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Assessment of soil properties, plant yield and composition, after different type and applications mode of organic amendment in a vineyard of Mendoza, Argentina

Evaluación de propiedades edáficas químicas, biológicas, rendimiento y composición vegetal en un viñedo de Mendoza (Argentina) con diferentes tipos y modos de aplicación de abono orgánico

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Abstract

Research on grapevines has indicated that organic amendment application (OAA) increases the nutrient content of soil and plant tissue. Microbial functional groups are extensively used as soil fertility indicators because they are highly sensitive to changes in climatic and management conditions and they accurately represent entire biological processes. The goal of the present study was to evaluate the interactive effects of OAA on microbiological and chemical properties of soil and plants of a vineyard in Mendoza, Argentina. The following factors were evaluated: type of organic amendment (compost or vermi compost), application mode (surface or buried) and frequency of application (one or two applications). The field experiment was carried out using a factorial randomized complete block design. The following soil parameters were analyzed before and after OAA: microbial abundance related to the carbon and nitrogen cycle, total microbial activity, salinity and fertility. Yield, pruning weight, trunk diameter and nutritional variables of the vine were determined at the end of the assay. The results showed that microorganisms were not affected by the type of amendment, the application method or frequency. After OAA, the total abundance of microorganisms was similar, and soil salinity was not affected. Phosphorus depended on the strategy or combinations. Total phosphorus in petioles was higher after one or two buried applications (0.43% and 0.39%, respectively). In conclusion, OAA to irrigated soil of arid areas in Mendoza, Argentina, could be considered a promising supplementary treatment to increase the nutrient content in soil and vine.

Keywords

compost • vermi compost • microorganisms • grapevine • organic fertilizers

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Resumen

La aplicación de abonos orgánicos (AAO) en viñedos es una práctica frecuente para aumentar el contenido de nutrientes del suelo y planta. Los grupos funcionales microbianos se utilizan ampliamente como indicadores de fertilidad del suelo porque son altamente sensibles a las condiciones climáticas y culturales, y son los responsables de los procesos biológicos. El objetivo de este estudio fue evaluar si estas premisas son válidas en las condiciones de la experiencia en un viñedo de Mendoza (Argentina). Los abonos empleados fueron compost y vermicompost con dos tipos de aplicación (superficial y enterrado) y frecuencia de aplicación (una y dos aplicaciones). Los indicadores medidos en suelo fueron: abundancia microbiana relacionada con el ciclo del carbono y nitrógeno; actividad microbiana total; variables de salinidad y fertilidad. En el cultivo se midió rendimiento, peso de poda, diámetro del tronco y contenido de nutrientes. El diseño experimental fue factorial de bloques completos al azar. La abundancia y actividad microbiana no se vieron afectadas por el tipo de abono, el modo o la frecuencia de aplicación. La salinidad del suelo no fue afectada por AAO. El fósforo en el suelo, respondió a las diferentes estrategias combinadas de aplicación. El fósforo total en los pecíolos fue mayor después de una o dos aplicaciones enterradas (0,43% y 0,39%, respectivamente). Los resultados indican la estabilidad de la actividad y abundancia microbiana en relación con la aplicación de los abonos en un suelo con coberturas vegetales. La aplicación de OAA demostró efectos beneficiosos sobre los indicadores nutritivos del cultivo y sobre la economía de los recursos.

Palabras claves
compost • vermi compost • microorganismos • vid • abonos orgánicos

Introduction

Organic amendment applications (OAA) as a sustainable vineyard management aim to preserve soil fertility and non-renewable resources, as well as optimization of land use. Organic amendments used in agriculture are manure, compost and vermi compost. The latter two products are stable and obtained through a composting process. Addition of compost or vermi compost to soil increases organic matter (OM) and nutrient concentration (5, 7, 8, 10, 11, 27). Studies in grapevines have indicated that OAA increase the nutrient content of soil and plant (21, 22). The effect of this agronomic practice respect chemical and microbiology aspect of the soils, depends on the crop, type of amendment, dose, application and frequency. Microbial functional groups (MFG) are extensively used as soil fertility indicators because they are highly sensitive to changes in climatic and management conditions, and they accurately represent entire biological processes. For example, dynamics of nitrogen availability can be precisely determined by measuring abundance of nitrifiers and nitrogen-fixing microorganisms.

In contrast, ammonifiers do not unanimously respond to changes produced in soil because their population is very heterogeneous (1).

Despite the low OM of soils in Mendoza, Argentina, there is limited information about the effects of OAA on soil properties and grapevine growth and yield. Composting and vermicomposting could be a viable recycling strategy for agricultural and industrial organic residues. As regards vermicomposting, earthworm activity results in stabilized OM that differs from the initial substrate.

The end product has a fine particulate structure, a high nutritional value and a great diversity of microorganisms (6, 26). A local study with vermi compost and compost of the same original material did not demonstrate any difference in nutrition or microorganism abundance (2). Application of organic amendments is usually in holes or furrows near the plant roots (9). Phosphorus is a nutrient required by the plant, but in calcareous soils it is rapidly transformed into compounds unavailable for the plant (12, 16).

However, Martínez and Nazrala (1968), concluded that surface application of this element was optimal for soil fertility. Other studies have demonstrated positive effects of compost mulch applications on soil fertility and vineyard quality (21).

Morlat (2008), assayed the response of vineyard nutrients after several years of OOA to determine an effect of consecutive applications.

The goal of the current study was to assess the effect of different organic amendments on the microbiological and chemical properties of soil and plants of a vineyard in Mendoza, Argentina.

The type of amendment (compost *vs.* vermicompost), application technique (surface *vs*. buried application) and application frequency (one *vs*. two applications) were assayed for their effect on chemical and microbiological characteristics of the soil and on grape plant growth and yield.

Materials and Methods

Experimental site and soil characteristics

The study was carried out in a vineyard located in Mendoza, Argentina (32°35' S and 68°31' W) during two consecutive growing seasons. The average annual precipitation of the experimental site is 245 mm and the average temperature in January is 28.9°C. The vineyard was planted with *cv. Sauvignon Blanc* in 1986 using a typical planting density of 2.5 m between plants and rows, which have a north-south orientation. Plants were guided by a horizontal canopy training system ("parral") and single Guyot pruned with 30 buds per plant. Vines were surface-irrigated and the inter-row areas were planted with cover crops: *Avena sativa*, *Hordeum vulgare* and *Vicia sativa*.

The cover crops were sown in winter and they were cut at the end of the season. In summer, growth of spontaneous vegetation covered the inter-rows. Soil was classified as Typic Torrifluvents with a silt loam texture, mixed, calcareous, thermal and it belongs to the *Las Compuertas* serie (24, 25).

Experimental design and treatments

The field experiment was carried out using a randomized complete block design with three factors and four replicates. Blocks were oriented so that the energy gradient was perpendicular to the irrigation factor. Homogeneity of the plants was measured through the trunk diameter. The following factors were applied:

- Type of organic amendment: compost (C) and vermi compost (V).
- Application mode: surface (S) and buried (B).
- Frequency of application: one and two applications.

Treatments resulted from combinations of the three factors. Each experimental plot corresponded to fifteen adjacent plants distributed throughout three consecutive rows. All measurements were performed on the five central vines. In addition, four control plots were left without OAA.

The piles were formed with chicken manure and poplar sawdust to standardize the C/N ratio to 30.

The piles were 1.50 m high and 30 m long. Temperature and humidity of the piles were maintained at 50°C and 50%, respectively, trough regular aeration and irrigation. After 60 days, the piles were divided into two, each one, 20 m long, 1 m wide and 0.35 m high.

One half was left to continue with the same maturation process (composting) and the other half was placed in vermicomposting beds for maturation. Vermicomposting beds were inoculated with approximately 30,000 worms m^{-2} (*Eisenia foetida*) and irrigated to maintain humidity at approximately 80%.

Composting beds were harvested after 120 days and vermicomposting beds after 180 days, respectively. Both products were sieved (2mm) and packed until application (table 1, page 21) (2).

Two application methods were assayed:
1- In buried, OAA was placed in a 20 cm deep furrow which was then covered with soil. Soil was furrowed and spread by a tractor equipped with a grading grid.
2- In surface, OAA was also placed in a furrow, but in this case it was manually covered with dry cover crop residues. The application rate in both cases waslow: 8 $Mgha^{-1}$.

The applications were performed one per year, for two consecutive years.

Soil sampling

Soil of each experimental plot was sampled once prior to each OAA (one per year, for two consecutive years). Soil samples (500 g) were collected from the top layer (0-20 cm) of each plot. Field-moist samples were immediately transported to the laboratory, dried for 24 h and subsequently passed through a 2 mm sieve. Subsamples of each plot were stored at 5°C for microbiological, physico-chemical and chemical analyses.

Chemical soil analysis

The pH of the soil was determined in saturated soil paste and the electrical conductivity (EC) in saturated extract (22). Oxidizable organic carbon (OOC) was determined according to the Walkley-Black method. Total nitrogen (TN) was measured using the Kjeldahl method. Available phosphorus (P) was extracted from water through bubbling with carbon dioxide and quantified colorimetrically using ascorbic acid supplemented with molybdate. Exchangeable potassium (K) was extracted with 1 M ammonium acetate, pH 7. All methods have been previously described by Page *et al.* (1982).

Microbiological soil analysis

Abundance of nitrifiers, ammonifiers and cellulolytic microorganisms was measured by the most probable number method in specific liquid culture media. Saccharolytic and nitrogen-fixing microorganisms (NFO) were determined by plate counting (3). Total microbial activity (TMA) was determined by soil respiration (4).

Table 1. Chemical and microbiological characteristics of compost and vermicompost obtained from a mixture of chicken manure + poplar sawdust and shavings.

Tabla 1. Características químicas y microbiológicas de compost y vermicompost obtenidos de una mezcla de cama de pollo y aserrín.

	Compost	Vermicompost
Humidity (%)	48.9	57.6
Organic matter (%)	25.7	29.0
Total Nitrogen (g kg^{-1})	17.3	16.2
Total Phosphorus (g kg^{-1})	15.0	15.4
Total Potassium (g kg^{-1})	3.5	1.9
Total Sodium (g kg^{-1})	4.1	3.5
Total Calcium (g kg^{-1})	135.2	114.9
Total Magnesium (g kg^{-1})	9.4	7.3
Nitrate as nitrogen (mg kg^{-1})	965.6	809.4
Ammonium as nitrogen (mg kg^{-1})	39.5	28.4
Total Carbon/Total nitrogen	8.6	10.4
Electrical conductivity (1:5) (dS m^{-1})	1.4	0.8
pH (1:5)	7.13	7.00
Saccharolytic microorganisms (log_{10} g^{-1})	0.48	0.30
Cellulolytic microorganisms (log_{10} g^{-1})	3.65	2.78
N_2-Fixing microorganisms (log_{10} g^{-1})	0.00	2.97
Ammonifying microorganisms (log_{10} g^{-1})	3.15	2.48
Nitrifying microorganisms (log_{10} g^{-1})	2.31	0.00

Vine growth and yield parameters

During the harvest at the end of the second growth period, clusters from five plants of each experimental plot were extracted. During dormancy, pruning was weighed and the trunk diameter of the plants was measured.

Nutritional analysis of leaf petioles

Inveraison at the end of the second growth period, adult and healthy leaves located between the fifth and seventh node were extracted from the plant. Total nitrogen was analyzed using the Kjeldahl method. Total phosphorus (P) was measured colorimetrically and K was determined using atomic absorption spectroscopy (AAS).

Statistical analysis

Data analysis was conducted with analysis of variances (ANOVA) using INFOSTAT software version 2010. Main effects and interactions were assessed for significance levels, and Fisher's LSD test was used to calculate differences between means.

Results

Soil parameters

Before OAA, soil ammonifiers were dominant, followed in number by saccharolytic and cellulolytic microorganisms and, to a lower degree, nitrifiers; also soil respiration was low before OAA (table 2, page 23). The soil had a sandy loam texture, a slightly alkaline pH, was not saline and presented no sodium or chloride toxicity risk (table 3, page 24). Initial fertility was satisfactory in TN content, high exchangeable K level, but low available P content. Soil OM was relatively high compared to normal values of soils in the area, as result probably, of the permanent plant cover (table 4, page 25).

Biological and chemical characteristics after OAA

Microorganisms were not affected by the type of amendment, the application method or frequency of application. After OAA, the total microorganisms abundance was similar between them, while at the beginning of the assay, ammonifiers were dominant. Soil salinity was not affected by OAA and, EC and chloride content did not increase after OAA.

The compost and vermi compost used in the experiment were slightly saline and the application dose was low (table 1, page 21).

Available P of the soil differed among the type of amendment and application procedure combinations. It was observed that this nutrient was in the lowest content in buried compost (4.00 mg kg^{-1}) (table 4, page 25, and figure 1, page 26).

Vine productivity

The yield vine productivity (table 5, page 27), was satisfactory in all treatments respect to the normal yield of high quality grapevine varieties. With regard to the application method, pruning weight of plants that had received surface compost application (2.13 kg pl^{-1}) was higher than that of plants after buried compost (1.49 kg pl^{-1}). Contrary, the trunk diameter was larger in plants that had received a single buried vermi compost application (figure 2, page 29; table 5, page 27).

Total K measured in leaf petioles was 15% higher ($p=0.0072$) in plots with amendment applications than in plots without it (control plots).

Total P content was higher in one and two buried applications (0.43% and 0.39%, respectively) compared to one surface application (table 4, page 25 and figure 1, page 26). A significant interaction was observed between the application method and frequency.

Table 2. Abundance of soil microorganisms (mo's) and microbiological activity before and after OAA (means ± SD, n = 4; Fisher's LSD Test $p \leq 0.05$).

Tabla 2. Abundancia de microorganismos de suelo y actividad microbiológica, antes y después de la AAO (valor medio ± desviación estándar, n = 4; Fisher Test $p \leq 0,05$).

	Saccharolytic Mo's (log_{10} g^{-1})	**Cellulolytic Mo's (log_{10} g^{-1})**	**N_2-Fixers (log_{10} g^{-1})**	**Ammonifiers (log_{10} g^{-1})**	**Nitrifiers (log_{10} g^{-1})**	**SR ($mgCO_2 g^{-1} week^{-1}$)**
Before OAA	5.18 ± 0.25	1.47 ± 0.56	5.94 ± 0.28	9.42 ± 0.15	0.99 ± 0.38	0.26 ± 0.04
Control	6.06 ± 0.16	5.43 ± 0.58	7.13 ± 0.13	5.43 ± 0.58	1.89 ± 0.41	0.36 ± 0.09
Type (T)						
Compost	6.29 ± 0.41	3.85 ± 0.68	7.09 ± 0.40	4.79 ± 0.47	2.35 ± 0.80	0.41 ± 0.14
Vermicompost	6.34 ± 0.47	4.16 ± 0.71	7.26 ± 0.20	4.79 ± 0.67	2.27 ± 0.60	0.36 ± 0.16
Mode (M)						
Buried	6.25 ± 0.49	3.96 ± 0.80	7.20 ± 0.30	4.79 ± 0.65	2.25 ± 0.52	0.40 ± 0.14
Surface	6.38 ± 0.38	4.05 ± 0.61	7.16 ± 0.35	4.79 ± 0.50	2.36 ± 0.85	0.36 ± 0.16
Application frequency (F)						
One application	6.29 ± 0.33	3.87 ± 0.67	7.12 ± 0.30	4.71 ± 0.69	2.09 ± 0.73	0.37 ± 0.15
Two applications	6.34 ± 0.53	4.14 ± 0.73	7.23 ± 0.35	4.87 ± 0.42	2.52 ± 0.60	0.40 ± 0.14
T	ns	ns	ns	ns	ns	ns
M	ns	ns	ns	ns	ns	ns
F	ns	ns	ns	ns	ns	ns
TxM	ns	ns	ns	ns	ns	ns
TxF	ns	ns	ns	ns	ns	ns
MxF	ns	ns	ns	ns	ns	ns
TxMxF	ns	ns	ns	ns	ns	ns

SR: Soil respiration, ns: not significant

SR: Respiración edáfica, ns: no significativa.

Table 3. Soil salinity and sodicity before and after OAA (means ± SD, n = 4; Fisher's LSD Test p ≤ 0.05).

Tabla 3. Salinidad y sodicidad edáfica antes y después de la AAO (valor medio ± desviación estándar, n = 4; Fisher Test p ≤ 0,05).

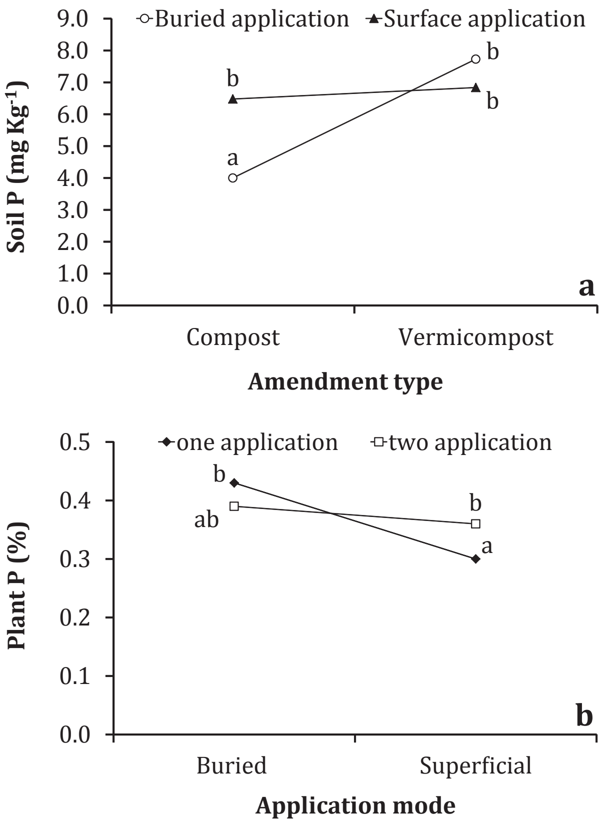
	EC (dSm^{-1})	pH	Chloride ($mmol_c\ L^{-1}$)	Sodium ($mmol_c\ L^{-1}$)	Calcium + Magnesium ($mmol_c\ L^{-1}$)	SAR
Before OAA	1.59 ± 0.81	7.50 ± 0.07	3.99 ± 0.92	4.97 ± 1.62	14.7 ± 10.29	1.94 ± 0.19
Control	1.39 ± 0.19	7.70 ± 0.13	4.51 ± 0.48	5.67 ± 1.08	16.76 ± 3.90	1.96 ± 0.20
Type (T)						
Compost	1.38 ± 0.29	7.71 ± 0.18	4.29 ± 1.14	4.76 ± 0.93	15.24 ± 2.96	1.78 ± 0.17
Vermicompost	1.35 ± 0.16	7.67 ± 0.16	4.61 ± 1.03	4.94 ± 0.95	15.93 ± 3.16	1.72 ± 0.18
Mode (M)						
Buried	1.35 ± 0.16	7.66 ± 0.15	4.29 ± 0.96	4.89 ± 0.87	15.86 ± 2.84	1.74 ± 0.20
Surface	1.39 ± 0.31	7.71 ± 0.19	4.61 ± 1.20	4.81 ± 1.01	15.30 ± 3.28	1.79 ± 0.16
Application frequency (F)						
One application	1.30 ± 0.16	7.75 ± 0.12b	4.12 ± 0.97	4.76 ± 0.88	14.70 ± 2.36	1.71 ± 0.16
Two applications	1.44 ± 0.29	7.63 ± 0.19a	4.78 ± 1.11	4.93 ± 0.99	16.46 ± 3.43	1.81 ± 0.20
T	ns	ns	ns	ns	ns	ns
M	ns	ns	ns	ns	ns	ns
F	ns	*	ns	ns	ns	ns
TxM	ns	ns	ns	ns	ns	ns
TxF	ns	ns	ns	ns	ns	ns
MxF	ns	ns	ns	ns	ns	ns
TxMxF	ns	ns	ns	ns	ns	ns

EC: Electrical Conductivity, SAR: Sodium Absorption Relation, ns: not significant; * significant (p ≤ 0.05)
Means followed by different letters within the same column are significantly different (P ≤ 0.05).
EC: Conductividad Eléctrica, SAR: Relación de Adsorción de Sodio; ns: no significativa; * significativo (p ≤ 0,05).
Valores medios seguidos de letras distintas indican diferencias significativas (P ≤0,05).

Table 4. Soil fertility before and after OAA (means ± SD, n = 4; Fisher's LSD Test P ≤ 0.05).
Tabla 4. Fertilidad edáfica antes y después de la AAO (valor medio ± desviación estándar, n = 4; Fisher Test P ≤ 0,05).

	Soil nitrogen ($mg\ kg^{-1}$)	Soil phosphorus ($mg\ kg^{-1}$)	Soil potassium ($mg\ kg^{-1}$)	SOM (%)
Before OAA	696.8 ± 114.9	1.86 ± 0.19	180.6 ± 24.9	1.20 ± 0.18
Control	554.94 ± 59.13	4.29 ± 1.73	211.00 ± 32.52	1.20 ± 0.26
Type (T)				
Compost	613.19 ± 154.52	5.19 ± 1.84	224.94±49.89	1.09 ± 0.30
Vermicompost	595.56 ± 147.36	7.41 ± 2.63	238.33 ± 46.89	1.09 ± 0.24
Mode (M)				
Buried	559.81 ± 126.06	5.85 ± 2.78	220.06 ± 48.31	1.01 ± 0.26
Surface	648.94 ± 160.09	6.66 ± 2.08	243.53 ± 46.47	1.16 ± 0.26
Application frequency (F)				
One application	590.31 ± 149.27	6.38 ± 1.99	228.38 ± 48.05	1.07 ± 0.30
Two applications	618.44 ± 151.84	5.85 ± 2.58	234.67 ± 49.69	1.11 ± 0.24
T	ns	*	ns	ns
M	ns	ns	ns	ns
F	ns	ns	ns	ns
T*M	ns	*	ns	ns
T*F	ns	ns	ns	ns
M*F	ns	ns	ns	ns
T*M*F	ns	ns	ns	ns

SOM: Soil Organic Matter; ns: not significant; * significant (p ≤ 0.05).
SOM: materia orgánica del suelo; ns: no significativo; * significativo (p ≤ 0,05).



Different letters indicate significant difference (Fisher's LSD Test, $p \leq 0.05$).
Letras diferentes indican diferencias significativas (Fisher Test, $p \leq 0{,}05$).

Figure 1. Interaction between amendment (compost or vermicompost) and application (buried or superficial) for available phosphorus (mg kg^{-1}) (a), and interaction between application (buried or superficial) and frequency (1 or 2 applications) for total plant phosphorus (%) (b). Data show means between two factors (n=8).

Figura 1. Interacción entre tipo de abono (compost and vermicompost) and modo de aplicación (enterrado y superficial) para fósforo disponible (mg kg^{-1}) (a), e interacción entre modo de aplicación (enterrado y superficial) y frecuencia de aplicación (1 y 2 aplicaciones) para fósforo total vegetal (%) (b). Los datos muestran el valor medio entre los dos factores mencionados (n=8).

Table 5. Yield, pruning weight, trunk diameter and nutrient content of vine (means ± SD, n = 4; Fisher's LSD Test P > 0.05).

Tabla 5. Rendimiento, peso de poda y diámetro de tronco de la planta de vid (valor medio ± desviación estándar, n = 4; Fisher Test P ≤ 0,05).

	yield (kg ha^{-1})	**pruning weight (kg plant^{-1})**	**trunk diameter (cm)**	**total nitrogen (%)**	**total phosphorus (%)**	**total potassium (%)**
Control	5762 ± 2265	1.18 ± 0.57	6.53 ± 0.38	0.76 ± 0.08	0.32 ± 0.04	1.83 ± 0.29
Type (T)						
Compost	7117 ± 2028	1.81 ± 0.80	6.80 ± 0.58	0.75 ± 0.04	0.35 ± 0.07	2.08 ± 0.22
Vermicompost	7577 ± 2622	1.88 ± 0.82	7.05 ± 0.70	0.75 ± 0.06	0.37 ± 0.08	2.07 ± 0.18
Mode (M)						
Buried	7265 ± 2403	1.77 ± 0.80	7.03 ± 0.63	0.74 ± 0.05	0.41 ± 0.05	2.09 ± 0.21
Surface	7428 ± 2304	1.92 ± 0.81	6.82 ± 0.67	0.77 ± 0.06	0.33 ± 0.08	2.06 ± 0.18
Application frequency (F)						
One application	6790 ± 2066	1.85 ± 0.82	7.04 ± 0.69	0.76 ± 0.05	0.35 ± 0.09	2.04 ± 0.21
Two applications	7904 ± 2484	1.84 ± 0.80	6.81 ± 0.60	0.75 ± 0.06	0.38 ± 0.04	2.12 ± 0.17
T	ns	ns	ns	ns	ns	ns
M	ns	ns	ns	ns	*	ns
F	ns	ns	ns	ns	ns	ns
T*M	ns	*	ns	ns	ns	ns
T*F	ns	ns	*	ns	ns	ns
M*F	ns	ns	*	ns	*	ns
T*M*F	ns	ns	ns	ns	ns	ns

ns: not significant; * significant ($p \leq 0.05$).

ns: no significativo; * significativo ($p \leq 0,05$).

Discussion

Biological soil characteristics

After OAA, the microorganisms had similar populations, which agrees with results obtained by Filippini *et al*. (2012), in plots cultivated with garlic.

The initial high quantity of ammonifiers in this study would indicate a major mineralization of the soil organic nitrogen. As a result, available ammonium would increase, which could encourage growth of different microorganisms, but especially nitrifiers (20).

Consequently, after OAA soil microorganisms increased in number, except for ammonifiers.

According to Noé and Abril (2008), variations in the abundance of microorganisms after one year were closely related to the climatic conditions and physiological characteristics of each MFG.

Abril (2003) stated that ammonifiers are not sensitive to changes in soil because they are an heterogeneous functional group whereas other authors observed that this population decreased after one year of plant residues decomposition or by fertilizers application (17).

Soil respiration did not show any difference among the factors assayed (table 2, page 23). Soil respiration levels were similar to soil with low microbial activity and soils with conventional tillage (19).

An increase in soil respiration would be controlled by the increased of microbial abundance after OAA. Cover crops could periodically provide OM and stimulate microbial activity in the soil, but the effect of the application of organic fertilizers is negligible.

Chemical soil characteristics

In addition to the low content of OM, soil in Mendoza presents a high risk of salinity and sodicity. After OAA, saline conditions stayed within acceptable levels indicating that this practice could be successful in these soils. At the end of the experiment, the pH only decreased in plots that received organic amendments, but the difference was not significant compared with normal parameters of calcareous and arid soils. This means that OAA to these soils would not affect soil alkalinity or acidity (table 2, page 23).

Available P, a soil fertility parameter, showed higher concentrations in soils after organic amendment when compared to initial values. This effect has also been detected by other authors (27) and in this case, this nutrient could be considered a sensitive indicator of OAA.

Surface OOA showed higher levels of available P in soil close to the sampling time, while buried applications increased foliar P. It is difficult to deduce whether surface applications would increase available P in the soil so that the plant would be able to absorb it after buried amendment and prior to soil sampling. Organic matter did not increase after the application; soil OM and nitrogen were not affected by the type, methodology or application frequency of the amendment.

Feasible explanations could be an increase in soil respiration, an augmented microbial abundance after OAA, or a high mineralization as a consequence of high temperature of arid soils (10, 17). Because changes in soil are generally long-term effects, an increase in soil OM could be detected after several years of repeated applications or in soils without cover crops initially.

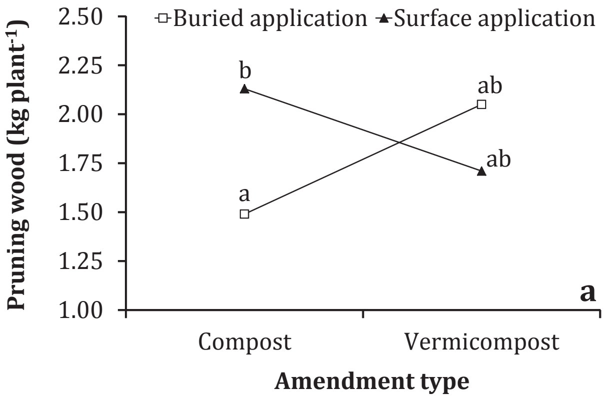
Nutrients, vine growth and yield

After OAA, higher concentrations of available P in soil and plants were measured. The greater uptake of P could result from P mineralization near the roots, especially after the buried method of application (one or two applications of buried vermi compost). This suggest that could be a correlation between variations in the plant nutritional status produced by OAA and intrinsic chemical soil characteristics or a change in physical soil conditions (15, 21, 22).

The results show that buried application was more favorable to the availability of P and its subsequent absorption by plants (table 5, page 27).

Pinamonti (1998) observed a higher concentration of exchangeable K in soil and likewise of the total potassium content in leaves after OOA.

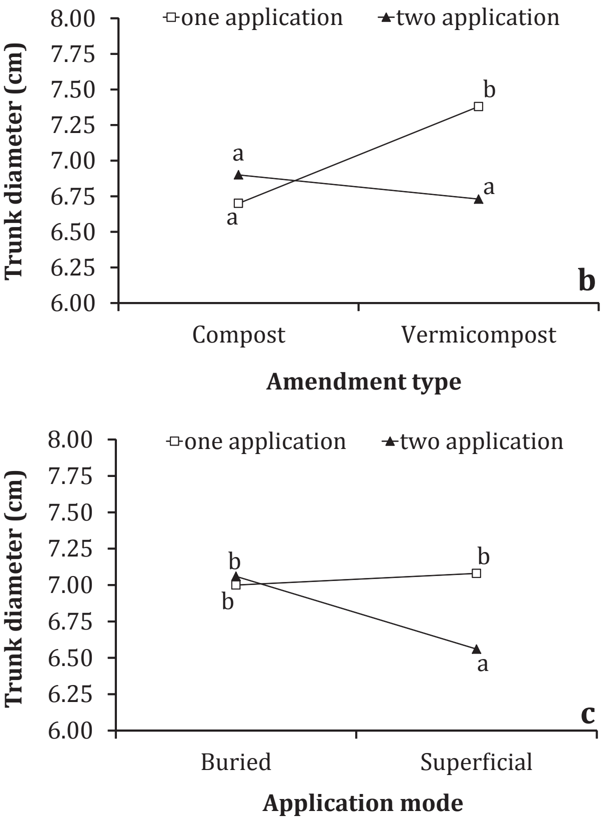
The benefits of surface compost applications significantly affected the pruning weight and so plant growth (figure 2). Nguyen *et al.* (2013), found an increase in pruning weight with mulched compost applications. Therefore, surface application would favor plant growth.



Different letters indicate significant difference (Fisher's LSD Test, p ≤ 0.05).
Diferentes letras indican diferencia significativa (Fisher's LSD Test, p ≤ 0,05).

Figure 2. Interaction between amendment (compost or vermicompost) and application (buried or superficial) for pruning weight (kg plant $^{-1}$) (a). and application frequency (one or two applications) for trunk diameter (cm) (b). interaction between application (buried or superficial) and application frequency (one or two applications) for trunk diameter (cm) (c). Data show means between two factors (n = 8).

Figura 2. Interacción entre tipo de abono (compost and vermicompost) y modo de aplicación (enterrado y superficial) para peso de poda (Kg planta^{-1}) (a) y frecuencia de aplicación (1 y 2 aplicaciones) para diámetro de tronco (cm)(b). la interacción modo de aplicación (enterrado y superficial) y frecuencia de aplicación (1 y 2 aplicaciones) para diámetro de tronco (cm). c. Los datos muestran el valor medio.



Different letters indicate significant difference (Fisher's LSD Test, $p \leq 0.05$).
Diferentes letras indican diferencia significativa (Fisher's LSD Test, $p \leq 0,05$).

Figure 2. cont. Interaction between amendment (compost or vermicompost) and application (buried or superficial) for pruning weight (kg plant^{-1}) (a). and application frequency (one or two applications) for trunk diameter (cm) (b). interaction between application (buried or superficial) and application frequency (one or two applications) for trunk diameter (cm) (c). Data show means between two factors (n = 8).

Figura 2. cont. Interacción entre tipo de abono (compost and vermicompost) y modo de aplicación (enterrado y superficial) para peso de poda (Kg planta^{-1}) (a). frecuencia de aplicación (1 y 2 aplicaciones) para diámetro de tronco (cm) (b). la interacción modo de aplicación (enterrado y superficial) y frecuencia de aplicación (1 y 2 aplicaciones) para diámetro de tronco (cm). c. Los datos muestran el valor medio.

Conclusion

After organic amendment to a vineyard with cover crops, soil microorganisms were not affected by the type of amendment, the application method or application frequency.

Before OAA, ammonifiers were predominant, but after OAA, abundance of total microorganisms was similar. Presence of cover crops in the vineyard may have played a key role in the absence of differences in microbial activity. Phosphorus in plants improved after buried applications, because the treatment facilitated absorption of more available P from the soil.

Vine nutrition and plant growth were more sensitive to the different application strategies (type, form and frequency of application) than microbiological soil properties.

The low risk of soil salinity would be another advantage of the use of stabilized organic amendment.

Finally, OAA to irrigated soils of arid areas in Mendoza, Argentina, could be considered a promising supplementary treatment to increase the nutrient content in soil and vines.

References

1. Abril, A. 2003. Are soil microorganisms good indicators of land-use impact in ecosystems? [¿Son los microorganismos edáficos buenos indicadores de impacto productivo en los ecosistemas?]. Ecología Austral. 13(2): 195-204.
2. Abril, A.; Noe, L.; Filippini, M. F.; Cony, M.; Martinez, L. 2011. Microbial dynamics and fertility characteristics in compost from different waste and maturation processes. The Open Agriculture Journal. 5: 19-29.
3. Alef, K.; Nannipieri, P. 1995. Methods in applied soil microbiology and biochemistry. London; San Diego: Academic Press.
4. Anderson, J. 1982. Soil respiration. Miller, A. R.; Keeney, D. (Eds.). Methods of Soil Analysis. Vol 2. Chemical and Microbiological properties. American Society of Agronomy and Soil Science. Madison, WI. p 831-872.
5. Arancon, N. Q.; Edwards, C. A.; Bierman, P. 2006. Influences of vermicomposts on field strawberries: Part 2. Effects on soil microbiological and chemical properties. Bioresource Technology, 97(6): 831-840. Available in: http://doi.org/10.1016/j.biortech. 2005.04.016.
6. Atiyeh, R.; Domínguez, J.; Subler, S.; Edwards, C. 2000a. Changes in biochemical properties of cow dung manure during processing by earthworms (*Eisenia andrei,* Bouche) and effects on seedling growth. Pedobiologia. 44(6): 709-724. Available in: http://doi.org/10.1078/S0031-4056(04)70084-0.
7. Atiyeh, R. M.; Subler, S.; Edwards, C.; Bachman, G.; Metzger, J. D. Shuster, W. 2000b. Effects of vermicomposts and composts on plant growth in horticultural container media and soil. Pedobiologia. 44(5): 579-590. Available in: http://doi.org/10.1078/S0031-4056(04)70073-6.
8. Beltrán Santoyo, M. A.; Álvarez Fuentes, G.; Pinos Rodríguez, J. M.; García Lopez, J. C.; Castro Rivera, R. 2017. Abonos obtenidos del compostado de heces de ganado bovino de leche *vs*. fertilizante en la producción de triticale (X *Triticum secale Wittmack*). Revista de la Facultad de Ciencias Agrarias. Universidad Nacional de Cuyo. Mendoza. Argentina. 49(1): 95-104.

9. Cony, M. 2005. Humus de lombriz: un abono orgánico de creciente uso en viticultura. El Vino y su Industria. 33: 84-92.
10. Filippini, M. F.; Abril, A.; Cony, M.; Noé, L.; Venier, M.; Cónsoli, D.; Vallone; R. 2012. Effects of organic amendement application on soil quality and garlic yield in Central-Western Argentina. The Open Agriculture Journal. 6: 1-8.
11. Gutiérrez-Miceli, F. A.; Santiago-Borraz, J.; Montes Molina, J. A.; Nafate, C. C.; Abud-Archila, M.; Oliva Llaven, M. A.; Dendooven, L. 2007. Vermicompost as a soil supplement to improve growth, yield and fruit quality of tomato (*Lycopersicum esculentum*). Bioresource Technology. 98(15): 2781-2786. Available in: http://doi.org/10.1016/j.biortech.2006.02.032.
12. Lipinski, V. 1978. Diagnóstico de deficiencia de fósforo en suelo del departamento de San Carlos, Mendoza. Tesis de Maestría. Universidad de Buenos Aires. Buenos Aires, Argentina.
13. Martínez, H.; Nazrala, M. 1968. Estudio tendiente a determinar la mejor forma de aplicación de estiércol y abonos químicos al viñedo. I Congreso Nacional Vitivinícola. Mendoza, Argentina. 1: 1-2.
14. Morlat, R. 2008. Long-term additions of organic amendments in a Loire Valley Vineyard. II Effects on root system, growth, grape yield, and foliar nutrient status of a *Cabernet franc* vine. American Journal Enology Viticulture. 59: 364-374.
15. Nguyen, T. T.; Fuentes, S.; Marschner, P. 2013. Effect of incorporated or mulched compost on leaf nutrient concentrations and performance of *Vitis vinifera* cv. Merlot. Journal of soil science and plant nutrition. 13(2): 485-497. Available in: https://dx.doi.org/10.4067/S0718-95162013005000038.
16. Nijensohn, L. 1991. Fósforo extraíble con agua carbonicada en el diagnóstico del nivel de fertilidad fosfórica en suelos aluviales regadíos. Actas de la II Jornada Nacional Fósforo del suelo. Asociación Argentina de la Ciencia del Suelo. 1: 32-36.
17. Noe, L.; Abril, A. 2008. Interacción entre calidad de restos vegetales, descomposición y fertilidad del suelo en el desierto del Monte de Argentina. Ecología Austral. 18(2): 181-193.
18. Page, A. L.; Miller, R. H.; Keeney, D. R. 1982. Methods of soil analysis Part 2 Chemical and Microbiological Properties. Madison, Wisconsin USA: American Society of Agronomy Inc, Soil Science Society of America Inc.
19. Pascual, J.; Garcia, C.; Hernandez, T.; Ayuso, M. 1997. Changes in the microbial activity of an arid soil amended with urban organic wastes. Biology and Fertility of Soils. 24: 429-434.
20. Paul, E. A.; Clark, F. E. 1989. Soil microbiology and biochemistry. San Diego: Academic Press.
21. Pinamonti, F. 1998. Compost mulch effects on soil fertility, nutritional status and performance of grapevine. Nutrient Cycling in Agroecosystems. 51(3): 239-248. Available in: http://doi.org/10.1023/A:1009701323580.
22. Ponchia, G.; Bozzolo, A.; Tateo, F.; Concheri, G. 2012. Compost Application in the vineyard and its influence on soil characteristics, vegetative and productive behaviour of grapevine. Acta Horticulture (ISHS). 938: 437-444.
23. Richards, L. 1962. Diagnóstico y rehabiliatación de suelos salinos y sódicos (Vol. Manual de). Riverside, California, USA.
24. Romanella, C. 1957. Los suelos de la región del Río Mendoza. Boletín de Estudios Geográficos. 4: 14.
25. SAGyP - INTA. 1990. Suelos de la República Argentina.
26. Tognetti, C.; Laos, F.; Mazzarino, M. J.; Hernandez, M. T. 2005. Composting *vs.* vermicomposting: A comparison of end product quality. Compost Science and Utilization, 13(August 2014), 6-13. Available in: http://doi.org/10.1080/1065657X.2005.10702212.
27. Tognetti, C.; Mazzarino, M. J.; Laos, F. 2008. Compost of municipal organic waste: Effects of different management practices on degradability and nutrient release capacity. Soil Biology and Biochemistry. 40(9): 2290-2296. Available in: http://doi.org/10.1016/j.soilbio.2008.05.006.