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SOIL ATTRIBUTES THREE YEARS AFTER MAKING RIDGES AND OR DRAINS FOR PLANTING GRAPEVINE ROOTSTOCK[1]

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ABSTRACT - Soil attributes are related to the crops development and production, both for annual and perennial species. This study aimed to determine the chemical and physical soil attributes three years after making or not ridges and or drains before planting of grapevine rootstock in a Hapludox soil with very clayey texture. Chemical soil attributes (pH in water and soil organic matter and macronutrients) were determined in samples collected in the layers of 0-0.1, 0.1-0.2, 0.2-0.3 and 0.3-0.4 m depth of the rootstock row. Physical soil attributes (clay content, bulk density, porosity, penetration resistance and aggregate stability) were determined in undisturbed samples collected in the layers of 0.025 to 0.075, 0.125 to 0.175, 0.225 to 0.275 and 0.325 to 0.375 m depth of the rootstock row. Correlations of dry weight of the rootstock roots sampled at layers of 0-0.2 and 0.2-0.4 m depth with soil attributes were also determined. The making of ridges significantly altered most soil chemical properties and provided greater uniformity in the values among layers, creating more favorable conditions for root growth in deeper layers. The physical attributes were less affected than the chemical ones by making ridges and did not have any restrictive value to root growth in the layers evaluated after four years of applying the soil management systems. Drains had lesser effect on soil chemical and physical attributes than ridges.

Index terms: pH, organic matter, macronutrients, bulk density, porosity, penetration resistance, *Vitis*.

ATRIBUTOS DO SOLO TRÊS ANOS APÓS CONFECÇÃO DE CAMALHÕES E DRENOS PARA PLANTIO DE PORTA-ENXERTOS DE VIDEIRA

RESUMO - Os atributos do solo estão relacionados com o desenvolvimento e a produção das culturas, tanto anuais como perenes. O presente trabalho teve como objetivo determinar os atributos químicos e físicos do solo três anos após a aplicação de sistemas de manejo para implantação de porta-enxertos de videira, em um Nitossolo Vermelho com textura muito argilosa. Os sistemas de manejo consistiram na confecção ou não de camalhões e/ou de drenos antes da implantação das mudas de porta-enxertos Dog Ridge. Os atributos químicos (pH em água e teores de matéria orgânica e de macronutrientes) foram determinados em amostras coletadas na linha da cultura, nas camadas de 0-0,1; 0,1-0,2; 0,2-0,3 e 0,3-0,4 m de profundidade. Os atributos físicos do solo (teor de argila, densidade, porosidade, resistência à penetração e estabilidade dos agregados) foram determinados em amostras coletadas com estrutura preservada nas camadas de 0,025-0,075; 0,125-0,175; 0,225-0,275 e 0,325-0,375 m de profundidade. Também foram determinadas a massa seca de raízes do porta-enxerto nas camadas de 0-0,2 e 0,2-0,4 m de profundidade e suas correlações com os atributos do solo. A confecção de camalhões alterou significativamente a maioria dos atributos químicos do solo e proporcionou maior uniformidade nos valores em profundidade, criando condições mais favoráveis ao crescimento radicular nas camadas mais profundas. Os atributos físicos foram menos afetados do que os químicos pela confecção de camalhões ou drenos, e não foram observados valores restritivos ao crescimento radicular nas camadas amostradas após quatro anos da aplicação dos sistemas de manejo do solo. A confecção de drenos alterou menos os atributos químicos e físicos do solo do que a confecção de camalhões.

Termos para indexação: pH, matéria orgânica, macronutrientes, densidade, porosidade, resistência à penetração, *Vitis*.

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INTRODUCTION

A feature frequently observed in the vineyards of the Midwest of Santa Catarina, Southern Brazil, is the shallow root system, even in deep soils of the Hapludox class. The causes are the high acidity in the subsoil and the occurrence of physical impairments, primarily related to the low permeability to water and air (DALBÓ et al., 2011). The root system distribution of perennial crops like grapevine can be affected by many factors, such as temperature, water availability, aeration, soil compaction and nutrient availability (LANYON et al., 2004).

Studying the effect of soil and vegetative structure on growth and distribution of the grapevine roots, Stepke (2010) observed that the growth of fine roots was stimulated by pH in KCl greater than 5.0 in the subsoil, medium or coarser texture and moderate water stress. Stepke (2010) also determined that the profile of root distribution is independent of the irrigation type used and then thicker roots (structural roots) seem to be less affected by soil management than the fine ones. Fráguas (1999) found wide variation in the behavior of grapevine rootstocks with the content of exchangeable aluminum in the soil, some of which are tolerant from moderate to high levels of this element. However, considering the analysis of the results of rootstocks root growth obtained in the field and in the greenhouse, Dalbó et al. (2011) observed that the soil acidity in the subsoil layers was not a limiting factor for the further development of the root system in a Hapludox soil with very clayey texture. The application of part of lime recommended for the entire area in furrows with 0.15 m width and 0.40 m depth increased pH in $CaCl_2$ from 4.3 to 5.0 in this layer, increased the root density up to 10 times regarding not doing deep liming (KIRCHHOF et al., 1991). This technique allowed the use of acids, dense and poorly drained soils to horticultural production.

The use of ridges, which refers to the relocation of topsoil from the mid-row, had lowered its surface onto the vine row to form a ridge, which had raised the surface, can improve soil physical and chemical properties relative to the original soil conditions (SHI et al., 2012; FAN et al., 2014). This technique has been used to overcome root zone waterlogging and restricted root distributions caused by shallow surface soils and dense impervious subsoil or even soils with chemical restrictions to root growth in the subsoil (KIRCHHOF et al., 1991; MYBURGH; MOOLMAN, 1991; CONRADIE et al., 2002; WHEATON et al., 2008). Eastham et al. (1996) found that the bulk density of ridges remained low (1.25 Mg m^{-3}) one year after forming compared to a flat surface (1.50 Mg m^{-3}). The better physical conditions allowed more rapid root development and significantly higher root lengths in ridges. Improved growth of young vines in ridges was related to the greater extraction of water and possibly nutrients by the denser vine root system.

In a shallow soil of South Africa, Steward (2005) observed a significant increase in root density in ridges, indicating that the grapevine develops a larger root volume in the ridges than in flat ground, which is related to the increase in the volume of soil explored by roots and, consequently, increased access to water and nutrients. Myburgh (1994) also observed that ridges tend to increase the efficiency and overall performance of the grapevine roots compared to the flat ground. This author observed that improving internal drainage, aeration and soil temperature in the ridges resulted in greater vegetative growth in early summer, but excessive drainage and high temperature at the end of the production cycle annulled this effect. Because this, Myburgh (1994) do not recommend making ridges too high and or too narrow in regions with periods of water shortage, in order to prevent excessive water loss. The effect of making ridges depends on the soil attributes, as evidenced by Hansen (2005) in a study conducted in three soils from Australia with varying combinations of constraints, where he observed increase in available water and grape production in a shallow soil and no beneficial effect in a deep soil.

The diagnosis of the causes for restricted depth of the grapevine rootstocks root system is important to develop strategies for soil tillage and management aiming to their best growth and, hence, the canopy varieties production. This study aimed to determine the chemical and physical soil attributes three years after planting grapevine rootstocks with and without making ridges and or drains in a Hapludox soil located in the Midwest Santa Catarina, Southern Brazil.

MATERIAL AND METHODS

The experiment was conducted in the experimental area of the Epagri, located in the geographical coordinates of 27º02’24” S and 51º08’05” W and altitude of 834 m, where occur a Hapludox soil with very clayey texture (Embrapa, 2004) and mesothermal humid with mild summers climate, of the Cfb type according to Köppen classification (PANDOLFO et al., 2002). This area had been used for growing annual crops for over ten years. Three years prior to the experiment beginning (six years before soil sampling), 30 t ha^{-1} of dolomitic limestone were applied throughout the area and incorporated with disk plow to approximately 0.3 m depth.

The treatments consisted of soil management with and without making ridges and or drains (CO – control, without ridges or drains; RI – with ridges in each row; DR – with one drain in the middle of each plot; and RD – with ridges and drain), allocated in a randomized block design with five replications. The drains were made by opening a trench with 0.6 m wide and 0.6 m deep in the plot center, following the slope. The trench was filled from the bottom to the top with a layer of 0.3 m height of stones, a plastic sheet and after that with soil removed from the corresponding layer until the soil surface. To make the ridges, the soil was plowed in the entire area to allow easy soil mobilization and then did three passes of disk plow from each side, moving the soil from the midrow, which had lowered its surface, onto the vine row to form a ridge.

Five seedlings of Dog Ridge rootstock were sowed in each plot, which was pruned annually to remove the branches produced in the previous growing season. Orchard fertilization consisted of only the application of 150 kg ha^{-1} y^{-1} of N as urea in the rootstocks row. In the winter period were seeded oat and oilseed radish in the total area, which were handled mechanically at the end of each cycle. The weed control during the summer season was performed by cutting or weeding the weeds, respectively in the rootstock interrow and row.

Sampling soil for physical and chemical analysis as well as root sampling was conducted at the end of the third growing season. The sample collection for soil chemical analysis was carried out with a Dutch-type auger in three points per plot along the rootstock row, at layers of 0-0.1, 0.1-0.2, 0.2-0.3 and 0.3-0.4 m depth, constituting a composite sample for each layer and plot. Chemical attributes (pH in water, organic matter and macronutrients) were determined in routine analysis, using the methodologies described in Tedesco et al. (1995). The samples for physical analysis, undisturbed soil cores were collected in the rootstock row, using rings with 0.05 m high and 0.06 m in diameter at layers of 0.025-0.075, 0.125-0.175, 0.225-0.275 and 0.325-0.375 m depth. The physical attributes (bulk density, resistance to penetration, classes of porosity, saturated hydraulic conductivity and aggregate stability) were determined in routine analysis, using the methodologies described in Veiga (2011).

The root mass was determined in samples collected at layers of 0-0.2 and 0.2-0.4 m depth in the trenches of 0.4 x 0.4 m side, open from 0.1 m of the central plant in each plot. The root fragments were separated from the soil mass by sieving and washing and divided manually into three classes of diameter (<2, 2-5 and >5 mm) and dried at 60° C to constant mass, than determined the dry mass of each class of diameter and the sum of the classes for each layer and plot.

The results of chemical and physical analyzes were subjected to analysis of variance for each layer individually and for the average of three layers. When checked statistical significance by F test, comparison of means was performed using Tukey's test ($P<0.05$). Correlations between mean values of the chemical and physical attributes with rootstock root mass of each class of diameter were also determined in the respective layer and plot.

RESULTS AND DISCUSSION

Significant differences were observed between soil management systems in most soil attributes studied when considering the average of the four layers sampled (Table 1). When there were differences between means, highest values usually were observed in ridges (RI), excepting the macro porosity and levels of exchangeable K and extractable P which were higher in drains (DR) and micro porosity which was higher in the control (CO). These results are related to the relocation of topsoil from the mid-row (furrow) onto the vine row to form a ridge, resulting in a greater thickness of the layer plowed in the rootstock row. Greater spatial heterogeneity and improving soil chemical and physical attributes were also observed in soils managed with ridges for annual cropping by Shi et al. (2012), Fan et al. (2014) and Choudhary et al. (2013). Müller et al. (2009), Jiang et al. (2011) and Campos-Herrera et al. (2013) also observed greater biological activity in the ridge.

The highest levels of P and K in the DR treatment can be explained by the redistribution of these in the profile due to greater soil disturbance in the middle of the plots in this treatment, even with the precaution of replacing soil layers at the same depths that have been taken. The greater macro porosity observed in DR is also related to greater soil disturbance, while the lowest macro porosity and largest micro porosity in the control should be due to the fact of not tilling the soil in this treatment. All these aspects can influence the root growth of grapevine rootstocks and hence the canopy varieties, as also determined by Richards (1983) and Stepke (2010).

A higher uniformity along the sampled layers was observed in the values of the chemical attributes in the RI system, as well as better levels in deeper layers in this system, except for P and K (Figure 1). The K levels were lower in the superficial layers of the RI system and P levels higher between 0.1 and 0.4 m depth in the DR system. These results are also related to the movement of soil from the mid-row onto the vine row, besides the sharp soil disturbance in the middle of the plot in DR system. Thus, in the RI systems there is an increase in the thickness of the layer with suitable conditions for rootstock root growth compared to systems without ridges, where the fertility gradient in depth was more pronounced.

Improving chemical conditions for rootstock root growth is proven by the significant positive correlations between most of the chemical attributes and dry mass of different classes of root diameter (Table 2), highlighting the organic matter content for greater class and for all classes of diameter and cation exchange capacity and exchangeable Ca to the smaller and medium class of diameter. These results differ from those obtained by Dalbó et al. (2011) in a study conducted in the same soil class, where they observed greater root growth of most rootstocks studied with lime application in subsoil layer. The root growth in RI treatment was also pointed out as the reason for the better performance of grapevines managed in other studies (MYBURGH, 1994; EASTHAM et al., 1996; STEWARD, 2005). These results can be explained by the improvement of soil conditions to biological activities in the ridge, as observed by Müller et al. (2009) and Jiang et al. (2011) in annual cropping systems and by Campos-Herrera et al. (2013) in citrus. According to Campos-Herrera et al. (2013), the central ridge supported greater entomopathogenic nematodes evenness, diversity and species richness, providing more effective control of *Diaprepes abbreviates*, a weevil pest of citrus. Choudhary et al. (2013), on the other hand, observed higher growth and yield of maize with ridges and furrow compared to other soil management systems and explained this due to the improvement of soil attributes in the to root environment.

Minor differences were observed between the means of physical attributes with and without making ridges or drains compared to that observed for chemical attributes, as well as different behavior between them (Figure 2). The RI system showed more homogeneous distribution and more appropriate values of most physical attributes in the soil profile as a whole, as also observed by other authors (SHI et al., 2012; FAN et al., 2014; CHOUDHARY et al., 2013). The control showed differences from others a greater number of times, with lower clay content, total porosity and macro porosity and higher bulk density and micro porosity in the surface layer, as also found by Eastham et al. (1996). These results are related to the fact that the soil has not been plowed in this treatment, representing the original soil profile before making ridges and or drains.

Soil bulk density was positively and significantly correlated with all classes of root diameter, while the clay content had a positive and significant correlation only with total root mass (Table 2). This result indicates no restriction on root growth in the range of bulk density observed in all treatments and layers of this study. This is evidenced by the fact that the penetration resistance was lower than 2.0 MPa in all layers, which is below to the restrictive value to root growth of annual crops (REICHERT et al., 2007), less resistant than the roots of perennial crops like grapevine. The greater root growth in the ridges is attributed to greater extraction of water and nutrients by denser root system of rootstocks (EASTHAN et al., 1996; MYBURGH, 1994), primarily by increasing the volume of soil explored (STEWARD, 2005). However, the ridges should not be too high or too narrow in drained soils (coarse texture and low organic matter content) or in regions with periods of water shortage, in order to prevent excessive water loss.

TABLE 1 - Chemical and physical soil attributes in the 0-0.4 m layer of a Hapludox soil three years after planting grapevine rootstocks with and without making ridges and or drain (averaged across four layers).

Attribute	Soil management				
	Control	Ridge	Drain	Ridge + Drain	CV%
Organic matter (g kg^{-1})	32^{ns}	36	34	36	25.7
pH in water (1:1)	6.0 bc	6.5 a	5.8 c	6.3 ab	3.0
CEC (cmol$_c$ dm^{-3})	14.7 b	17.5 a	14.9 b	16.2 ab	12.7
Base saturation (%)	76 b	85 a	75 b	82 a	6.0
Exchangeable Ca (cmol$_c$ dm^{-3})	6.3 b	9.3 a	7.2 b	8.7 a	17.7
Exchangeable Mg (cmol$_c$ dm^{-3})	4.6 b	5.4 a	3.5 c	4.3 b	18.2
Exchangeable K (mg dm^{-3})	142 ab	130 b	219 a	127 b	23.9
Extractable P (mg dm^{-3})	2.5 b	2.7 ab	3.8 a	3.4 ab	45.5
Clay (g kg^{-1})	610 b	646 a	622 ab	632 ab	2.6
Bulk density (Mg cm^{-3})	1.04 bc	1.07 ab	1.01 c	1.10 a	4.1
Penetration resistance (MPa)	1.48^{ns}	1.63	1.63	1.58	31.3
Total porosity (m^3 m^{-3})	0.609^{ns}	0.600	0.620	0.611	2.7
Macro porosity (m^3 m^{-3})	0.111 c	0.149 ab	0.159 a	0.130 bc	15.6
Micro porosity (m^3 m^{-3})	0.498 a	0.451 c	0.461 bc	0.480 ab	5.5

CEC: cation exchange capacity; Means followed by the same letter in the line did not differ significantly (Tukey test, P< 0.05); ^{ns}: not significant difference.

TABLE 2 - Pearson correlation coefficients between chemical and physical soil attributes and root mass of the grapevine rootstock three years after their planting with and without making ridges and or drain in a Hapludox soil, considering jointly the layers of 0-0.2 and 0.2-0.4 m.

Attributes	Classes of root diameter			
	Total	< 2 mm	2-5 mm	> 5 mm
Organic matter	0.5491***	0.4180**	0.3206*	0.5618***
pH in water	0.3022ns	0.2228ns	0.2979^{ns}	0.2565ns
Cation exchange capacity	0.4135**	0.5012***	0.4081**	0.3056ns
Base saturation	0.4251**	0.3994*	0.3953*	0.3203*
Exchangeable Ca	0.4574**	0.5521***	0.5224***	0.3067ns
Exchangeable Mg	0.2757ns	0.2214ns	0.1565ns	0.2815ns
Exchangeable K	-0.0330ns	0.0474ns	-0.1435ns	0.0053^{ns}
Extractable P	0.0992ns	0.2087ns	0.0929ns	0.0553ns
Clay	0.3243*	0.2353ns	0.2471ns	0.3086ns
Bulk density	0.3987*	0.3760*	0.3911*	0.3203*
Penetration resistance	0.1317^{ns}	0.0814ns	0.2316ns	0.0698ns
Total porosity	-0.2261ns	-0.2362ns	-0.3071ns	-0.1398ns
Macro porosity (Ø > 50 µm)	0.1609ns	0.1356ns	0.1813ns	0.1225ns
Micro porosity (Ø ≤ 50 µm)	-0.2803ns	-0.2375ns	-0.2753ns	-0.2312ns

^{ns}, *, ** and ***: correlation not significant or significant at 5, 1 and 0,1% level, respectively.

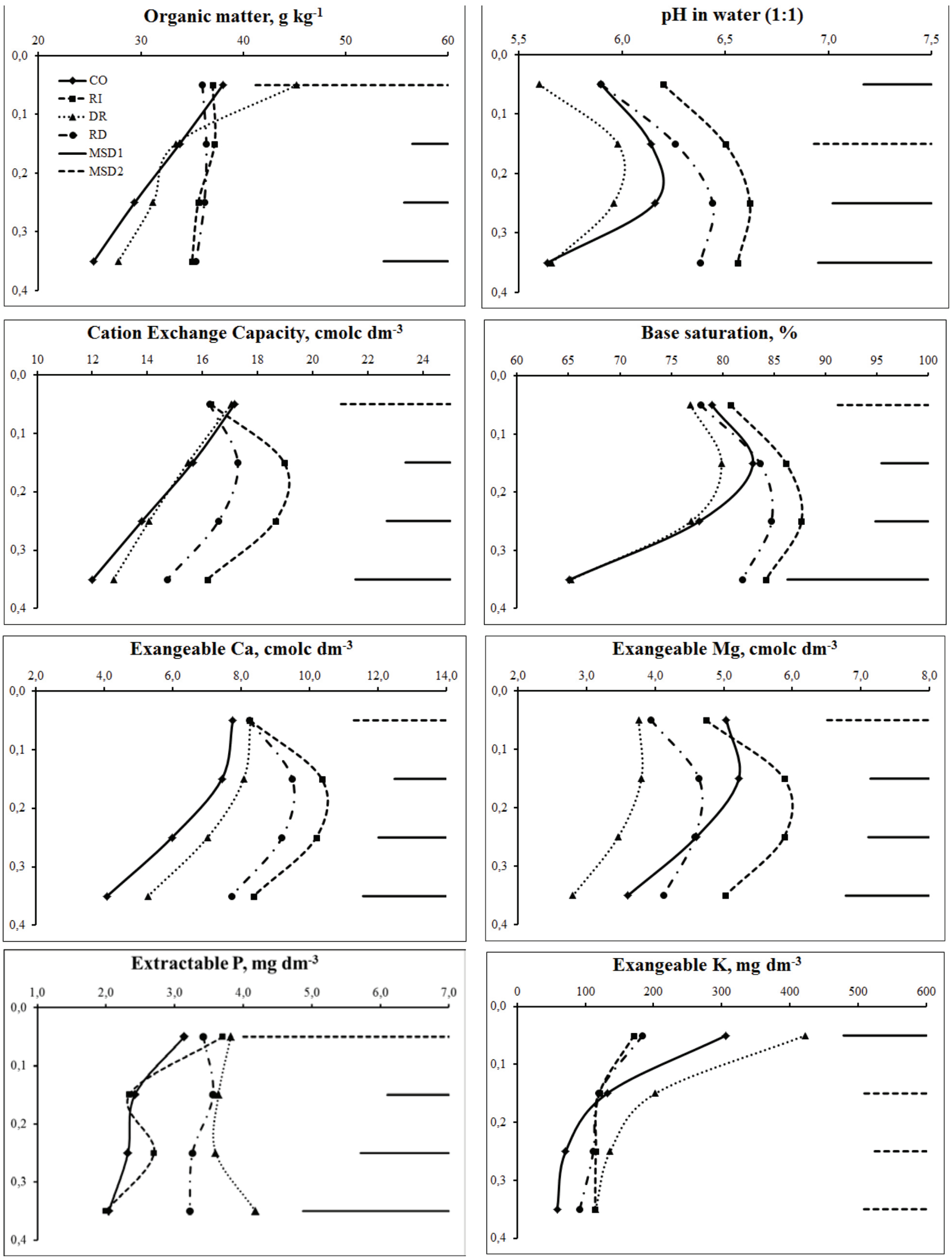

FIGURE 1- Profiles of soil chemical attributes three years after planting grapevine rootstock with and without making ridges and or drain in a Hapludox soil. CO: control; RI: ridge; DR: drains; RD: ridge + drains; MSD1 and MSD2: minimum significance difference, respectively with and without differences among means within each layer (P<0.05).

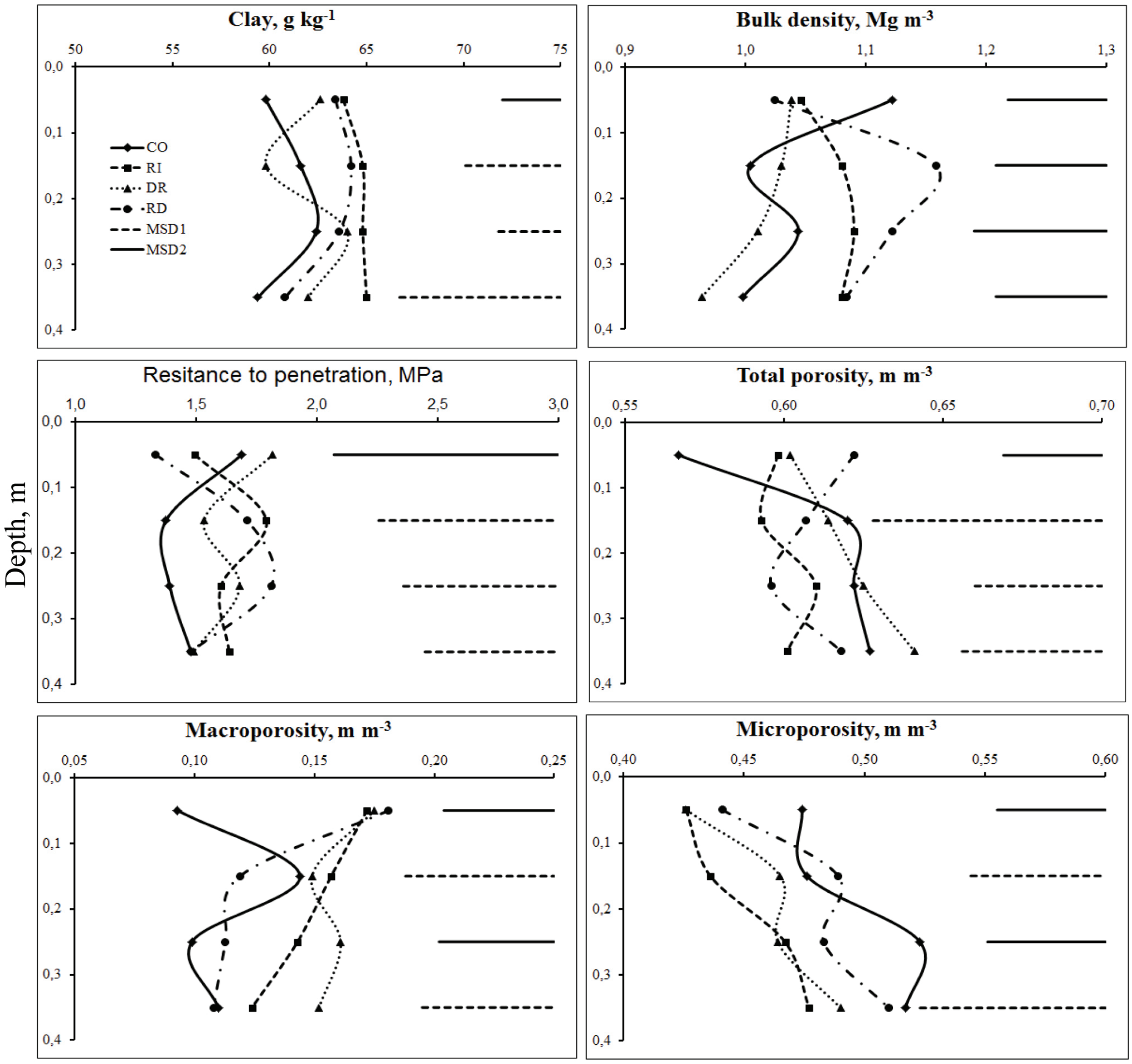

FIGURE 2- Profiles of soil physical attributes three years after planting grapevine rootstocks with and without making ridges and or drain in a Hapludox soil. CO: control, without ridges or drain; RI: ridge; DR: drains; RD: ridge + drains; MSD1 and MSD2: minimum significance difference, respectively with and without differences among means within each layer (Tukey test, P<0.05).

CONCLUSIONS

Ridges significantly alters most soil chemical attributes and provides greater uniformity in the values in depth, creating more favorable conditions to root growth of rootstocks in the deeper layers;

The physical attributes were less affected than chemical ones by making ridges and did not have restrictive values to root growth in the sampled layers until three years after their making;

Drains have lesser effect on soil chemical and physical attributes than ridges.

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