EXTENDED ABSTRACT

Water retention properties of viticultural calcisols from PDO Valdepeñas (Spain)

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ABSTRACT

Context and purpose of the study – A good knowledge of the soil physicochemical properties, as well as its ability to retain and put the necessary water available to the plants, is essential when it comes at the design of an irrigation plan. The latter must be capable of satisfying the water needs of the crops, avoiding both excess water (which is not used and causes soil leaching) and its deficit, since that ends up harming both the crops and their yields. In growing vineyards for winemaking, the quality of the grapes used will depend on the frequency and the amount of water supplied to the plant. Therefore, this aspect is especially relevant for viticulture in Mediterranean climates where water scarcity is an increasingly limiting reality (which is expected to be worse due to the influence of climate change).

The purpose of the study is the determination of the moisture retention properties corresponding to 33 vineyard calcisols selected as representative from the Protected Designation of Origin "Valdepeñas" in Castilla-La Mancha (Spain) and also, related them with other physicochemical soil properties to determine which of them are statistically correlated.

Material and methods – In this research, standard commercial pressure plate apparatus from Soilmoisture Equipment Corp. (Santa Barbara, California, USA), was used to apply the specified pressures from -10 kPa to -1500 kPa to the soil samples of the surface and subsurface horizons from the 33 calcisols soils (6 of them do not have subsurface horizon). After that, the gravimetric method was carried out on those same soils, and finally, the soil water retention curves were developed.

Results – The moisture values at Field Capacity (-33 kPa), Permanent Wilting Point (-1500 kPa) and Available Water of the surface (A) and subsurface (B) horizons were compared, concluding that soil depth statistically influences these parameters. The available water values of each horizon were related to the most relevant soil physicochemical properties in terms of moisture retention (bulk density, sand, silt, clay, organic matter, calcium carbonate and active calcium carbonate) to know whether they were correlated. For A horizons, silt and active calcium carbonate are positively correlated with available water ($r = 0.43$ and $r = 0.42$, respectively), however, calcium carbonate and active calcium carbonate are the most positive correlated properties with the available water of B horizons ($r = 0.68$ and $r = 0.57$, respectively).

INTRODUCTION

One of the major concerns in agronomy today is the study of how the proper development of crops can be affected by variations in soil water content. Research interest in soil drying and wetting processes is constantly increasing as more attention is paid to the environment and natural resources. The amount of water available in the soil is one of the most important factors in crop development, as it is a key compound in plant physiology, and with its limited use in the agricultural sector becoming more and more important, the emphasis on research and interest in this topic has increased recently.

A good knowledge of the physicochemical soil properties, as well as its capacity to retain and make the necessary water available to the plants, is essential when it comes to the design of an irrigation plan. The latter must be capable of satisfying the water needs of the crops, avoiding both excess water (which is not used and leads to the leaching of nutrients and other soluble elements from the soil) and water deficit, as these end up damaging the crops and their yields. In wine grape growing, the quality of the grapes used in winemaking will depend in part on the amount of water supplied to the vineyard. Therefore, this aspect is particularly relevant for viticulture in Mediterranean climates where water scarcity is an increasingly limiting reality (which is expected to become worse due to the influence of climate change) (Costa et al., 2016).

This research is focused on the "Valdepeñas" Protected Designation of Origin (PDO) of wine located in Ciudad Real (Castilla-La Mancha, Spain) and, more specifically, on the winegrowing calcisols and their water retention properties. It is important to note that Valdepeñas PDO is in the middle of the semiarid Mediterranean area, (where grapevines are subjected to excessive heat and water stress), which makes adequate soil water storage capacity essential (Jiménez-Ballesta et al., 2021). Calcisols are typical of this geographical indication and in the Castilla-La Mancha region (Amorós et al., 2010; Jiménez-Ballesta et al., 2021) because of the precipitation and consequent accumulation of calcium carbonate that is quite common in arid or semiarid regions (Gile, 1999).

These viticultural soils were previously studied in the report prepared by the research group "Suelos Vitícolas" of the High Technical School of Agricultural Engineers of Ciudad Real (University of Castilla-La Mancha) (García-Navarro et al., 2019) and classified as calcisols according to the world reference base for soil resources 2006 (FAO, 2007). In the report published in 2019, the description, physicochemical laboratory analysis and mapping of the 33 soil profiles included in this research were carried out, but nothing about their moisture retention properties was researched, with the significance that this entails in a semiarid growing area like Castilla-La Mancha (Ortega et al., 2005; Jiménez-Ballesta et al., 2021).

RESEARCH OBJECTIVES

The main objective of this research is to contribute to the knowledge of the calcisols soils under this geographical indication (Valdepeñas PDO), by determining the peculiar attributes about the moisture retention properties corresponding to the winegrowing calcisols soils of this area and also, related them with other physicochemical soil properties that are relevant in terms of moisture retention (bulk density (only in the surface horizon), sand, silt, clay, organic matter (OM), calcium carbonate (CaCO3) and active calcium carbonate) to determine which of them are statistically correlated. This information can help winegrowers under this PDO by making agronomic decisions easier in terms of the vineyard water needs, guaranteeing good irrigation practice, efficient and adapted to their calcisols physicochemical properties, in order to obtain the best yields with the best use of available irrigation water.

MATERIAL AND METHODS

33 vineyard calcisols were selected as representative from the Valdepeñas PDO in Castilla-La Mancha (Spain). The research area covers six municipalities (Alcubillas, Moral de Calatrava, San Carlos del Valle, Santa Cruz de Mudela, Torrenueva and Valdepeñas) completely and four partially (Alhambra, Granátula de Calatrava, Montiel and Torre de Juan Abad). This PDO is characterised by a large plain where some mountain ranges and their associated reliefs stand out within the geographical context located in the connection zone between Campo de Montiel and Campo de Calatrava. With an average altitude of 705 metres above sea level, it has a dry continental or semiarid climate with maximum temperatures that exceed 40 °C and minimum temperatures that can reach -7 °C. The average annual temperature is 16 °C. Rainfall is scarce, between 200 and 400 litres per year, being more frequent in spring, and usually of short duration and stormy in nature.

To measure their water retention properties, the soil water characteristic curve of the surface and subsurface horizons (if the latter was not bedrock) of each of them was obtained by using the original samples from the report published in 2019 that were passed through a 2 mm mesh sieve and preserved in plastic bags in the laboratory. The selected method to carry out this determination is the pressure plate apparatus or pressure plate extractor manufactured by Soilmoisture Equipment Corp. (Santa Barbara, California, USA), which is available in the soil science laboratory of the High Technical School of Agricultural Engineers in Ciudad Real.

The soil water characteristic curve determination using the pressure plate apparatus is a procedure widely described in the literature. This principle has remained unchanged over the years (since the publication of L.A. Richards in 1947) and only some details have been added or modified in order to obtain a more accurate measurement (ASTM International, 2016). The measurement procedure used in this research has been transferred from the above-mentioned publications. After the soil samples have reached apparent equilibrium, the gravimetric method was carried out on those same soils, and finally, the moisture content (%) at field capacity (FC) (33 kPa), permanent wilting point (PWP) (1500 kPa) and available water capacity (AWC) (difference between FC and PWP) were obtained together with the soil water retention curves in the useful range for most plants (from 10 to 1500 kPa).

All these results in conjunction with the data of the following soil properties: bulk density (g/cm3) (only in the surface horizon), sand (%), silt (%), clay (%), OM (%), CaCO3 (%) and active calcium carbonate (%) from the previous report were submitted to statistical analysis. The programme used to carry out the statistical study is Statgraphics Centurion XVII, under license from the University of Castilla-La Mancha. This software is a useful tool for analyzing data and performing various statistical analyses like descriptive, multivariate and time series ones, among others. It also includes interactive graphics and the ability to generate reports. A linear regression analysis was carried out using the above-mentioned programme to determine the correlation coefficient between the calcisols physicochemical characteristics and their moisture retention properties.

RESULTS

The statistical programme was used to find out whether calcisols depth influences the moisture retention properties of these soils, by means of an analysis of variance (ANOVA) of the available water values in the surface and subsurface horizons. The results showed that there is a statistically significant difference between the mean available water values (%) of the A (7.48) and B (10.88) horizons at the 5 % level of significance. Therefore, it can be said at a 95 % level of confidence that difference is real and most of the subsurface horizons have a greater capacity to store water in comparison with the superficial horizons in these calcisols.

Next, the influence or correlation of some physicochemical properties on the moisture retention properties of these viticultural calcisols was analyzed (tables 1 and 2). This statistical study was subdivided into surface and subsurface horizons and finally, a table with Pearson's product moment correlation was obtained for each type of horizon. Pearson's coefficient range between -1 to +1 and reflects the strength of the linear relationship between the variables. Below that, and in brackets, is the number of data pairs used to calculate each of the above coefficients, and finally, the results obtained from correlations between two variables include a p-factor in the table. This third value can be less than or equal to 0.05 (red colour), indicating a statistically significant non-zero relationship with a 95 % confidence level, or greater than 0.05 (black colour), showing a statistically non-significant relationship which may be due to a random chance. Depending on how close that p-factor is to 1 the confidence percentage will be higher or lower.

For the A horizons, focusing on AWC, table 1 shows a remarkable positive correlation with silt ($r = 0.43$) and active calcium carbonate ($r = 0.42$) and a negative relation with sand ($r = - 0.30$) and bulk density ($r = - 0.26$), but the latter two do not show correlations significantly different from zero, due to a p-factor greater than 0.05. Therefore, we cannot be sure that there is a real relationship between them as there is for silt and active calcium carbonate with available water.

With regard to the B horizons, focusing again on AWC, table 2 shows a remarkable positive correlation with calcium carbonate ($r = 0.68$) and active calcium carbonate ($r = 0.57$), and no negative relationships are worth mentioning. In this case, the p-factor is much smaller than 0.05 for both positive correlated properties which ensures a real relationship with available soil water. Therefore, the results are unlikely to have occurred by chance and are more likely to reflect a real difference between the variables.

All the results can be verified in the tables at the end of this document.

CONCLUSION

Considering the results obtained, it can be concluded that differences exist between the surface and subsurface horizons of these viticultural calcisols. The physicochemical properties have a different correlation with AWC, depending on whether it is the A or the B horizon. Hence, it can be deduced that calcisols, under this PDO, with a higher content of silt, $CaCO3$ and active $CaCO3$ will have a greater capacity to store water, allowing them to be irrigated for longer times and less frequently, whereas calcisols with higher sand content may require shorter and more frequent irrigation to ensure better water use by plants.

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TABLES

Table 1. Pearson's coefficients, number of data and p-factor between variables for the surface horizons.

		A.% sand	A.% silt	A.% clay	% OM	% $CaCO_3$	% Active Calcium Carbonate	FC-A	PMP-A	AWC-A	Bulk Density (g/cm^3)
A.% sand	PC		-0.7388	-0.6687	-0.3307	-0.2196	-0.2459	-0.5203	-0.542	-0.3045	0.6033
	data		(33)	(33)	(33)	(33)	(30)	(33)	(33)	(33)	(33)
	p-factor		0.0000	0.0000	0.0602	0.2195	0.1903	0.0019	0.0011	0.0849	0.0002
A.% silt	PC			-0.0071	0.2773	0.4807	0.5192	0.4811	0.3700	0.4262	-0.5680
	data			(33)	(33)	(33)	(30)	(33)	(33)	(33)	(33)
	p-factor			0.9686	0.1183	0.0046	0.0033	0.0046	0.0340	0.0134	0.0006
A.% clay	PC				0.1849	-0.2049	-0.2049	0.2407	0.3953	-0.0185	-0.2683
	data				(33)	(33)	(30)	(33)	(33)	(33)	(33)
	p-factor				0.3031	0.2526	0.2773	0.1771	0.0228	0.9186	0.1312
% OM	PC					0.1273	0.2150	0.2352	0.3653	0.0050	-0.5827
	data					(33)	(30)	(33)	(33)	(33)	(33)
	p-factor					0.4802	0.2539	0.1876	0.0366	0.9781	0.0004
% $CaCO_3$	PC						0.8832	0.3263	0.2632	0.2755	-0.4116
	data						(30)	(33)	(33)	(33)	(33)
	p-factor						0.0000	0.0639	0.1389	0.1208	0.0173
% Active Calcium Carbonat	PC							0.3215	0.1194	0.4152	-0.4389
	data							(30)	(30)	(30)	(30)
	p-factor							0.0832	0.5297	0.0225	0.0152
FC-A	PC								0.8427	0.8046	-0.4586
	data								(33)	(33)	(33)
	p-factor								0.0000	0.0000	0.0075
PMP-A	PC									0.3584	-0.4814
	data									(33)	(33)
	p-factor									0.0406	0.0046
AWC-A	PC										-0.2612
	data										(33)
	p-factor										0.1421

Abbreviaton: PC → Pearson´s coefficient

Table 2. Pearson's coefficients, number of data and p-factor between variables for the subsurface horizons.

		B.% sand	B.% silt	B.% clay	% OM	% $CaCO_3$	% Active Calcium Carbonate	FC-B	PMP-B	AWC-B
B.% sand	PC		-0.6492	-0.6887	-0.3066	-0.0247	0.0739	0.0268	-0.0649	0,0688
	data		(26)	(26)	(21)	(26)	(25)	(26)	(26)	(26)
	p-factor		0.0003	0.0001	0.1765	0.9048	0.7257	0.8965	0.7526	0.7385
B.% silt	PC			-0.1070	0.2209	0.2901	0.3457	0.0942	0.0550	0.0958
	data			(26)	(21)	(26)	(25)	(26)	(26)	(26)
	p-factor			0.6028	0.3358	0.1506	0.0905	0.6471	0.7896	0.6414
B.% clay	PC				0.1838	-0.2444	-0.4354	-0.1257	0.031	-0.1816
	data				(21)	(26)	(25)	(26)	(26)	(26)
	p-factor				0.4252	0.2289	0.0296	0.5407	0.8805	0.3747
% OM	PC					-0.1373	0.0792	0.1107	0.3005	-0.0281
	data					(22)	(21)	(22)	(22)	(22)
	p-factor					0.5423	0.7328	0.6239	0.1742	0.9011
% $CaCO_3$	PC						0.8205	0.6603	0.3533	0.6806
	data						(26)	(27)	(27)	(27)
	p-factor						0.0000	0.0002	0.0707	0.0001
% Active Calcium Carbonate	PC							0.6682	0.5814	0.5699
	data							(26)	(26)	(26)
	p-factor							0.0002	0.0018	0.0024
FC-B	PC								0.7206	0.9383
	data								(27)	(27)
	p-factor								0.0000	0.0000
PMP-B	PC									0.4365
	data									(27)
	p-factor									0.0228

Abbreviaton: PC → Pearson´s coefficient