Revista Brasileira de Ciência do Solo
ISSN: 0100-0683
revista@sbcs.org.br
Sociedade Brasileira de Ciência do Solo
Brasil

Dalla Rosa, Jaqueline; Mafra, Alvaro Luiz; Medeiros, João Carlos; Albuquerque, Jackson Adriano; Miquelluti, Davi José; Nohatto, Marcos André; Zacca Ferreira, Evandro; Pereira de Oliveira, Odoni Loris

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Revista Brasileira de Ciência do Solo, vol. 37, núm. 5, 2013, pp. 1352-1360
Sociedade Brasileira de Ciência do Solo
Viçosa, Brasil

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# SOIL PHYSICAL PROPERTIES AND GRAPE YIELD INFLUENCED BY COVER CROPS AND MANAGEMENT SYSTEMS[(1)]

**Jaqueline Dalla Rosa[(2)], Alvaro Luiz Mafra[(3)], João Carlos Medeiros[(2)], Jackson Adriano Albuquerque[(3)], Davi José Miquelluti[(3)], Marcos André Nohatto[(4)], Evandro Zacca Ferreira[(5)] & Odoni Loris Pereira de Oliveira[(6)]**

**SUMMARY**

**The use of cover crops in vineyards is a conservation practice with the purpose of reducing soil erosion and improving the soil physical quality. The objective of this study was to evaluate cover crop species and management systems on soil physical properties and grape yield. The experiment was carried out in Bento Gonçalves, RS, Southern Brazil, on a Haplic Cambisol, in a vineyard established in 1989, using White and Rose Niagara grape (*Vitis labrusca* L.) in a horizontal, overhead trellis system. The treatments were established in 2002, consisting of three cover crops: spontaneous species (SS), black oat (*Avena strigosa* Schreb) (BO), and a mixture of white clover (*Trifolium repens* L.), red clover (*Trifolium pratense* L.) and annual rye-grass (*Lolium multiflorum* L.) (MC). Two management systems were applied: desiccation with herbicide (D) and mechanical mowing (M). Soil under a native forest (NF) area was collected as a reference. The experimental design consisted of completely randomized blocks, with three replications. The soil physical properties in the vine rows were not influenced by cover crops and were similar to the native forest, with good quality of the soil structure. In the inter-rows, however, there was a reduction in biopores, macroporosity, total porosity and an increase in soil density, related to the**

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[(1)] Part of the Masters Dissertation of the first author. Study conducted in Embrapa Uva e Vinho (Embrapa - CNPUV), Bento Gonçalves (RS), Brazil. Received for publication on March 15, 2012 and approved on July 25, 2013.

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**compaction of the surface soil layer. The M system increased soil aggregate stability compared to the D system. The treatments affected grapevine yield only in years with excess or irregular rainfall.**

**Index terms: soil management, soil structure, vineyards, viticulture.**

**RESUMO:** *PROPRIEDADES FÍSICAS DO SOLO E RENDIMENTO DE UVA INFLUENCIADOS POR PLANTAS DE COBERTURA E SISTEMAS DE MANEJO*

*A utilização de cobertura do solo nos parreirais é uma prática conservacionista utilizada para diminuir a erosão e melhorar a qualidade física do solo. O objetivo deste estudo foi avaliar espécies de plantas de cobertura e sistemas de manejo da cobertura sobre as propriedades físicas do solo e sobre o rendimento de uva. O experimento foi conduzido em Bento Gonçalves, RS, sobre um Cambissolo Háplico, num parreiral implantado em 1989, com os cultivares Niágara Branca e Niágara Rosada no sistema de latada. Os tratamentos, estabelecidos em 2002, foram três coberturas vegetais: vegetação espontânea (SS), aveia-preta (*Avena strigosa Schreb*) (BO) e consórcio de trevo branco (*Trifolium repens L.*) + trevo vermelho (*Trifolium pratense L.*) + azevém (*Lolium multiflorum L.*) (MC). Dois sistemas de manejo foram utilizados: dessecado com herbicida (D) e roçada mecânica (M). O solo em uma área de floresta nativa foi coletado como condição de referência. O delineamento experimental foi de blocos ao acaso com três repetições. As propriedades físicas nas linhas do parreiral não diferiram estatisticamente entre as coberturas avaliadas e foram similares à floresta nativa, demonstrando boa qualidade estrutural. Entretanto, nas entrelinhas, ocorreram redução de bioporos, macroporosidade, porosidade total e aumento na densidade do solo, em razão da compactação da camada superficial do solo. O sistema de manejo da cobertura pela roçada teve maior estabilidade dos agregados do que o manejo dessecado. Os tratamentos influenciaram o rendimento da videira em anos, com excesso ou distribuição irregular de chuvas.*

*Termos de indexação: manejo do solo, estrutura do solo, vinhedos, viticultura.*

## INTRODUCTION

The “Serra Gaúcha”, in Southern Brazil, is the main region for grape production in Brazil. Vineyards in this region are on steep slopes with shallow and rocky soils managed with incomplete or no soil cover with intercrops (Emater, 2001; Oliveira et al., 2004). Bare soil surfaces increase the disruption of soil aggregates and erosion, which negatively affect vine root development (Egger et al., 1995). Mechanical operations also influence soil erosion in vineyards, as reported by Martínez-Casasnovas & Concepción Ramos (2009) in the Mediterranean region of Spain.

The intercrop soil cover in vineyards can improve soil physical, chemical and biological properties (Oliveira et al., 2004), and it is necessary to control erosion and increase water infiltration (Martínez-Casasnovas & Sánchez Bosch, 2000). Cover crops can be a useful floor management practice in grapevine, mainly in areas with adequate water available supply during the growing season or with irrigation (Monteiro & Lopes, 2007). The cover crops dissipate the kinetic energy of rainfall, prevent the breakdown of aggregates and reduce erosion. Additionally, cover crop residues left on the soil surface, and reduced tillage, increase soil organic carbon, which plays a fundamental role in soil aggregate formation and stabilization (Carpenedo & Mielniczuk, 1990).

Cover crops can improve the soil structure, with beneficial effects on soil aggregation, but such effects vary among species (Albuquerque et al., 1995), depending on the length and distribution of the root system. A better physical soil quality was observed in the inter-rows of an orange orchard, permanently covered with grasses, compared to treatments with legumes and spontaneous species (Fidalski & Tormena 2007). Soil cover and stable aggregates reduced the erosion rate in vineyards with permanent intercrop management (Peregrina et al., 2010). Another important aspect to consider is the rate of biomass decomposition, which influences the persistence of soil cover (Perin et al., 2004).

The goal of the cover crop management, besides the protection of the soil surface, is also the avoidance of competition with the cultivated plants in the rows (Lipecki & Berbec, 1997; Ripoche et al., 2011; Guerra & Steenwerth, 2012). There is little information, however, on cover crop management in vineyards of the Serra Gaúcha region, on how to improve soil conditions and grape yields (Oliveira et al., 2004). In general, in these vineyards, two forms of intercrop management are performed. Conventionally, the weed is controlled with herbicides, applied in the beginning of the vine growing season and reapplied as required for weed regrowth, leaving the soil permanently bare. An alternative intercrop management is mechanical mowing, leaving the biomass between the rows in the summer and in the total area in winter (Oliveira et al., 2004).

This study was therefore conducted to evaluate the effect of different cover crops and phytomass management on soil physical properties and grape yield in a Haplic Cambisol.

## MATERIAL AND METHODS

The study was carried out in Bento Gonçalves, RS, Southern Brazil (29º 09' 42" S; 51º 32' 18" W, 640 m asl), on a Haplic Cambisol (FAO, 2006) derived from basalt, with the following particle size distribution: 283 g $kg^{-1}$ clay, 327 g $kg^{-1}$ silt and 390 g $kg^{-1}$ sand in the 0-0.10 m surface layer. The climate is humid mesothermal, Cfb (according to the Köppen classification), with a mean annual temperature of 17.6 ºC and annual pluvial precipitation of 1,793 mm (Falcade & Mandelli, 1999).

The vineyard was established in 1989, using the grapevine cultivars (*Vitis labrusca* L.) White and Rose Niagara, the plants spaced 1.5 m and the rows 2.5 m apart, with a horizontal overhead trellis system.

The treatments were established in 2002, using three cover crops and two management systems. The cover species were: spontaneous species (SS); black oat (BO) (*Avena strigosa* Schreb); and a mixture (MC) of white clover (*Trifolium repens* L.), red clover (*Trifolium pratense* L.) and annual rye-grass (*Lolium multiflorum* L.). The weed management was two-fold: desiccation with herbicide (D); and mechanical mowing (M), annually performed before sowing the cover crops, in autumn. The experiment was arranged in a randomized complete block design with three replications. The plots (22.5 $m^2$) consisted of 12 plants, with four plants in three rows. Additionally, an area of native forest (NF) adjacent to the experimental plots was evaluated, representing a reference soil.

The winter annual species were broadcast sown on all experimental plots, without seed incorporation, using 100 kg $ha^{-1}$ black oat (BO treatment), and 25 kg $ha^{-1}$ ryegrass, 3 kg $ha^{-1}$ white clover, and 6 kg $ha^{-1}$ red clover for the mixed cover crop treatment (MC treatment). Annual re-sowing was needed only for black oats, whereas the other species regrew naturally in the area. The intercrop management consisted of one annual application of the systemic herbicide Glyphosate (4 L $ha^{-1}$) for the management system D and a mechanical tractor mower for M, at the beginning of April. Fifteen days after herbicide desiccation and immediately after mechanical mowing, black oat was sown.

Disturbed and undisturbed soil samples were collected in March 2006, at 0-0.05 and 0.05-0.10 m depths in the grapevine rows and inter-rows, as well as in the native forest. The undisturbed samples were collected with a cylindrical metal sampler (height 0.05, diameter 0.05 m).

Undisturbed samples to determine water retention curves were collected in the grapevine rows, and the volumetric water content was measured using a sand tension table at the matric potentials of -1 and -6 kPa, and a Richards chamber, with porous plates, at matric potentials of -10, -30, -50, -100, -300 and -1,500 kPa. The van Genuchten (1980) model was fitted to soil water retention data using the software Soil Water Retention Curve - SWRC (Dourado Neto et al., 2000). Soil bulk density (Bd) was determined after drying samples at 105 °C (Embrapa, 1997).

The water available to plants (available water content - AWC) was estimated by the difference between the water content at a matric potential of -10 kPa, referred to as the field capacity (FC), and -1,500 kPa, considered as the permanent wilting point (PWP) (Carlesso, 1995).

Soil pore distribution of biopores (BP) was determined in samples collected in volumetric rings, on a sand tension table, at a matric potential of -1 kPa (Ringrose-Voase, 1991), and at a matric suction of -6 kPa for soil macroporosity (Ma) (Topp & Zebchuk, 1979). Total soil porosity (TP) was calculated as the relationship between soil bulk density (Bd) and particle density (Pd), through the equation proposed by Vomocil (1965), where TP (%) = (1-Bd/Pd) x 100. Soil microporosity (Mi) was determined by the difference between total porosity and macroporosity (Embrapa, 1997). Soil aggregate stability was analyzed by wet sieving (Kemper & Chepil, 1965), and expressed by the geometric mean diameter (GMD). The treatment response in grapevine and soil physical properties was evaluated in the growing seasons from 2004 to 2006, collecting all bunches of grapes from four plants per plot, to measure the weight of fresh fruits per plant.

The experimental design was a randomized block with three replications. The treatments involved a 3 x 2 factorial model (three cover crops and two cover crop managements) with sampling at two depths, totaling 36 soil samples. Statistical analyses were performed considering groups of experiments, fixing the sampling depth and position, and evaluating the effects of the interaction between cover crops and management systems. A multivariate analysis of variance was performed, and when significant, univariate analysis with contrasts was used to compare the means ($p>0.05$). Means of AWC were compared by the Tukey test ($p>0.05$), considering only the effect of the cover crops. Confidence intervals (95 %) based on the t test were calculated for native forest data.

## RESULTS AND DISCUSSION

### Soil physical properties

The GMD of aggregates observed in the native forest was 5.3 mm and ranged from 3.4 to 5.5 mm in the vineyard (Table 1). In the 0.05-0.l0 m layer, in the rows, a higher GMD was observed in BO and in the MC than in the SS treatment. Possibly this was related to the root quantity of these cover species. The use of cover plants increased the aggregate stability in a semiarid Mediterranean vineyard, as observed by Peregrina et al. (2010). The GMD values were higher in the M than the D management system, both in the rows and inter-rows (Table 1). This effect can be related to the activity of the root system, which remains active after mowing and releases exudates that enhance soil aggregation. Silva & Mielniczuk (1997) pointed out that roots stabilize soil aggregates due to the production of organic exudates, which stimulate microbial activity, besides a greater interaction between soil particles caused by pressure during root growth. The GMD was positively correlated with organic carbon (r= 0.39**, Table 2), being an evidence of the influence of biological processes on aggregate stability, as already reported by Tisdall & Oades (1979). The organic matter acts as a binding agent, through roots and hyphae; in fact, it is considered one of the main factors controlling the aggregate stability in some soils (Tisdall & Oades, 1982).

The biopore sizes ranged from 0.02 to 0.08 $cm^3 cm^{-3}$ (Table 1), with no statistical difference between cover crops (BO, MC, SS) or management systems (M, D). The BP size was smaller in soil of the inter-rows than the rows and in the deeper layers, which may be due to compaction caused by machine traffic, with a negative correlation between biopores and bulk density

**Table 1. Soil physical properties of a Haplic Cambisol influenced by cover crops and management systems, in a vineyard and under native forest**

| Cover/Management | GMD | | BP | | Ma | | Mi | | TP | | Bd | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | mm | | $cm^3 cm^{-3}$ | | | | | | | | $Mg m^{-3}$ | |
| | 0-0.05 m | | | | | | | | | | | |
| | R | IR | R | IR | R | IR | R | IR | R | IR | R | IR |
| Spont. species (SS)[1] D[2] | 5.1 | 4.9 | 0.06 | 0.03 | 0.24 | 0.09 | 0.37 | 0.41 | 0.60 | 0.50 | 0.97 | 1.21 |
| Black oat (BO)[3] D | 5.5 | 5.0 | 0.08 | 0.02 | 0.23 | 0.06 | 0.36 | 0.41 | 0.57 | 0.47 | 1.01 | 1.29 |
| Mixed cover (MC)[4] D | 5.2 | 4.6 | 0.05 | 0.03 | 0.21 | 0.09 | 0.38 | 0.41 | 0.57 | 0.51 | 1.04 | 1.19 |
| Spont. species (SS) M[5] | 5.2 | 5.2 | 0.08 | 0.02 | 0.22 | 0.10 | 0.37 | 0.42 | 0.58 | 0.50 | 1.03 | 1.21 |
| Black oat (BO) M | 4.7 | 5.4 | 0.04 | 0.03 | 0.21 | 0.09 | 0.37 | 0.40 | 0.58 | 0.48 | 1.04 | 1.25 |
| Mixed (MC) M | 5.1 | 5.2 | 0.04 | 0.03 | 0.19 | 0.08 | 0.39 | 0.40 | 0.55 | 0.48 | 1.09 | 1.25 |
| | 0.10 m | | | | | | | | | | | |
| Spont. species (SS) D | 4.6 | 3.4 | 0.05 | 0.02 | 0.14 | 0.05 | 0.38 | 0.39 | 0.50 | 0.44 | 1.20 | 1.39 |
| Black oat (BO) D | 4.4 | 3.9 | 0.03 | 0.03 | 0.13 | 0.06 | 0.38 | 0.41 | 0.48 | 0.46 | 1.21 | 1.32 |
| Mixed cover (MC) D | 4.8 | 3.6 | 0.04 | 0.02 | 0.13 | 0.06 | 0.38 | 0.39 | 0.50 | 0.45 | 1.24 | 1.35 |
| Spont. species (SS) M | 4.8 | 5.0 | 0.03 | 0.02 | 0.17 | 0.05 | 0.38 | 0.40 | 0.53 | 0.46 | 1.15 | 1.32 |
| Black oat (BO) M | 5.1 | 4.9 | 0.02 | 0.03 | 0.13 | 0.07 | 0.38 | 0.39 | 0.48 | 0.45 | 1.24 | 1.32 |
| Mixed (MC) M | 5.2 | 5.0 | 0.03 | 0.03 | 0.13 | 0.08 | 0.38 | 0.38 | 0.49 | 0.44 | 1.24 | 1.37 |
| General mean | 4.98 | 4.68 | 0.05 | 0.03 | 0.18 | 0.07 | 0.38 | 0.40 | 0.54 | 0.47 | 1.12 | 1.29 |
| | Native forest (0-0.1 m) | | | | | | | | | | | |
| | 5.3 ± 0.4 | | 0.05 ± 0.03 | | 0.19 ± 0.05 | | 0.40 ± 0.02 | | 0.56 ± 0.04 | | 1.10 ± 0.14 | |
| Statistic | | | | | | | | | | | | |
| Contrast | 0-0.05 m | | | | | | | | | | | |
| SS x (BO, MC) | ns | ns | ns | ns | ns | * | ns | ns | ns | ns | ns | ns |
| BO x MC | ns | ns | ns | ns | ns | * | * | ns | ns | ns | ns | ns |
| | 0.10 m | | | | | | | | | | | |
| SS x (BO, MC) | * | ns | ns | ns | ns | ns | ns | ns | ns | ns | ns | ns |
| SSD x SSM | * | * | ns | ns | ns | ns | ns | ns | ns | ns | ns | ns |
| BOD x BOM | * | * | ns | ns | ns | ns | ns | ns | ns | ns | ns | ns |
| MCD x MCM | * | * | ns | ns | ns | ns | ns | ns | ns | ns | ns | ns |

[1] (SS): spontaneous species; [2] D: desiccated management; [3] (BO): Black oats; [4] (MC): mixed cover; [5] M: mowed management; R: rows; IR: inter-rows; GMD: Geometric Mean Diameter of aggregates; BP: biopores; Ma: macroporosity; Mi: microporosity; TP: total porosity; Bd: bulk density; * significant at 5 %; ns: no significant. The values of the native forest refer to the average depths, and are followed by confidence intervals (95 %), calculated by t test. Only the significant contrasts are shown.

(r = -0.66**, Table 2). These results agree with those obtained in an orange orchard by Lima et al. (2005), showing that machine traffic caused soil surface compaction and changed the shape and distribution of the pore spaces, mainly of the biopores.

The Ma in the NF was 0.19 $cm^3$ $cm^{-3}$, similar to the average in the rows of cover crop treatments (Table 1). However in the inter-row, Ma decreased to 0.07 $cm^3$ $cm^{-3}$, which is lower than the 0.10 $cm^3$ $cm^{-3}$ considered the threshold value for plant development, especially in periods with high soil moisture, due to the restricted root aeration (Tormena et al., 1998). This Ma value in the inter-row position indicated compaction, confirming the origin of this effect, i.e., machinery traffic. Macroporosity was negatively correlated with Bd (r = -0.87**, Table 2) as also reported by Becerra et al. (2010). More macropores were observed in the SS than in the BO and MC treatments, in the surface layer (0.00-0.05 m) and inter-rows. The MC treatment had more macropores than BO, which may be related with the root systems of the cover species. On the other hand, the values observed in the rows were adequate, particularly in the 0.00-0.05 m layer, which was equivalent to the NF, and indicated a good structural condition for the growth of grapevine roots. The amount of microporosity (Mi) in vineyard soil ranged from 0.36 to 0.42 $cm^3$ $cm^{-3}$ and was 0.40 $cm^3$ $cm^{-3}$ in the NF (Table 1). The MC had higher Mi as compared to BO in the 0.00-0.05 m layer and in the rows. There was an increase in Mi in the inter-rows than in the rows, due to compaction that decreases Ma and increases Bd (Carpenedo & Mielniczuk, 1990).

The cover crops and management systems had no effect on TP, which ranged from 0.44 to 0.60 $cm^3$ $cm^{-3}$ in the vineyard, and was 0.56 $cm^3$ $cm^{-3}$ in NF (Table 1). This indicated good soil conditions, particularly in the rows, similar to the native forest. Lower total porosity was observed in the inter-rows which was associated with soil compaction. The TP was negatively correlated with Bd (r = -0.95**) and with clay (r = - 0.54**, Table 2).

The Bd was 1.10 g $cm^{-3}$ in the NF while in the vineyard was 1.12 and 1.29 g $cm^{-3}$ in the rows and inter-rows, respectively, in the 0-0.10 cm layer, with no effect of treatments (Table 1). In the vineyard, higher Bd values were observed in the inter-rows and in the 0.05-0.10 cm layer. The increase in Bd may restrict root development and reduce grape yields. In a French vineyard, a negative effect of a very high bulk density on root development was observed (Morlat & Jacquet, 1993). A negative correlation between Bd and OC (r = -0.48**, Table 2), GMD (r = -0.36**), BP (r = -0.66**), Ma (r = -0.87**) and TP (r = -0.95**) was found, indicating the relationship between these properties.

The mean soil water retention in the vineyard ranged from 0.52 to 0.59 $cm^3$ $cm^{-3}$ in saturated soil, and from 0.28 to 0.29 $cm^3$ $cm^{-3}$ at PWP, with no effect of the cover crops and management systems. In the NF, the values were 0.58 ± 0.042 and 0.28 ± 0.017 $cm^3$ $cm^{-3}$, respectively, in the saturation and PWP (Figure 1). Differences between the layers (0-0.05 and 0.05-0.10 m), especially for the NF, are probably related to the quantity, type and distribution of pores, and also depend on soil organic matter.

The FC ranged from 0.37 to 0.38 $cm^3$ $cm^{-3}$ in grapevine soils and 0.39 ± 0.015 $cm^3$ $cm^{-3}$ in the NF. The AWC was 0.08 $cm^3$ $cm^{-3}$ in the average of D, and 0.09 $cm^3$ $cm^{-3}$ in the M management system, increasing to 0.11 $cm^3$ $cm^{-3}$ in the NF. It is important to consider that management conditions should maintain the stability of the soil structure, porosity and a good distribution of pore size, which is important for soil water dynamics and affect aspects such as drainage and quantity of water available for the plants (Dexter, 2004).

## Grapevine yields

The grape yields in the year of 2004 ranged from 2.0 to 4.2 kg of grapes per plant (Figure 2), and may have been influenced by the heavy rains occurring in December 2003 (Figure 3), which caused fruit rot.

In the 2005 season the production of grapes per plant ranged from 5.0 to 6.2 kg, with no statistical difference between treatments. In 2006, the fruit yield decreased to 1.5 to 3.2 kg of grapes per plant, related to irregular rainfall conditions. This harvest was not affected by the cover crop but there was greater

**Table 2. Pearson correlation between organic carbon and soil physical properties under different cover crops and management systems in a Haplic Cambisol in a vineyard**

| | GMD | BP | Ma | Mi | TP | Bd | Clay |
|---|---|---|---|---|---|---|---|
| OC | 0.39** | 0.27** | 0.32* | $0.16^{ns}$ | 0.45** | - 0.48** | $- 0.19^{ns}$ |
| GMD | | 0.30** | 0.43** | $- 0.16^{ns}$ | 0.32** | - 0.36** | - 0.50** |
| BP | | | 0.78** | - 0.53** | 0.62** | - 0.66** | - 0.31** |
| Ma | | | | - 0.50** | 0.83** | - 0.87** | $- 0.53^{ns}$ |
| Mi | | | | | $- 0.15^{ns}$ | $0.12^{ns}$ | $0.21^{ns}$ |
| TP | | | | | | - 0.95** | - 0.54** |
| Bd | | | | | | | 0.50** |

OC: organic carbon; GMD: Geometric mean diameter of aggregates; BP: biopores; Ma: macroporosity; Mi: microporosity; TP: total porosity; Bd: bulk density; Clay: total clay. ** and *: significant at 1 and 5 %, respectively.

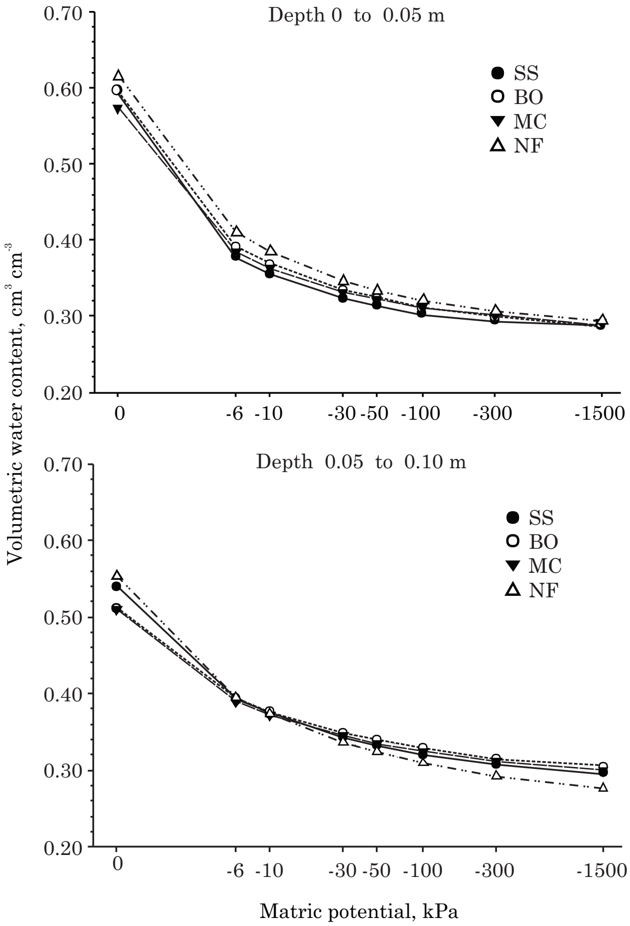


**Figure 1. Soil water retention curves of a Haplic Cambisol under cover crops (SS: spontaneous species; BO: black oats; MC: mixed cover) on the average of the management systems of the biomass and native forest (NF).**

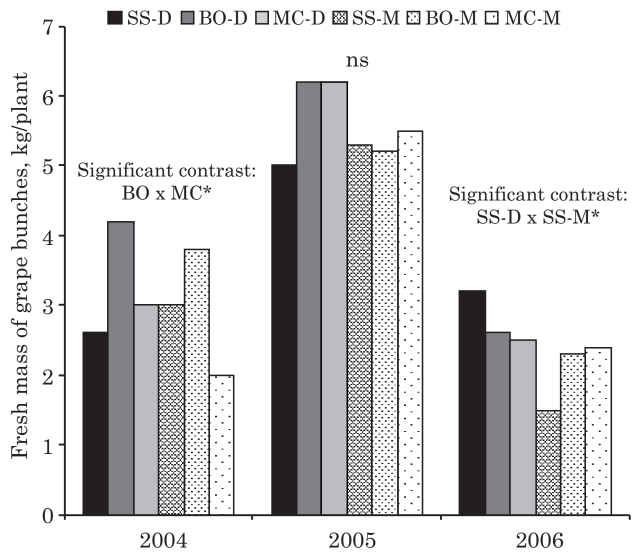


**Figure 2. Fresh mass yield of grape bunches per plant under different cover crops and management systems, in three harvest seasons, on a Haplic Cambisol, SS: spontaneous species; BO: black oats; MC: mixed cover; D: desiccated management system; M: mowed management system.**

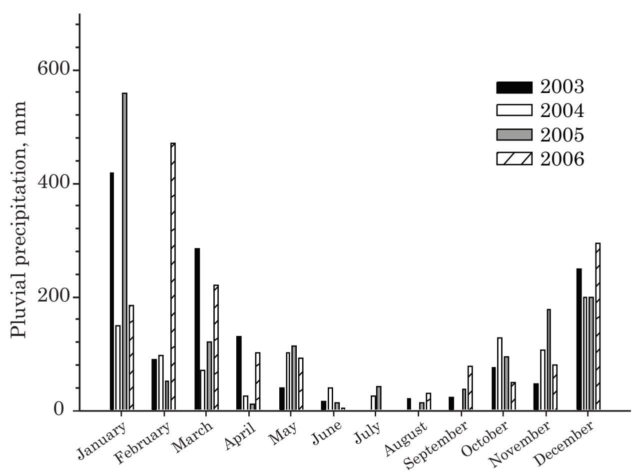


**Figure 3. Rainfall distribution during the experimental grape growing seasons. Agroclimatic station Embrapa Uva e Vinhos (Latitude: 29º 09' 44'' S; Longitude: 51º 31' 50'' W).**

production in the D system compared to the M system under SS (Figure 2). These differences between cover management systems may be related to competition between cover crops and grapevine, or related to the availability of nutrients in the soil. Possibly the decomposition of plant cover was faster in the D system and promoted greater nutrient release, while in the M system, competition for nutrients occurred by the intercrop plant regrowth.

## Management of cover crops in vineyards

The use of cover crops in vineyards is a conservation practice to protect the soil against erosion (Klik et al., 1998), especially under the conditions of the Serra Gaúcha, where heavy rains occur and many areas have shallow soils on steep slopes. The stage of development of the grapevine plants needs to be considered, in addition to climatic and edaphic conditions, if a more efficient cover crop management in vineyards is to be achieved (Skroch & Shribbs, 1986). The most common management practices are the maintenance of a permanent soil cover of spontaneous or cultivated species in the inter-rows, and weeding or mowing, desiccating with herbicides, or mulch application in the grapevine rows.

Usually grapevine can respond positively in terms of vegetative growth to improvements in soil physical quality, especially to those involving mechanical strength and water supply. These changes were important for increasing the effective root depth, as observed in vineyards on soils with physical limitations in Victoria, Australia (Wheaton et al., 2008). In a semiarid Mediterranean vineyard, the use of permanent cover crops was an effective strategy to enhance organic carbon stocks and improve soil quality (Peregrina et al., 2010).

Cover crop species have to produce enough phytomass to positively influence edaphic aspects such as mechanical strength, aeration, aggregation and availability of water and nutrients. It is important to consider differences among plants and their effects on soil, as observed for macroporosity, which was higher in the surface layer and in inter-rows in the presence of spontaneous cover plants than in the other treatments (Table 1). In addition to effects on soil physical properties, cover crops can have other beneficial influences, for example on the nutrient and organic carbon cycling, and a greater biomass increases aggregate stability, as evidenced by the positive correlation between organic carbon and geometric mean diameter of aggregates (Table 2). For an organic vineyard in Southern Brazil, Amaral et al. (2011) reported positive effects of cover crops on soil organic carbon and microbial biomass, compared to a conventional management, using herbicide to control spontaneous plants.

The intercrop management has to be adjusted according to the development of the cultivated plants, in order to improve soil conditions and reduce competition for water and nutrients, as verified in a peach orchard by Parker & Meyer (1996) and for grapevine by Sanguankeo et al. (2009). Thus the choice of cover plants is very important and the use of an annual winter species that grows during the period of grapevine dormancy is quite common. There was a better effect of the M than the D system on aggregate stability (Table 1), but no effect on the other soil physical properties.

Considering intercrop management practices, Dal Bó & Becker (1994) found that desiccation of a legume cover (*Vicia sativa* L.) at the end of grapevine dormancy reduced the competition exerted by the cover crop and increased the grape yield of cultivar Isabel, when compared to uncovered soil. However, Faria et al. (2004) found that a legume soil cover had no effect on the yield and grape quality of cultivar Italy. Rombaldi et al. (2004) observed no differences in the yield and grape quality of cultivar Isabel, when using cover crops in the winter. Baumgartner et al. (2008) reported that cover crops in a Californian vineyard had no effect on grape yield, vine growth or nutrition, compared to the tilled control, with no cover. According to Wutke et al. (2011), intercrop management was similar to traditional mulch used in a study carried out in a Brazilian vineyard, with no influence on the grape yield of cultivar Rose Niagara.

The response of grapevine in terms of fruit production was seasonal (Figure 2), possibly due to climatic factors. The effects of cover crops on fruiting were found only in the years with lower productivity, in the 2004 and 2006 harvests, which was probably related to changes in nutrient availability or plant health, since the soil properties such as water availability, porosity and bulk density were not affected by the treatments (Figure 1 and Table 1). However, there was an increase in Bd and a reduction in Ma to almost critical limits for root development in the inter-rows (Table 1), which could be due to machine traffic. Thus, it is necessary to maintain a permanent soil cover to improve soil quality and crop yield, with beneficial effects on soil organic matter, microbial activity and aggregate stability, contributing to water infiltration and storage in the surface soil layer, and minimizing soil compaction caused by machine traffic (Mulumba & Lal, 2008), as well as, reducing soil erosion (Ruiz-Colmenero et al., 2011).

## CONCLUSIONS

1. Cover crop species did not affect the soil physical properties in the 0-0.1 m layer of a vineyard in the Serra Gaúcha region, after four years of intercropping. The soil physical properties in the grapevine rows were similar to the native forest, indicating a good structural quality of the soil.

2. In the inter-rows, the biopores, macroporosity and total porosity decreased and bulk density increased, indicating compaction of the topsoil layer.

3. The mechanical mowing of cover crops increased soil aggregate stability in relation to desiccation.

4. The treatments affected grapevine yields in years with excess or irregular rainfall (2004 and 2006), but not in the year with typical weather (2005).

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