide ranges of values (2.47 to 3.36 mg/g^{-1} d.w. for MB; 0.04 to 0.36 mg/g^{-1} d.w. for FB; 4.14 to 10.73 µg CO_2 g^{-1} w·h^{-1} for respiration) with statistically significant differences among the sampling times. In 2010, the MB was statistically lower, while in contrast, the FB was statistically higher than at the other sampling times (2011 and 2017). In 2011 and 2017, respiration, qCO_2, and CEM were statistically higher compared to 2010 (Fig. 1). FB was generally positively correlated to OM (rs: −0.770, $P < 0.01$) and negatively correlated with soil pH (rs: 0.817, $P < 0.01$). Microbial respiration was positively correlated with pH (rs: 0.745, $P < 0.001$) and with C/N ratio (rs: 0.917, $P < 0.01$). Additionally, CEM was positively correlated with pH (rs: 0.753, $P < 0.001$) and negatively correlated with soil OM (rs: −0.817, $P < 0.01$). The SQIs values ranged from 0.55 to 0.80 (Fig. 1). The statistically higher SQI values were observed in 2011, whereas no statistically significant differences were observed for the other sampling times (e.g. 2010 and 2017).

Table 1
Mean values (± s.e.) of pH, water content (WC, expressed as % d.w.),water holding capacity (WHC, expressed as % d.w.), bulk density (BD expressed in mg cm^{-3}), porosity (expressed in % d.w.), organic matter (OM, expressed as % d.w.), N contents (expressed as % d.w.) and C/N ratios in soils collected at the mesocosms in seven years. Different letters indicate statistically significant differences (One way ANOVA, $P < 0.05$) between years of sampling.

	2010	2011	2017
pH	7.47 ± 0.05^{bc}	7.96 ± 0.07^{ac}	8.10 ± 0.04^{a}
WC	33.4 ± 0.90^{a}	33.8 ± 0.67^{a}	7.62 ± 1.12^{b}
WHC	42.3 ± 3.90^{a}	40.7 ± 1.23^{a}	47.4 ± 3.15^{b}
BD	0.90 ± 0.11^{a}	1.20 ± 0.12^{b}	0.85 ± 0.05^{a}
Porosity	65.4 ± 4.31^{a}	54.7 ± 4.54^{b}	67.9 ± 2.21^{a}
OM	7.99 ± 0.43^{a}	5.49 ± 0.57^{ab}	3.36 ± 0.71^{b}
N	0.24 ± 0.05^{ab}	0.11 ± 0.01^{a}	0.36 ± 0.05^{b}
C/N	11.3 ± 1.18^{a}	20.5 ± 1.55^{b}	13.5 ± 1.69^{ab}

4. Discussion

Before compost addition (2010), the Technosol contained a good level of organic matter content that enhanced the formation and stabilisation of soil pores, contributing to soil water storage (Rui et al., 2016). In spite of the high microbial biomass, respiration and CEM were lower than values reported by other authors (Memoli et al., 2017; Ventorino et al., 2012), suggesting scarce organic matter levels, as confirmed by the positive correlation found between respiration and C/N ratios. In fact, high values of C/N ratio suggested the presence of recalcitrant compounds (Yanardağ et al., 2017). Unfavourable microenvironmental conditions for a many of the microorganisms cannot be discounted.

In the short term after compost addition (2011), stimulation of microbial activity occurred as significant increases were observed for respiration, qCO_2 and CEM relative to the initial values. This finding could be observed due to an improvement of the microenvironmental conditions related to compost addition. Soil pH increased, favouring microbial activities and was corroborated by the positive correlations found between pH and respiration and CEM (Lehmann, 2006). Additionally, the statistically higher qCO_2 value compared to the initial

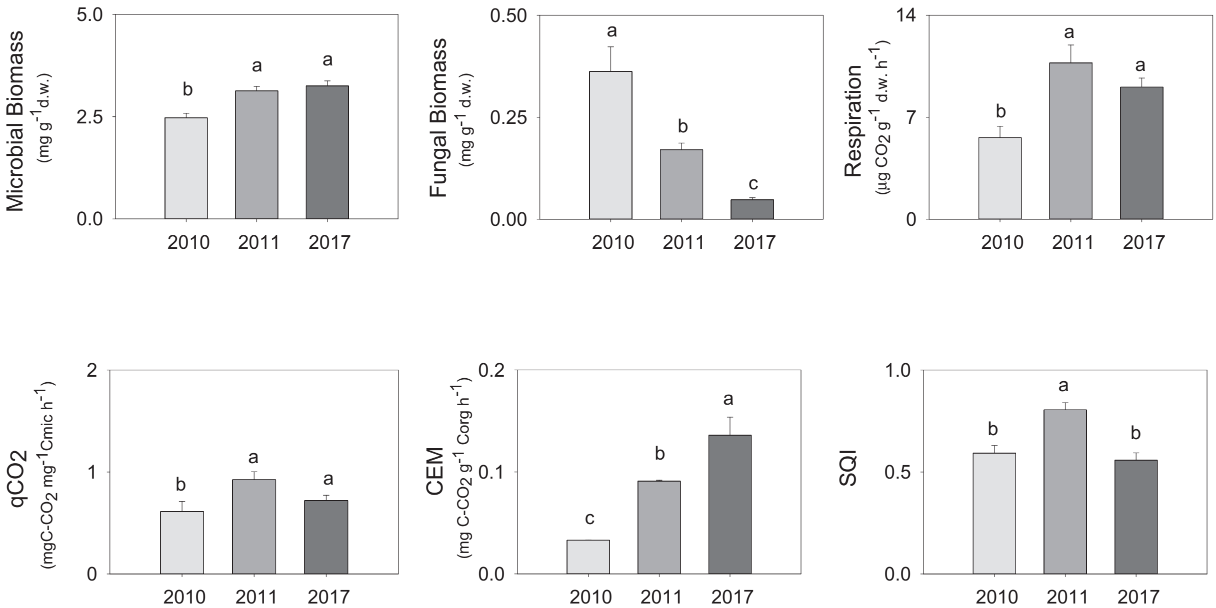

Fig. 1. Biological parameters and soil quality index of Technosols - Mean values (± s.e.) of microbial biomass (MB); fungal biomass (FB); microbial respiration; metabolic quotient (qCO_2); coefficient of endogenous mineralisation (CEM); and soil quality index (SQI) as measured in 2010, 2011 and 2017. Different letters indicate statistically significant differences between years of sampling (one-way ANOVA, $P < 0.05$).

values suggested activation of the metabolism of the native soil microbial community. The increase in microbial activity could be due to the presence of more easily metabolised substrates derived from the compost application, as confirmed by the highest CEM values (Ondoño et al., 2014). All of these aspects highlighted a sudden improvement in the properties of the investigated Technosol that determined a statistically significant increase of the SQI value (0.80).

In 2017, the physicochemical characteristics of soil varied statistically compared to the properties observed for other years; in particular, soil pH became alkaline, and N content increased, but organic matter and water content drastically decreased. Even with these changes, the biological parameters investigated did not vary further after seven years from the compost addition compared to the variations observed after only one year from the compost addition. The lowest value of water content in 2017 was linked to the low levels of organic matter, which has a high capacity for water retention (Eck and Stewart, 1995). The progressive decrease in organic matter content was probably compensated for by the increase in N content that supplied energy for microbial growth and activity. Over time, the fungal biomass declined, whereas the bacterial biomass remained nearly constant. In favourable environmental conditions, bacteria are more competitive than fungi in resource usage and, in addition, they are capable of releasing compounds that inhibit fungal growth (Memoli et al., 2017; Van Elsas et al., 2006). A particular role in contrasting the fungal abundance seems to be provided by increased soil pH and decreased organic matter content as corroborated by the statistically significant correlations observed. In addition, fungal growth appeared to be limited in alkaline soil. Seven years after a single compost application, the SQI value was lower than in 2011 and similar to that in 2010 (before compost addition). The decrease in the SQI value of the Technosol over time (in 2017) could be primarily due to a decline in physical and chemical properties, rather than in biological properties (in 2017, these were similar to those in 2011 and higher than those in 2010). A beneficial effect for the long term due to a single compost addition cannot be excluded as the SQI remained constant and was likely due to a new balance and favourable microclimatic conditions that was able to sustain microbial activities having similar values over time (Amlinger et al., 2003).

In conclusion, in the short term, a single compost application improved the soil quality, an effect that remained almost constant until seven years later. Over time, soil pH increased, and organic matter content decreased, causing a progressive decline in fungal biomass. A single application of compost, limiting management costs, appeared sufficient to guarantee the stability and evolution of Technosol.

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