SOIL CHEMICAL AND MICROBIAL PROPERTIES IN VINEYARDS UNDER ORGANIC AND CONVENTIONAL MANAGEMENT IN SOUTHERN BRAZIL[1]

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SUMMARY

Organic cropping systems with input of fresh organic matter can modify the physical and chemical properties of soils and consequently affect their biological composition. The purpose of this study was to determine the effects of juice grape (*Vitis labrusca* L.) management on the soil chemical and microbial properties of a sandy-textured Oxisol. In October 2006, soil was sampled from two vineyard experiments set up in 2000, and from a neighboring forest area. The following treatments were evaluated in a 2 x 2 x 2 factorial design: (i) organic (ORG) and conventional (CONV) vineyard managements; (ii) cultivars in rootstock/graft combinations: grafts Isabel and Bordô on rootstock IAC-766 and (iii) spatial heterogeneity (row and inter-row). Based on the analyses, the vineyard soils were separated in three groups (CONV, ORG/row and ORG/inter-row), which differed from the adjacent forest area. All microbial and chemical variables, except K, were modified in the vineyards. Rootstock/graft cultivar combinations affected the N microbial biomass and basal respiration (CO_2), while P, pH, Mg, micronutrients, and C microbial biomass were influenced by spatial heterogeneity. Soil Organic C (SOC) and microbial biomass in the rows and inter-rows were higher in the organic than the conventional vineyard management. In the rows under organic management, SOC was 172 % higher, C_{mic} 100 % and N_{mic} 223 % than in CONV. The same was observed in inter-rows, but to a lesser extent. The most relevant factors differentiating areas by changes in soil chemical properties, mainly

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SOC, and in microbial biomass were mainly caused by the vineyard management and soil spatial heterogeneity.

Index terms: microbial indicator, soil nutrients, soil quality, soil organic matter.

RESUMO: *ALTERAÇÕES NAS PROPRIEDADES QUÍMICAS E MICROBIANAS DE SOLOS CULTIVADOS COM VIDEIRAS SOB MANEJO ORGÂNICO E CONVENCIONAL NO SUL DO BRASIL*

*O cultivo orgânico com inclusão de material orgânico fresco altera propriedades físicas e químicas do solo e, com isso, pode resultar em modificações nas características biológicas deste. Assim, o objetivo deste estudo foi estudar os efeitos do manejo da videira (*Vitis labrusca *L.) sobre as propriedades químicas e microbianas do solo. Em outubro de 2006, amostras de solo foram coletadas de dois experimentos instalados em 2000 e de uma área adjacente com floresta. Os seguintes tratamentos foram avaliados em um esquema fatorial 2 x 2 x 2: (i) orgânico (ORG) e convencional (CONV); (ii) dos cultivares (IAC-766/Isabel e IAC-766/Bordô); e (iii) da heterogeneidade espacial (linha e entrelinha) sobre as propriedades químicas e microbianas de um solo arenoso. Foi observada a formação de três grandes grupos (CONV, ORG/linha e ORG/entrelinha), que se destacaram na área de floresta. As variáveis químicas e microbianas, com exceção do K, foram alteradas em relação aos manejos da videira. Houve efeitos do cultivar no N da biomassa microbiana e na respiração basal (CO_2). Também foram observados efeitos de heterogeneidade espacial do solo no C da biomassa microbiana e em atributos químicos, como P, pH, Mg e micronutrientes. No sistema orgânico da videira, aumentaram-se o carbono orgânico do solo (COS) e a biomassa microbiana na linha e entrelinha, em comparação com a videira convencional. Os aumentos foram de 172 % no SOC, 100 % no C_{mic} e 223 % no N_{mic}, na linha do orgânico. Os manejos da videira e a heterogeneidade espacial do solo foram os fatores mais relevantes no agrupamento (ou separação) das áreas devido às mudanças nos atributos químicos do solo, principalmente o COS, e na biomassa microbiana.*

Termos de indexação: Indicador microbiano, nutrientes do solo, matéria orgânica do solo qualidade de solo.

INTRODUCTION

Different cropping systems with input of fresh organic matter can trigger changes in the physical and chemical properties of soils and consequently affect their biological composition (Powlson & Brookes, 1987). Soil microbial density and biomass are widely used to measure variations in the effects of agricultural managements (Matsuoka et al., 2003; Balota et al., 2004; Ochiai et al., 2008) because they respond faster than chemical and physical variables.

According to the Brazilian Ministry of Agriculture, Livestock and Supply, Instrução Normativa número 07, an "organic" system is a management in which technologies are adopted that optimize the use of natural and socio-economic resources, with a view to minimize the dependence on non-renewable energy and eliminate the use of pesticides and other toxic substances, genetically modified organisms (GMO), or ionizing radiation (Brasil, 1999). In this study, practices are regarded as organic when based on applications of composted animal manure, green manure, slow-solubility fertilizers, mulches, cover crops, and on mechanical tillage instead of herbicides for weed control. Conventional soil management practices consist of applications of synthetic fertilizers and the use of herbicides for weed control while the integrated production system includes elements of both organic and conventional practices (Glover et al., 2000). Numerous studies reported that the use of non-conventional management forms, such as intercropping with legumes and grasses, increase grape productivity and improve fruit and soil quality (Rombaldi et al., 2004; Wutke et al., 2004) and that the incorporation of cover crops or other organic soil amendments significantly improve soil microbial properties under potato (Ochiai et al., 2008). These alternative cropping practices are considered promising to make agriculture more sustainable and increase yields (Glover et al., 2000; Probst et al., 2008). In an apple orchard, soil bulk density was reduced and biological soil properties improved in the organic compared to the conventional management, however, there were few significant differences in soil properties between the integrated and organic systems (Glover et al., 2000). Although these papers studied the effects of management on soil properties in the past, the contribution of this study was to examine the same soil, climate and cultivars in field experiments to compose a database for the monitoring of vineyard impacts in the south of Brazil, where this issue was poorly studied so far. Thus, the assumption in this study was that, even in the short term, the organic system differs from the traditional conventional vineyard management, mainly due to the practice of applying rich fresh plant residues to the soil. Consequently, the objectives of this study were to examine changes caused by juice grape management, based on some soil variables that are most responsive to farming practices and a comparison with the soil properties of an adjacent forest area.

MATERIALS AND METHODS

Site description

The study was conducted in two field experiments, organic (ORG) and conventional (CONV) vineyard managements, in September 2000, at the experimental station of Universidade Estadual de Maringá (UEM), Maringá, Paraná State, southern Brazil (23º 25' S; 51º 57' W; 580 m asl). According to Köppen's classification (http://koeppengeiger.vu-wien.ac.at), the climate is humid and subtropical (Cfa), with hot and rainy summers (December–March) and cold winters (June–July). Average annual temperature and rainfall are 25 °C and 1490 mm, respectively. Meteorological data were collected from the UEM station near the experimental site. The soil (Oxisol) was classified as a Typic Haplorthox (Soil Survey Staff, 1999) with a sandy texture, containing 206 g kg^{-1} clay, 27 silt and 767 sand, with a soil particle density of 2.65 g cm^{-3}. From each vineyard (ORG and CONV) and the adjacent forest area, seven sub-samples were taken from 0–10 cm, pooled for each area, dried and sieved (4 mm) for chemical analyses. As this is a medium-term field study, aiming at comparisons after two years of cultivation, the main soil chemical characteristics of the two vineyard managements and from the neighboring forest fragment were included (Table 1).

Vineyard management and organic amendments

The soil of the conventionally managed vineyard (CONV) was fertilized as recommended according to each crop phase (grape planting, growth and production) with regular annual amounts of NPK fertilizer (approximately: 60 kg ha^{-1} N, 12 kg ha^{-1} P, and 20 kg ha^{-1} K).

Spontaneous plants were controlled by desiccant herbicide (glyphosate) and hand weeding every two months. The vineyard under organic management (ORG) was managed according to the general rules for organic management. Soil P and K were supplied in the form of low-solubility fertilizers, such as thermophosphates and potassium sulfate, respectively. Other nutrients were supplied by liquid biofertilizers (fermented product of fresh manure and micronutrients). Cover crops were grown in the inter-rows in rotations of *Crotalaria spectabilis* Roth or *Canavalia ensiformis* L. in summer with black oat *Avena strigosa* Schreb in winter. Pests and diseases were controlled by organic compounds prepared according to procedures described elsewhere (Bettiol et al., 1997), according to the Brazilian legislation, as established by the Instrução Normativa número 07 (Brasil, 1999). Spontaneous plants in the rows and inter-rows were controlled by a soil cover of sugarcane bagasse (2 kg m^{-2}) in the first year only and by hand hoeing when necessary.

Experimental design and soil sampling

The experiment was arranged in a completely randomized block design with four replications and treatments in a factorial design (2 x 2 x 2). The plot size was 16 m^2 (4 x 4 m) and contained four plants. For the statistical analysis, the following treatments were considered as factors: factor 1 (V) = organic (ORG) and conventional (CONV) vineyard managements; factor 2 (G) = graft cultivars Isabel and Bordô on an intermediate-vigor rootstock (IAC-766); and factor 3 (SH) = sampling points row and inter-row, for spatial heterogeneity evaluation. Only for multivariate analysis, an adjacent area (deciduous tropical forest fragment in regeneration) was also evaluated, located between the two experimental fields (approximately 120 x 2000 m).

Table 1. Soil chemical characteristics in the vineyards under organic and conventional management and an adjacent forest area

Soil(1)	pH $CaCl_2$(2)	SOC(3)	P	K	H + Al	Ca^{2+}	Mg^{2+}
		g kg^{-1}	mg dm^{-3}		$cmol_c$ dm^{-3}		
Organic	5.3	17	52	0.52	2.8	4.2	1.7
Conventional	5.4	16	22	0.25	2.5	1.8	0.9
Forest	4.0	20	8	0.11	5.0	0.7	0.3

(1) Soil was sampled from the 0–10 cm layer two years before this study, in March 2004. (2) pH: 0.01 mol L^{-1} $CaCl_2$. (3) Soil organic carbon (SOC): Walkley and Black; P and K: Mehlich-1; H + Al: SMP; Ca^{2+} and Mg^{2+}: 1 mol L^{-1} KCl. Values are means of six repetitions.

Soil from the two experimental vineyards (ORG and CONV) was sampled in early October 2006 from the rows (between plants) and in-between the row as well as from an adjacent forest area for comparison. The top soil layer (0–10 cm) was sampled at eight randomly chosen points of each plot and mixed to form a composite sample. In the laboratory, each bulked, field-moist sample was mixed and split into two subsamples for chemical and microbial analyses and maintained at 6–8 °C.

Soil chemical analyses

Soil subsamples were air-dried, sieved (< 2 mm) and chemically analyzed according to the routine laboratory procedures (Pavan et al., 1992). Soil pH was determined potentiometrically using 0.01 mol L^{-1} $CaCl_2$ (at a 1:2.5 ratio of soil : $CaCl_2$ solution). The total soil organic carbon (SOC) concentration was evaluated by the Walkley–Black procedure of potassium dichromate–sulfuric acid oxidation (Nelson & Sommers, 1982). Phosphorus and K were extracted with Mehlich-1 solution, and determined colorimetrically by UV–visible spectrophotometry and flame photometry, respectively. Exchangeable Ca^{2+} and Mg^{2+} were extracted with a non-buffered 1 mol L^{-1} KCl solution and measured by atomic absorption spectrophotometry. Potential acidity (H + Al) was determined using the SMP single-buffer method (McLean, 1982). Concentrations of Cu, Zn, and Fe were determined in soil samples after 0.01 mol L^{-1} HCl extraction and analyzed by inductively coupled argon plasma spectrometry (ICP-AES).

Soil microbial analyses

Field-moist soil samples were sieved (< 4 mm) and stored in the dark at 6–8 °C until analysis less than five days later. The gravimetric water content was determined by drying sub-samples in an oven for about 48 h at 105 °C. Soil microbial biomass C and N contents (C_{mic} and N_{mic}) were determined by a modified chloroform fumigation–extraction method, according to Vance et al. (1987) for C_{mic} and to Brookes et al. (1985) for N_{mic}. Briefly, 20 g of moist soil were fumigated with alcohol-free chloroform in closed desiccators for 24 h and extracted with 0.5 mol L^{-1} K_2SO_4. A second unfumigated set of soil subsamples was extracted under similar conditions. The C and N contents extracted by K_2SO_4 from the $CHCl_3$-fumigated and unfumigated soils were estimated by potassium dichromate-sulfuric acid oxidation according to the Walkley-Black procedure described by Nelson & Sommers (1982) and Bremner & Mulvaney (1982), respectively. Microbial biomass was calculated based on the differences between C and N extracted from the fumigated and unfumigated soil samples using conversion factors $KC = 0.33$ for C_{mic} (Sparling & West, 1988) and $KN = 0.54$ for N_{mic} (Brookes et al., 1985). Basal respiration was obtained from the measurement of CO_2 released from the unfumigated soil using NaOH to trap CO_2 followed by flow injection analysis for electric conductivity (Balota et al., 2004). The microbial metabolic quotient (qCO_2) was calculated by dividing basal respiration by the C_{mic}, expressed as μg g^{-1} h^{-1} C-CO_2 in soil.

Statistical analyses

Principal component analysis (PCA) was performed based on Pearson´s correlation matrix of soil chemical and microbial independent variables from the two vineyards and an adjacent forest area to investigate the most relevant variables. The treatments were grouped based on the variance maximum of *eigenvalues* by discriminant analysis. Correlations between all factors and their interactions were studied by Pearson's correlation matrix and were represented graphically, based on the complete linkage cluster analysis, to assess the similarity of forest and vineyard soils. Only for the independent chemical and microbial soil variables, an exploratory data analysis of two-way ANOVA (graft and sampling points) was conducted by a general linear model (GML) within each experiment (ORG and CONV) to check the equality of variance according to the Cochran & Cox (1966) procedure. Thereafter, the effects in the nested mixed model were tested by three-way analysis of variance (ANOVA) with the following group factor 1= vineyard managements, factor 2 = cultivars and factor 3 = spatial heterogeneity as main fixed effects. The procedure of Tukey's honestly significant difference (HSD) was applied to compare means. The water content data were arcsine-transformed to obtain normal distributions and homogeneity of variances and all chemical and microbial independent variables were also natural-log (ln) transformed, except for soil pH, Mg and K. All statistical analyses were performed with SAS® for Windows. Version 9.1 (SAS, 1998), with a significant at 5 % level.

RESULTS AND DISCUSSION

Principal component analysis

The principal component analysis (PCA) indicated that the first two axes based on eigenvalues, considering microbial and chemical parameters, accounted for 87.9 % of the variation. The X-axis 1 (66.6 %) was characterized by C_{mic}, N_{mic}, basal respiration (C-CO_2), P, SOC, pH, Ca, Mg, K, Cu, Zn, and Fe, while the potential acidity (H + Al) values were combined as the Y-axis 2, accounting for 21.3 % of the variance. Based on the PCA biplot of the chemical and microbial properties, the treatments of the two vineyards and the forest were grouped into four main groups. First, the CONV treatments (cultivars and soil spatial heterogeneity) were placed in the negative quadrant of the two axes; and secondly, the forest soil proprieties located in the negative quadrant of X-axis 1 and in the positive quadrant of Y-axis 2. Conversely, the ORG were separated in two subgroups, evidencing the spatial heterogeneity (Figure 1a).

Cluster analysis indicated the same grouping as PCA analysis. However, the most discriminating character and Pearson´s coefficient of correlation (similarity) indicated that vineyard management was the most significant factor. In the conventional treatments, neither cultivars nor sampling positions were clearly grouped (Figure 1b).

It was assumed that C input derived from cover crops in-between the rows may also have contributed to the difference in microbial biomass between the two vineyard managements. For example in organic farming with perennial crops, manure application and management of spontaneous plants between rows can alter several soil properties (Flieβbach et al., 2007; Ochiai et al., 2008; Probst et al., 2008) and the cover crop sustained greater values of potential C availability (Steenwerth & Belina, 2008). In contrast, in a long-term field trial of potato and winter rye, the green manure had slightly negative effects on the soil organic C content and no effects on crop yield, microbial biomass of C, N, and P, but positive effects on ergosterol in comparison with the farmyard manure treatment (Heinze et al., 2011).

Soil chemical properties

The effect of triple interaction of vineyard (V) and cultivars (G) and spatial heterogeneity (SH) (V*G*SH) was observed in soil pH and Mg values (Table 2). Soil pH under forest was 3.9 and, due to liming of the soil cultivated with grape plants, varied as expected from 5.02 to 6.90 in the CONV-inter-rows and ORG-rows, respectively. The concentrations of Mg^{2+} was higher in soil under ORG than in CONV vineyard and the values ranged from 3.6 to 0.7 $cmol_c$ dm^{-3} of soil, respectively.

On the other hand, P, Zn and Fe soil concentrations were affected by the SH factor; and Ca influenced by the V factor, and K showed no significant differences by the factors. Soil P concentrations varied from 100 to 335 mg dm^{-3} and from 35 to 141 mg dm^{-3} in the ORG and CONV managements, respectively, which differ significantly among the vineyards and soil spatial heterogeneity (Table 2).

The Cu, Zn, and Fe levels in the soils were higher under ORG management than in the forest or under CONV management. Because these values were greater than the current thresholds for sludge residues and their by-products in Brazil (CONAMA, 2006), these heavy metals must be monitored in the soil in long-term experiments under tropical conditions. Soil chemical analysis indicated that after six years of ORG and CONV vineyard management soil fertility was different from undisturbed native vegetation. These changes probably occurred due to the establishment of the vineyard experiments, involving liming, organic composting, and fertilizer supplementation, increasing soil fertility.

As expected because liming had been applied to correct soil acidity, the soil samples from the forest soil (undisturbed native vegetation) had a lower soil pH than those from under the ORG and CONV vineyards. In the vineyard under CONV management the highly soluble, synthetic fertilizer applications, such as ammonium sulfate and urea, are mainly responsible for soil acidification.

Organic carbon and microbial and water content of the soil

The effect of triple interaction between vineyard management (V), graft cultivars (G) and spatial heterogeneity (SH) (V*G*SH) was not observed for SOC and microbial and water content of the soil. Graft

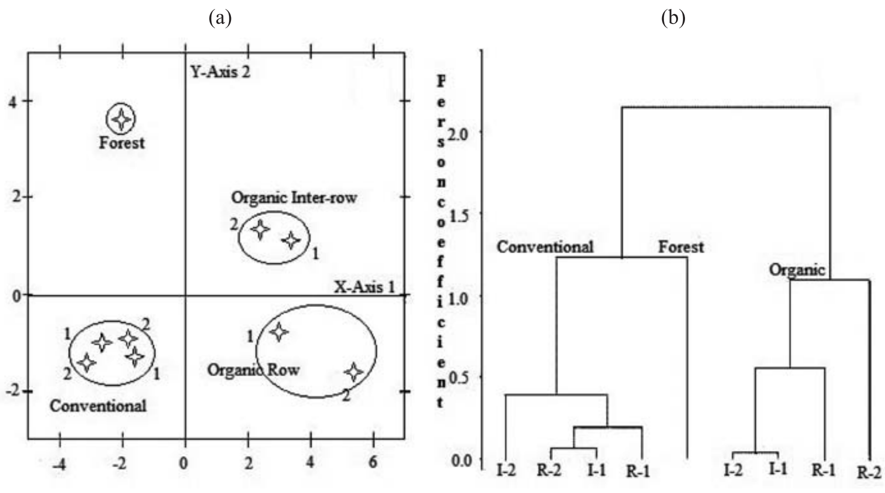

Figure 1. (a) Discriminant analysis by PCA. (b) Cluster analysis. R: Row, I: Inter-row; 1: Isabel cultivar, 2: Bordô cultivar.

Table 2. Selected chemical characteristics of soil in vineyards after six years of organic and conventional management and from an adjacent forest area

	Spatial heterogeneity	Graft	P	pH $CaCl_2$ (2)	H + Al	Ca^{2+}	Mg^{2+}	K^+	Cu	Zn	Fe
			mg dm^{-3}		cmol$_c$ dm^{-3} soil				mg kg^{-1} soil		
Organic	Row	Isabel	332	6.9	2.8	4.4	3.0	0.62	5.0	27.1	184.8
		Bordô	336	6.9	2.7	4.9	3.6	0.66	8.5	66.9	404.9
	Inter-row	Isabel	111	5.8	2.4	4.2	2.6	0.51	3.2	8.9	89.4
		Bordô	100	6.4	2.1	4.1	2.6	0.54	3.0	9.8	87.7
Conventional	Row	Isabel	141	5.6	2.9	2.5	0.9	0.21	4.3	10.0	93.1
		Bordô	103	5.3	3.0	2.1	0.8	0.22	3.7	7.2	69.0
	Inter-row	Isabel	50	5.2	2.4	2.1	0.8	0.21	3.1	6.4	31.0
		Bordô	35	5.1	2.7	2.1	0.7	0.19	2.7	4.6	28.8
		Forest	4(0.9)	3.9(0.2)	7.2(1.0)	1.2(0.7)	0.6(0.2)	0.14(0.03)	1.4(0.2)	1.7(0.4)	103.3(47)
			Probability levels of the three-way ANOVA								
Vineyards (V)			<.0001*	0.015*	0.0032*	<.0001*	<.0001*	0.610^{ns}	0.007*	<.0001*	<.0001*
Grafts (G)			0.089^{ns}	0.005*	0.7618^{ns}	0.685^{ns}	0.360^{ns}	0.590^{ns}	0.460^{ns}	0.499^{ns}	0.334^{ns}
Spatial he terogeneity (SH)			<.0001*	<.0001*	0.2339^{ns}	0.769^{ns}	0.0003*	0.063^{ns}	<.0001*	0.0004*	<.0001*
V*G			0.079^{ns}	0.005*	0.0234*	0.384^{ns}	0.017^{ns}	0.890^{ns}	0.060^{ns}	0.253^{ns}	0.176^{ns}
V*SH			0.615^{ns}	0.029*	<.0001*	0.722^{ns}	0.0001*	0.760^{ns}	0.033*	0.162^{ns}	0.438^{ns}
G*SH			0.610^{ns}	0.003*	0.1377^{ns}	0.304^{ns}	0.192^{ns}	0.913^{ns}	0.116^{ns}	0.299^{ns}	0.221^{ns}
V*G*SH			0.611^{ns}	0.030*	0.5368^{ns}	0.864^{ns}	0.037*	0.920^{ns}	0.123^{ns}	0.638^{ns}	0.214^{ns}
Coefficient variation (%)			12.11	2.30	8.86	22.01	12.11	19.10	18.34	31.01	8.81

Soil sampled from the 0–10 cm layer. Means of four replications. P and K by Mehlich extractor; pH by $CaCl_2$ 0.01 mol L^{-1}; exchangeable Ca, Mg and H + Al: by KCl 1 mol L^{-1}. *p*-values followed by ns: not significant by Tukey's test ($p < 0.05$). Data from forest soil were not included in the statistical analyses. Standard deviation in brackets; n=4.

cultivar (G) interaction with SH (G*SH) and V*G demonstrated significant effects on N_{mic}. The C_{mic} concentration was affected by V*SH and basal respiration (BR) by V*G. The microbial biomass values (C_{mic} and N_{mic}) were greater in the soil under ORG than in the soil under CONV management because of the greater organic matter input and maintenance of the soil water content (moisture), benefitting microorganism growth. The factor vineyard (V) affected the SOC values and factor SH influenced the water content. There were significant ($p < 0.05$) differences in the total SOC contents that ranged from 29.7 to 33.0 g kg^{-1} under ORG and from 9.9 to 11.6 g kg^{-1} in the CONV management. The average of soil total C under forest was 39.6 g kg^{-1} (Table 3). There was a reduction in the soil total carbon in both vineyards compared with that in the forest soil, except in-between the rows under ORG management. This increase was induced by the input of organic residues left on the soil surface, such as organic compounds and sugarcane "bagasse", and from the large amounts of shoot and root biomass produced by the cover crops. Organic farming practices increased soil C and organic matter compared with conventional farming due to organic supplementation (Marriott & Wander, 2006; van-Diepeninge et al., 2006). The low amount of SOC in the soils with history of manure application, even under organic management, was ascribed to restricted root growth or fast C mineralization (Wander et al., 2007).

There were significant differences between the factors vineyards and graft cultivars in basal respiration, with values from 0.97–1.15 mg g^{-1} h^{-1} C-CO_2 in soil in the ORG vineyard and 0.29–0.72 mg g^{-1} h^{-1} C-CO_2 in soil of the CONV vineyard. The vineyard managements had significant effects on soil microbial traits, however, the cultivar had significant effect on N_{mic} and CO_2 (basal respiration) and no significant effect of the sampling position was observed. The water content of the soil samples varied from 12.1 to 13.8 % in soils under ORG and from 4.9 to 9.5% under CONV management. The difference between the vineyards and soil spatial heterogeneity of this variable was significant ($p < 0.05$) and high (Table 3).

Our findings are in agreement with the results obtained earlier in the same experimental area, where higher microbial carbon was detected in the soil under ORG than under CONV management (Amaral, 2005). The same tendency was observed by Xavier et al (2006) in a study with "acerola" (*Malpighia emarginata*) under ORG and CONV in comparison with pasture and native vegetation. In general, organic cultivation is based on cover crops for nutrient recycling and weed control that increase soil organic matter. Increases

Table 3. Soil organic carbon (SOC), microbial biomass of carbon (C_{mic}) and nitrogen (N_{mic}), basal respiration (BR) and water content (%) of soils after six years under organic and conventional vineyard management and an adjacent (semi-deciduous subtropical) forest area

	Spatial heterogeneity	Grafts	SOC	C_{mic}	N_{mic}	BR	Water content
			g kg^{-1}	—— µg g^{-1} soil ——		µg g^{-1} h^{-1} C-CO_2 in soil	%
Organic	Row	Isabel	23	265	62	1.15	12.2
		Bordô	24	280	62	1.13	13.8
	Inter-row	Isabel	21	207	48	1.12	12.1
		Bordô	22	262	48	0.97	13.6
Conventional	Row	Isabel	9	139	21	0.72	9.5
		Bordô	8	160	16	0.33	8.8
	Inter-row	Isabel	9	124	21	0.56	7.8
		Bordô	7	86	13	0.29	4.9
		Forest	31(1)	255(17)	53(7)	0.49(0.1)	11.6(1)
			Probability levels of the three-way ANOVA				
	Vineyards (V)		<.0001*	<.0001*	<.0001*	<.0001*	<.0001*
	Grafts (G)		0.190 ns	0.617 ns	0.020*	0.001*	0.479 ns
	Spatial he terogeneity (SH)		0.097 ns	0.136 ns	0.473 ns	0. 758 ns	0.049*
	V*G		0.160 ns	0.412 ns	0.014*	0.042*	0.052 ns
	V*SH		0.365 ns	0.029*	0.367 ns	0.176 ns	0.073 ns
	G*SH		0.710 ns	0.160 ns	0.011*	0.156 ns	0.311 ns
	V*G*SH		0.483 ns	0.910 ns	0.287 ns	0.760 ns	0.330 ns
	Coefficient variation (%)		5.21	6.16	5.51	20.28	14.28

Soil was sampled from a 0–10 cm layer. All values are means of four repetitions. *P*-values followed by ns: not significant by Tukey's test (p < 0.05). Data from forest were not included in the statistical analyses, standard deviation in brackets.

in chemical and microbial soil characteristics were observed in other studies of organic farming, mainly with regard to microbial biomass, organic matter sequestration and nutrient retention, depending on the quantity and quality of the applied manure, organic supplementation, and crop rotation with legumes (Graham & Haynes, 2006; Marriott & Wander, 2006; Flieβbach et al., 2007; Probst et al., 2008). In India, data from a field study of soil quality as related to fertilizer and manure application for 31 years showed the highest quality indices in manure-treated plots (Masto et al., 2007).

The effects of vineyard management (V) were more significant on total C and microbial biomass (C_{mic} and N_{mic}) and more relevant in ORG inter-row treatments (Table 3), but the basal respiration (CO2) results were lower in soil of from the inter-rows than from rows under ORG. Thus, these treatments could be separated by PCA analysis (Figure 1b). Graft cultivars (G) had higher significance for the variable basal respiration and its interaction with vineyards (V). Basal respiration in soil growing cultivar Isabel was higher than in soil under Bordô. These results confirm the conclusion that microbial carbon is lost in the CONV management and that in other areas, as in forest and ORG vineyard, more organic matter is provided, improving some biological properties. Some authors discussed these changes in soil organic matter that might explain modifications of the microbial community (van-Diepeningen et al., 2006; Steenwerth & Belina, 2008).

The soil metabolic in C-CO_2 quotient (qCO_2), calculated in µg g^{-1} h^{-1} C-CO_2 in soil, was 1.92 in forest soil, 2.06–5.18 under CONV and 3.70–5.42 in the ORG management (Figure 2a). In general, the values for microbial C/N ratio were higher in soil of the CONV than of the ORG management or in the forest, regardless of the cultivar or spatial heterogeneity (Figure 2b). The proportion of C_{mic}:SOC was lower and ranged from 0.47 in soil in CONV Bordô inter-rows to 1.22 % in forest soil. In this study, the ORG vineyard was managed with practices such as cover crops and soil mulching, serving as fertilizers and weed control, and may have also resulted in lower thermal variation and consequently better conditions for the microbial community. Studies of production systems under different crop management practices have shown greater soil microbial activity and biomass under organic than under conventional management (Bulluck III et al., 2002; Xavier et al., 2006; Flieβbach et al., 2007; Probst et al., 2008). The inter-row management, with cover crops in the winter and summer, had a strong influence on all variables studied. It has been suggested that cover crops and organic residues maintain and improve microbial properties, e.g., higher microbial carbon was observed

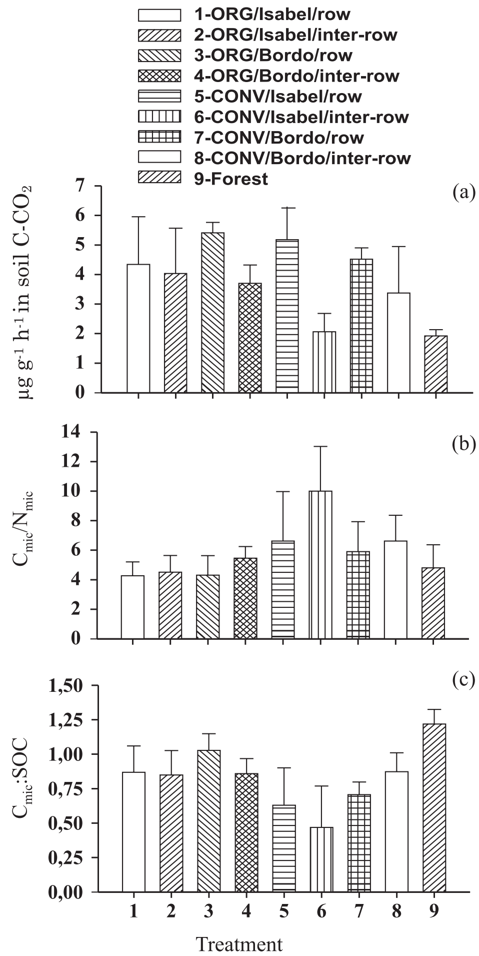

Figure 2. Microbial indices: (a) metabolic quotient (qCO_2); (b) microbial carbon/nitrogen ratio and (c) percentage of C_{mic} in relation to SOC in soils after six years under organic (ORG) and conventional (CONV) vineyards and from an adjacent forest fragment. Vertical bars indicate standard deviation (n=4).

in the sugarcane rows than the inter-rows because of the absence of cover crops or organic matter (Graham & Haynes, 2006).

Differences in microbial biomass can also be related to soil management practices (fertilizers, liming, cover crops, etc.) and weather conditions at sampling time, mainly soil moisture, which was higher in ORG soil (Table 3). The microbial activity measured by basal respiration ($C\text{-}CO_2$) was on average lower in CONV soil than in areas under grape ORG management. Organic farming is characterized by the absence of synthetic pesticides in favor of organic fertilizers, cover crops and green manure, often with reduced tillage. The conversion of conventional cropping to organic farming increases the input of organic matter to the soil, a vital management practice to maintain the sustainability of grape production in regions where soils are affected by a shortage of organic matter.

The highest ratio of C_{mic}/N_{mic} was in soils under CONV/Isabel/inter-rows, but it did not differ from other treatments and the forest area. This microbial index is usually related to the composition of the soil microbial community, for example, the proportion of microbial groups such as fungi and bacteria. In general, higher C_{mic}/N_{mic} values indicated a greater fungal than bacterial population, predominantly because of the very high C content of fungal hyphae.

Similarly, it was shown that C_{mic}/N_{mic} in organic soils was lower than in conventionally managed soils (Scherer, 2005; Flieβbach et al., 2007). In our study, the ORG vineyard with the highest soil pH and that received more organic matter input by cover crops and biofertilizers than the CONV management was more benefited to bacterial than the fungal population. The highest values for the percentage of C_{mic} in relation to SOC were found in forest soil, indicating that a significant fraction of C had already been lost. This is in agreement with Scherer (2005), who also found lower C_{mic}/C_{tot} values in soils under organic than conventional coffee (*Coffea arabica* L.).

In our study, under subtropical conditions, ORG vineyard management had effects on the microbial biomass and availability of soil organic matter to the soil microorganisms. Differences were observed in a pairwise comparison of organically and adjacent, conventionally managed vineyards, but the authors argued that the positive effects might have been obscured by the land-use history (Probst et al., 2008). Therefore, controlled long-term field experiments on this subject are required.

CONCLUSIONS

1. Compared to conventional vineyards, the organic management increases SOC and microbial biomass in the rows as well as inter-rows; under organic management, SOC increased by 172 %, C_{mic} 100 % and N_{mic} 223 % in the row, which was observed to a lesser extent in inter-rows as well.

2. Vineyard managements and soil spatial heterogeneity are the most relevant factors differentiating areas according to chemical (mainly SOC) and microbial biomass changes in soil by farming practices.

3. The levels of the chemical and microbial proprieties of forest soil were in-between those of vineyard soil under conventional and organic management, indicating that organic farming can be an important tool to improve soil quality in vineyards.

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