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# Influence of organic amendments on soil quality potential indicators in an urban horticultural system

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ABSTRACT

The short-term response of some soil physical, chemical and biological properties, and the growth of beet, to the application of vermicompost–compost mix and/or bone meal at different doses in an organic system was evaluated in the present work. Fractions of soil organic matter after amendment application were also evaluated. Though no differences were found in oxidizable carbon, the particulate organic carbon was incremented in treatments with the application of vermicompost–compost mix (VC) and the combination of compost and bone meal (VC–BM). When analyzing the fulvic, humic and humin fractions, the highest fulvic acids were found in vermi-compost and bone meal mix, at the higher dose (VC2–BM2). In general, the addition of compost and/or bone meal stimulated microbial respiration. The treatments produced a slight but significant increase in electrical conductivity, thought it was still far from limits that involve risk of salinization. An increment in extractable P was found in all the treatments with amendment application with the exception of bone meal applied at the lower dose (1 kg $m^{-2}$). The cation exchange capacity showed a significant increment in VC2–BM2. A single application of VC at dose of 2 kg $m^{-2}$ was enough to significantly reduce bulk density. An increment in kg dry matter $m^{-2}$ of beet was observed in all the treatments, but it only was significant in VC2–BM2. However, the highest N and P concentration was found in beet aerial tissues from the treatments with the higher dose of the compost–vermicompost mix (VC2 and VC2–BM2). Particulate organic carbon, fulvic acid fraction, C from respiration, and bulk density were the soil properties that showed a positive change after amendment application. Treatment combining vermicompost–compost and bone meal (VC2–BM2) seemed to be the best option to achieve an improvement both in soil and crop production and quality.


## 1. Introduction

Intensive horticultural cropping, as occurs with several densely populated cities, is one of the main activities in the green belt around Buenos Aires, where vegetables are usually grown with relatively high fertilizer and pesticide inputs. Intensive use of soil for years, together with inappropriate production technologies like continuous soil removal and the widespread use of pesticides and fertilizers, has created in many cases major problems of pollution and soil degradation (Albiach et al., 2000; Ferreras et al., 2006). Thus, the need to minimize environmental impact without reducing yields leads to look for alternatives that achieve a sustainable production.

Maintenance of soil organic matter is important for the long-term productivity of agroecosystems. Soil application of organic amendments is a management strategy to counteract the progressive loss of organic matter (Marinari et al., 2000; Tejada et al., 2008). The addition of organic amendments may improve soil physico-chemical, biochemical and microbiological properties involved in biogeochemical cycles and thus positively influence plant productivity parameters. The organic amendments are a source of slow-releasing nutrients and highly available energy for soil microorganisms (Gomez et al., 2006). Among the main benefits attributed to the use of organic amendments are an improved soil aggregation and reduced bulk density, greater water holding capacity, stabilization of pH, increased CEC and organic matter (Sasal et al., 2000; Tejada et al., 2008), less nutrient potential loss and a reduction in the loss of nitrate. Organic amendments can also promote plant health, and it is also possible to obtain equivalent or even increased yields in organic production with respect to those obtained with conventional soil management (Bulluck et al., 2002; Courtney and Mullen, 2008).

Previous research has demonstrated that positive changes are observed in several physical, chemical and biological properties after organic amendment application in a horticultural soil with an extended history of conventional management (Ferreras et al.,

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2006; Gomez et al., 2006). In the current study, the objectives were: (i) to evaluate the response of some soil physical, chemical and biological properties after the application of different types and doses of amendments in an organic system; (ii) to detect sensitive properties that can be used as potential indicators for monitoring changes in quality of horticultural soils; (iii) to determine the effect of the amendment on growth parameters of beet, a common crop in the horticultural production of the area. Previous research has focused on the evaluation of soil total organic carbon after amendment application, but labile carbon may be more easily modified by management practices, so we specially focused on the evaluation of the dynamics of active carbon fractions.

## 2. Methods

### 2.1. Site and experiment description

The study was conducted in the Experimental Organic Orchard, Facultad de Agronomía, Universidad de Buenos Aires (FAUBA, 34°38′ S–58°28′W) in a Typic Argiudoll with a history of more than 15 years of organic production and recent predecessor crops corn, cabbage, broccoli and pea. The main physical and chemical characteristics of the surface horizon (0–20 cm) from the experimental site prior to the addition of the amendments were bulk density 0.85 g $cm^{-3}$, pH 6.9 and electrical conductivity 0.67 dS $m^{-1}$, organic matter 49 g $kg^{-1}$, cation exchange capacity 20 cmol $kg^{-1}$, extractable phosphorous 66.5 mg $kg^{-1}$ and total nitrogen 2.3 g $kg^{-1}$.

The experiment was established in November 2008, in plots of 0.8 m × 1.2 m in a complete randomized block design with three replicates. Seedlings of beet (*Beta vulgaris* L. var. cicla, cv. Bressane) were placed in the plots at a planting density equivalent to 5 plants $m^{-2}$. Seven days before transplanting, the soil was loosened with a spade and the amendments were applied with a shovel on the planting line and evenly mixed in the first 15 cm of soil using a gardening rake. Weed control was performed through the use of mulching, which also acted as temperature and humidity insulating layer and prevented erosion. Water was supplied by rainfall supplemented by drip irrigation.

The following treatments were established:

- Vermicompost–compost (mix), dose 1 kg $m^{-2}$ (VC1)
- Vermicompost–compost (mix), dose 2 kg $m^{-2}$ (VC2)
- bone meal, dose 0.05 kg $m^{-2}$ (BM1)
- bone meal, dose 0.15 kg $m^{-2}$ (BM2)
- vermicompost–compost (mix), dose 2 kg $m^{-2}$ + bone meal, dose 0.15 kg $m^{-2}$ (VC2–BM2)
- control (C)

The vermicompost was the mature product composed of fecal pills of Californian red earthworm (*Eisenia foetida*); the compost was elaborated with straw, green material and rabbit manure. Both were mixed (1:1) for application. Compost and vermicompost were produced in the Orchard of FAUBA in an attempt to give the waste a productive use while reducing the environmental problem of its accumulation. Bone meal was a commercial product derived from cattle bones from slaughters, which was included in the treatments as it is an amendment often used even in traditional horticulture. Chemical characteristics of the amendments are shown in Table 1.

### 2.2. Sampling and analysis of soil and plant

At the end of the crop production cycle (132 d), plant and soil samples were collected for analysis. Soil samples were collected with a small spade to the depth of 0–15 cm, air-dried and sieved (2 mm mesh, if not otherwise indicated).

#### 2.2.1. Oxidizable organic carbon (Cox)

Soil organic carbon was determined by Walkley & Black (Nelson and Sommers, 1982). Briefly, organic matter from the soil (1 g) is oxidized with $K_2Cr_2O_7$ 1 N (10 ml) in concentrated sulphuric acid for 30 min, followed by titration of the excess of $K_2Cr_2O_7$ with ferrous-ammonium sulphate 0.5 N and *N*-phenyl anthranilic acid to indicate the end point.

#### 2.2.2. Particulate organic carbon (POC)

The POC was determined by dispersing 10 g of soil in 30 ml of sodium hexametaphosphate solution (5 g $L^{-1}$) and shaking for 15 h on a reciprocal shaker. The dispersed soil samples were passed through a 53-μm sieve, rinsing several times with water, and the material retained on the sieve was dried at 50 °C overnight (Cambardella and Elliott,1992). The dried samples were ground with a mortar and analyzed for total organic C (Nelson and Sommers, 1982).

#### 2.2.3. Humic acids (HA), fulvic acids (FA) and humin (H)

The approach described by Richter (1979) was performed. Briefly, 0.5 g of soil (sieved through 0.5 mm) were percolated with $H_2SO_4$ 0.1 N and precipitated humic acids were separated from fulvic acids in solution, and then separated in an alkaline solution (20 ml NaOH 0.5 N). After dissolution of the humic fraction, both fulvic and humic acids were valued by titration with ferrous-ammonium sulphate and *N*-phenyl anthranilic acid to indicate the end point. Humins were determined on the remaining fraction from the percolates by Walkley & Black (Nelson and Sommers, 1982).

#### 2.2.4. Carbon from microbial respiration (C resp)

Soil samples at 75% of water holding capacity were incubated at 25 °C 7 d in hermetic flasks; the $CO_2$ evolved was trapped in excess of 0.5 N NaOH. The alkali was titrated to the phenolphthalein with HCl in the presence of $BaCl_2$ to precipitate the carbonate.

The following properties were also determined: *pH* in soil:water 1:2.5; *Electrical Conductivity* (EC) by potentiometry; *Extractable P* (Pe) by Bray and Kurtz (1945); *Total Nitrogen* (N) by Kjeldahl (Bremner and Mulvaney, 1982); *Cation Exchange Capacity* (CEC) by extraction with ammonium acetate pH 7.0 (Richter et al., 1982); *Bulk Density* (BD) by the cylinder method (Forsythe, 1975).

#### 2.2.5. Beet yield and nutrient concentrations in plant aerial biomass

Beet yield (kg dry matter $m^{-2}$) was determined when the crop reached commercial size. Samples composed by the aerial part of 5 plants per plot were oven-dried at 60 °C 48 h and the dry weights

**Table 1**
Chemical composition of the amendments used.

| Amendment | C (g $kg^{-1}$) | N (g $kg^{-1}$) | C/N | pH (1:2.5) | EC (dS $m^{-1}$) | P (mg $kg^{-1}$) | Ca (g $kg^{-1}$) |
|---|---|---|---|---|---|---|---|
| Compost | 70 | 3.5 | 20 | 7.3 | 0.7 | 11.2 | 20 |
| Vermi–compost | 100 | 7.5 | 13 | 7.2 | 3.7 | 7.2 | 20 |
| Bone meal | 60 | 30 | 2 | 7.9 | 5.0 | 11 | 225 |

calculated. Then, the samples were grounded for N and P analysis using standard analytical procedures (Westerman, 1990).

### 2.3. Statistical analysis

Results were statistically analyzed by ANOVA (SAS 1990, version 6.12.) and comparison of means was performed by Fisher LSD test ($P < 0.05$).

## 3. Results and discussion

The Cox was high in all the treatments and also in the control, no significant differences were found among them (Fig. 1). Ferreras et al. (2006) found that soil organic carbon significantly increased in plots amended with household solid waste and horse and rabbit manure, after 6 months of amendment incorporation at 20 Mg ha$^{-1}$ rate, in a soil from a long history of conventional horticultural management. In the present work, the lack of response in Cox is consistent with favorable initial organic matter content.

However, there were significant differences in the POC between VC1, VC2 and VC2–BM2 which showed the highest values, and BM treatments; the lowest POC was observed in the control (Fig. 1). More labile fractions of organic matter are much more sensitive to changes produced by management practices (Six et al., 1999). The POC is an active fraction from COT, which constitutes a substrate easily available for microbial biomass (Cambardella and Elliot, 1994); this fraction has been reported as an early indicator of carbon increment as a result of soil management (Bulluck et al., 2002).

When analyzing the fulvic, humic and humin fractions of soil organic matter, there was a significant difference in FA between VC2–BM2, which showed the highest value with respect to the control; the other treatments did not differ with VC2–BM2 and with the control (Fig. 2A); HA did not show significant differences (Fig. 2B), and H were lower in BM1 with respect to the other treatments and to the control (Fig. 2C). The resulting FA fraction is consistent with what was observed with the POC, since FA is the more labile humus fraction. As regards HA and H, these are the more stable fractions from humus. Though no significant differences were found, larger amounts of HA were observed in those treatments where the higher dose of the compost–vermicompost mix was applied (VC2 and VC2–BM2). In Table 2, the percentage composition of humic fractions and the AH/AF ratio is presented. Orlov (1995) characterized soils according to their humus content, thus, soils with a ratio AH/AF > 2 are considered humic, while ratios AH/AF between 1 and 2 are indicative of a balanced relation between fulvic and humic acids. The soil where the experiment was carried out would be placed in a moderate to high humification, indicating that the amendments applied could lead to an increment in the stable fraction of soil organic matter.

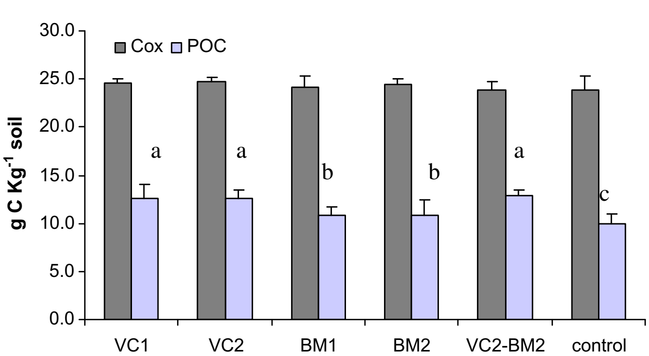


**Fig. 1.** Oxidizable organic carbon (Cox) and Particulate organic carbon (POC) measured after 132 days from amendment application. VC1: vermicompost–compost (mix 1:1), 1 kg m$^{-2}$; VC2: vermicompost–compost (mix 1:1), 2 kg m$^{-2}$; BM1: bone meal, 0.05 kg m$^{-2}$; BM2: bone meal, 0.15 kg m$^{-2}$. Means followed by different letters indicate significant differences (Fisher $p < 0.05$), n = 3.

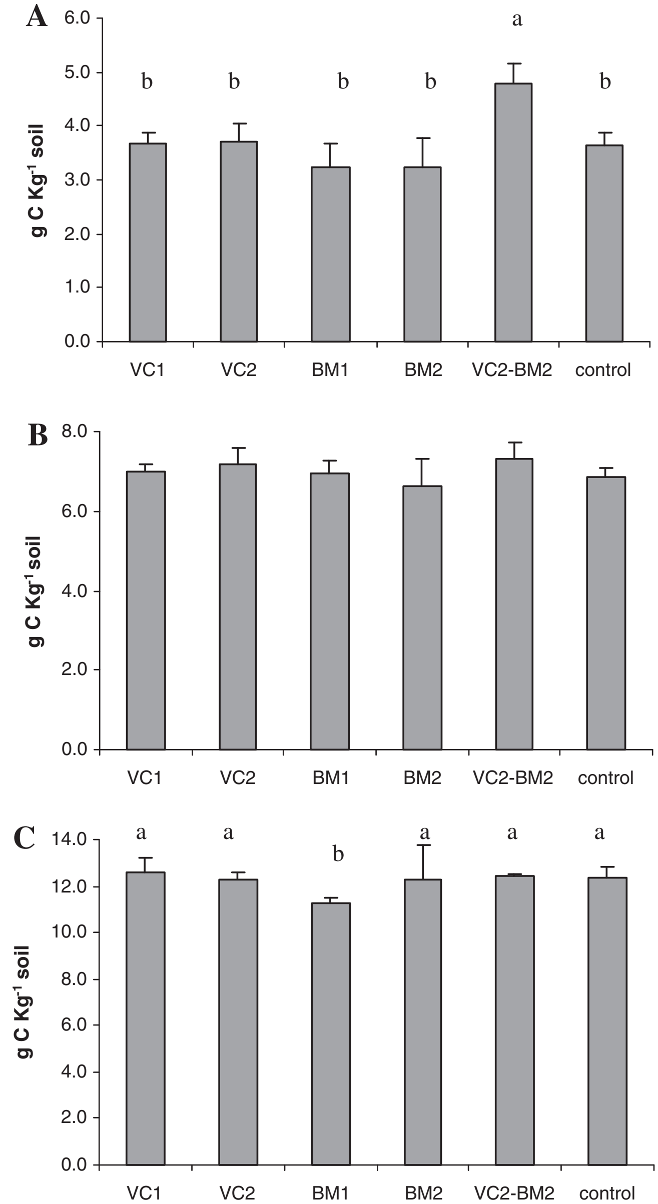


**Fig. 2.** Soil humic fractions after 132 days from amendment application: (A) Fulvic acids (B) Humic acids (C) Humines. VC1: vermicompost–compost (mix 1:1), 1 kg m$^{-2}$; VC2: vermicompost–compost (mix 1:1), 2 kg m$^{-2}$; BM1: bone meal, 0.05 kg m$^{-2}$; BM2: bone meal, 0.15 kg m$^{-2}$. Means followed by different letters indicate significant differences (Fisher $p < 0.05$), $n = 3$.

**Table 2**
Average composition of humic fractions. VC1: vermicompost–compost (mix 1:1), 1 kg m$^{-2}$; VC2: vermicompost–compost (mix 1:1), 2 kg m$^{-2}$; BM1: bone meal, 0.05 kg m$^{-2}$; BM2: bone meal, 0.15 kg m$^{-2}$.

| Treatments | Fulvic acids (%) | Humic acids (%) | Humin (%) | AH/AF |
|---|---|---|---|---|
| VC1 | 16.14 | 30.31 | 53.55 | 1.88 |
| VC2 | 16.08 | 30.97 | 52.95 | 1.93 |
| BM1 | 15.35 | 32.37 | 52.28 | 2.11 |
| BM2 | 14.31 | 29.86 | 55.83 | 2.09 |
| VC2–BM2 | 19.30 | 29.83 | 50.86 | 1.55 |
| C | 15.97 | 30.14 | 53.89 | 1.89 |

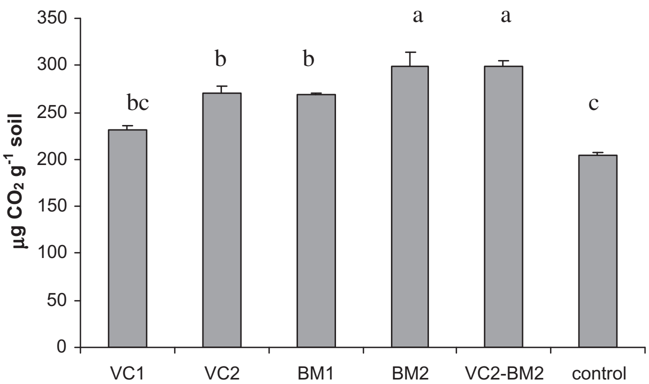


**Fig. 3.** Carbon from microbial respiration measured after 132 days from amendment application. VC1: vermicompost-compost (mix 1:1), 1 kg m$^{-2}$; VC2: vermicompost–compost (mix 1:1), 2 kg m$^{-2}$; BM1: bone meal, 0.05 kg m$^{-2}$; BM2: bone meal, 0.15 kg m$^{-2}$. Means followed by different letters indicate significant differences (Fisher $p < 0.05$), $n = 3$.

Microbial respiration was the lowest in the control; VC1 did not differ from the control, VC2 and BM1, while BM2 and VC2–BM2 showed the highest values (Fig. 3). Soil microbial respiration, measured through carbon dioxide production is a direct indicator of microbial activity, and indirectly reflects the availability of organic material (Gomez et al., 2001). Amendment applications stimulated in general soil microbial respiration. A larger respiration was observed in those treatments applied at a higher dose, in line with what found by other researchers (Marinari et al., 2000; Tejada et al., 2009) and consistently with a greater supply of sources of energy and nutrients which stimulates soil autochthonous microbial activity and with the incorporation of exogenous microorganisms.

In Table 3, pH, EC, N, Pe, CEC and BD are shown. An increment in soil pH and the build up of soil EC due to high salt content of some compost that can restrict crop development are two of the concerns arising from long-term applications (Courtney and Mullen, 2008). The pH was not affected by the amendments application, as it would be expected since it is not a property subject to change in the short term. As regards EC, all the treatments produced a slight but significant increase, thought EC was still far from limits that involve risk of salinization.

An increment in N and Pe was found in all the treatments with amendment application with the exception of Pe in BM 1. The highest N was found in soil amended with bone meal in both doses, consistently with the highest concentration of this nutrient in BM. The higher Pe was found in VC2–BM2, probably due to P supply from both combined amendments. Amendment quality is defined by the nature and amounts of the components (Grigatti et al., 2004), and in the case of VC2–BM2 an incremented Pe could be related to a stimulated microbial activity and to the action of organic acids derived from microorganisms in the vermicompost on P present in the bone meal.

The CEC showed a significant increment in VC2–BM2 and no differences were found in the rest of the treatments with respect to the control (Table 2). The increment observed in VC2–BM2 is consistent with the higher FA in plots from this treatment. Fulvic acids consist of weak acids due to the presence of carboxyl, carbonyl and fenyl reactive groups, which have the ability of capturing cations and thus incrementing CEC (Stevenson, 1982).

A single application of compost at dose of 2 kg m$^{-2}$ (VC2) was enough to significantly reduce bulk density, the other treatments showed a lower BD, but this trend was not significant. The decrease in bulk density is attributable to the mixing of the soil mineral fraction with less dense organic material in the compost (Tejada et al., 2006).

Beet yield (kg dry matter m$^{-2}$), N and P concentration in plant are presented in Table 4. An increment in kg dry matter m$^2$ of beet was observed in all the treatments, but it only was significant in VC2–BM2. Nitrogen and phosphorus, however, was significantly larger in all the amendments with respect to the control, and the highest N and P concentration was found in beet from the treatments with the higher dose of the compost–vermicompost mix (VC2 and VC2–BM2). Mylavarapu and Zinati (2009) also found an increment in N and P, after application of a composted mix of municipal solid waste and biosolids, to a parsley crop, suggesting the mineralization of organic N and P fractions from the amendments.

**Table 4**
Beet yield (kg dry matter m$^2$), N and P concentration in plant aerial biomass. VC1: vermicompost-compost (mix 1:1), 1 kg m$^{-2}$; VC2: vermicompost-compost (mix 1:1), 2 kg m$^{-2}$; BM1: bone meal, 0.05 kg m$^{-2}$; BM2: bone meal, 0.15 kg m$^{-2}$.

| Treatments | kg m$^2$ | N (mg kg$^{-1}$) | P (mg kg$^{-1}$) |
|---|---|---|---|
| VC1 | 3.77ab | 23.48b | 4.12b |
| VC2 | 3.61ab | 25.00a | 4.76a |
| BM1 | 3.66ab | 22.87b | 3.70c |
| BM2 | 3.57ab | 21.90b | 3.90c |
| VC2–BM2 | 3.85a | 24.20a | 4.50a |
| C | 3.54b | 19.24c | 3.38d |

Means followed by different letters indicate significant differences (Fisher $p < 0.05$), $n = 3$.

## 4. Conclusions

Particulate organic carbon was more sensitive than other soil properties to detect the effect produced by the application of different amendments, while fulvic acid was modified when both amendments were applied at the higher dose. Respiration was significantly high at larger doses of both amendments. Bulk density showed lower values whenever compost was incorporated. Electrical conductivity showed an increment after amendment application, and may serve as a warning against potential risks of salinization in the long term.

The effect of the amendments was also reflected in N and P concentration in beet aerial biomass, though the crop yield was only incremented in VC2–BM2. Combining compost, vermicompost and bone meal was the best option to achieve an improvement both in most of soil properties evaluated and crop production parameters.

**Table 3**
Soil physical and chemical properties measured after 132 days from amendment application. VC1: vermicompost–compost (mix 1:1), 1 kg m$^{-2}$; VC2: vermicompost-compost (mix 1:1), 2 kg m$^{-2}$; BM1: bone meal, 0.05 kg m$^{-2}$; BM2: bone meal, 0.15 kg m$^{-2}$.

| Treatments | pH | EC (dS m$^{-1}$) | Pe (mg kg$^{-1}$) | N (g kg$^{-1}$) | CEC (cmol kg$^{-1}$) | BD (g cm$^{-3}$) |
|---|---|---|---|---|---|---|
| VC1 | 6.97 ns | 0.72b | 77.56a | 2.32c | 16.68b | 0.88ab |
| VC2 | 7.01 ns | 0.71b | 67.42b | 2.30c | 16.51b | 0.85b |
| BM1 | 6.98 ns | 0.74ab | 59.28c | 4.61a | 14.4b | 0.91a |
| 4.61 aBM2 | 7.02 ns | 0.77b | 70.75b | 4.86a | 17.55b | 0.91a |
| vc2–Bmn2 | 7.02 ns | 0.74ab | 79.49a | 3.56b | 23.04a | 0.87ab |
| C | 6.97 ns | 0.69c | 60.77c | 2.32c | 16.63b | 0.92a |

Means followed by different letters indicate significant differences (Fisher $p < 0.05$), $n = 3$.

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