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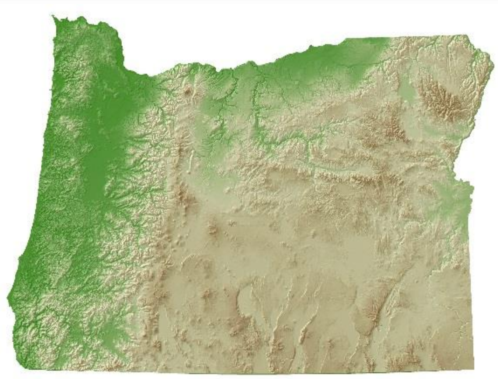

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EFFECT OF VINEYARD FLOOR MANAGEMENT PRACTICES ON WATER USE: A CASE STUDY AT A TERROIR OF THE "DÃO" WINEGROWING REGION IN PORTUGAL

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Abstract
Aiming to evaluate the effect of vineyard floor management practices on water use and vine performance, a field experiment was carried out at the Dão Wine Research Station, located at Nelas, Center Portugal. The experiment was set up in 2010 in a mature vineyard planted with the red grape variety 'Touriga Nacional', using a 2x2 factorial design with the following treatments: inter-row soil management (permanent resident vegetation *vs.* soil tillage) and undervine floor management (mulch *vs*. herbicide). In this paper it will be presented data from 2013 growing season (four seasons after experiment setup). The volumetric soil moisture, assessed with a capacitance probe to a 1.5 m depth, showed a decreasing pattern throughout the growing season in all treatments with the resident vegetation presenting lower values as compared to the tillage treatment, while no significant differences were observed between the two undervine floor management practices. From budburst to flowering the resident vegetation treatment showed a higher soil water depletion (up to 1.5 m depth) than the tillage treatment but the relative situation was reversed during the flowering-veraison period, while no significant differences were observed during the ripening period. Vine stem water potential values showed a decreasing pattern along the season attaining very low values during September but with no significant differences between treatments. In general the soil management practices did not significantly affect vine vigor, yield and berry composition however, since these results are only from one season, further data analysis in ongoing in order to allow stronger conclusions.

***Keywords**: grapevine, mulch, cover cropping, soil tillage, soil moisture; stem water potential, water use.*

1 INTRODUCTION

For a long time, until recently, the soil management practices used in Portuguese vineyard consisted mainly on cultivation and/or herbicide applications undervine or in the entire vineyard area. These techniques have negative environmental consequences, such as soil erosion, nitrate leaching, loss of organic matter, reduction of biodiversity, the appearance of herbicide resistant weeds and groundwater contamination, among others (Monteiro et al. 2012, Guerra and Steenwerth 2012).

The effects of soil and floor management practices are reported in many works (e.g. review from Guerra and Steenwerth 2012). The main advantages of soil cultivation include the suppression of weed competition (Lipecki and Berbeć 1997), the incorporation of fertilizers and weed/cover crops (Monteiro et al. 2012), break up hardpans that hinder root penetration and promote the destruction of the surface crust, helping to reduce runoff (Merwin et al. 1994). The main disadvantages of this method include soil compaction and degradation of soil structure (Nicholas 2004). Furthermore, tillage reduces soil organic matter (Lal and Kimble 1997, Steenwerth and Belinda 2008).

Vineyard inter-row cover cropping either by sown selected species or by resident vegetation contributes to a more sustainable viticulture, allowing, for example, for the reduction of herbicides. This technique was originally used in humid climates in order to reduce soil moisture and therefore vine vigour (Ruiz-Colmenero et al. 2011). Cover cropping may also be beneficial to the soil proprieties like for example increase the infiltration rate (Celette et al. 2008, Ruiz-Colmenero et al. 2011), reduction of erosion (Ruiz-Colmenero et al. 2013) and increase of soil organic matter content (Steenwerth and Belinda 2008). Furthermore cover crops might improve the access of agricultural machinery after a rainfall event (Nicholas 2004), which is a very important aspect due to the high level of mechanization used in viticulture. In the Mediterranean area, and particularly in non-irrigated vineyards, a major limitation to implementing cover cropping is associated with the risk of water (Celette et al. 2008, Lopes et al. 2011) and nutrients competition (Celette et al. 2009).

The use of mulches is also a floor management practice widely used to provide weed control (Frederikson et al. 2011) and soil moisture conservation (Varga and Májer 2004), to reduce soil loss rates by runoff (Prosdocimi et al. 2016), to improve soil structure (Oliveira and Merwin 2001), and soil physical and chemical characteristics (Jordán et al. 2010), to reduce soil temperature fluctuations (Pinamonti 1998) and the negative effects caused by the impact of raindrops (White 2009). Besides being costly (manufacture and spreading) mulches present other disadvantages: coarse mulch may provide shelter for some pests and increased vertebrate problems (Nicholas 2004), the layer of organic mulches should be at least 10 cm thick and need to be reapplied every 2-3 years (Lanini et al. 2011).

The use of herbicides is a cheap and effective method of soil management (Tourte et al. 2008). Some reasons to reduce herbicide use include the risk of development of herbicide resistant weeds (Jasienuk et al. 2008) and environmental contamination. Herbicides have also been combined with mulches to control seed germination and seedlings in vineyards (Guerra and Steenwerth 2012).

This paper aims to present and discuss the effects of four soil management practices on vine water use and its consequences on vigor, yield and berry composition of the red variety Touriga Nacional grown at the Dão Wine-growing region, Portugal, during the 2013 season (four seasons after experiment setup).

2 MATERIAL AND METHODS

The experiment was carried out at the Dão Wine Research Station located in Nelas in the centre of Portugal (Latitude 40° 31'N, Longitude 7° 51'W, Elevation 440 m). The experiment was set up in 2010 in a mature non-irrigated vineyard, planted with the Touriga Nacional red grape variety, grafted onto 110R rootstock. The vines were spaced 1.1 m within and 2.0 m between rows, trained on a vertical shoot positioning with a pair of movable wires and spur-pruned (12 nodes per vine) on a bilateral Royat Cordon system. The soils are of granite origin, light-texture, porous and permeable with low water holding capacity and low organic matter.

The experimental layout used was a 2x2 factorial experimental design with the following treatments: inter-row soil management (RV – permanent resident vegetation *vs*. ST – soil tillage) and undervine floor management (Mul – woodchips mulch *vs*. Her – herbicide). Vegetation mowing and soil tillage were performed twice a year. The resident vegetation was mowed with a brush cutter, and soil tillage was performed using a cultivator mounted on a tractor. The herbicide was sprayed on a 50 cm wide undervine strip. A 0.25 x 0.10 m woodchips mulch strip was applied manually.

Soil water content was monitored using a capacitance probe (Diviner 2000®, Sentek Pty Ltd). Readings were taken periodically at increments of 0.1 m from soil surface to a depth of 1.5 m. Eight access tubes per treatment were placed along the row between two contiguous vines and in the middle of the inter row.

Stem water potential (Ψ_{stem}) was measured at midday on 3 leaves per replication (12 per treatment) had been covered with a plastic bag and aluminium foil 2 hours before measurement, in order to prevent leaf transpiration (Choné et al. 2001).

The cluster number and weight per vine were assessed at harvest and a 100 berries sample per replication was collected to evaluate fruit composition. During winter pruning the number and pruning weight per vine was recorded. The data was subjected to ANOVA using SPSS 17 (IBM Company).

3 RESULTS AND DISCUSSION

In all treatments, the average volumetric soil water content in the 0-1.5 m profile showed a decrease pattern from early spring to mid-September and then a slight increase caused by the first rains (Fig. 1). While no significant differences were observed between the two undervine treatments, significantly higher volumetric soil moisture values were observed in RV treatment as compared to ST (Fig.1A).

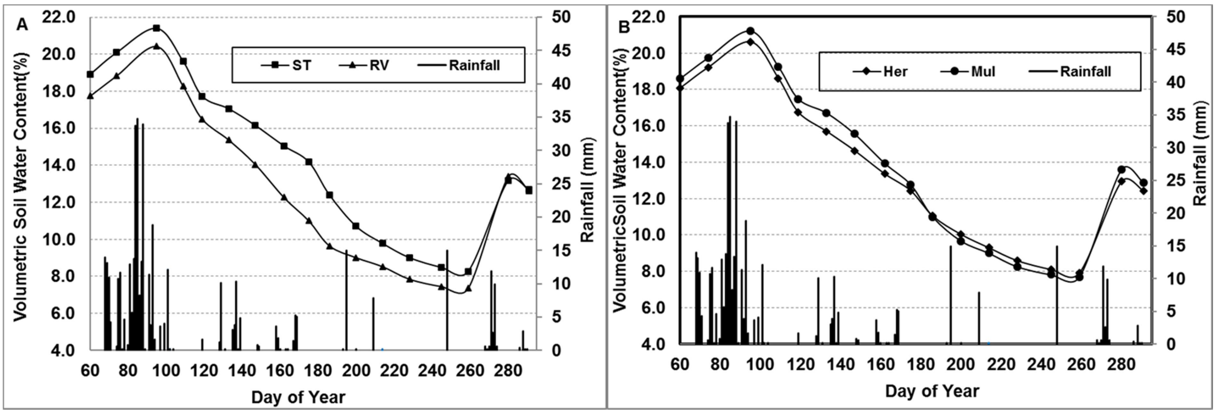

Figure 1: Effects of soil management practices in the inter-row (A) and undervine (B), in the evolution of the average volumetric soil water content in the 0-1.50 m profile (average of 8 access tubes installed on inter-row) during 2013. ST: Soil tillage on the inter-row; RV: permanent resident vegetation on the inter-row; Her: herbicide strip undervine; Mul: woodchips mulch strip undervine.

In order to estimate soil water extraction during the key phenological stages we have used a simplified version of the general equation of the water balance for a given time interval and for the relevant profile (Eq. 1):

$$\text{Water use} = R + \Delta S \qquad \text{(Eq. 1)}$$

where ΔS is the soil water storage variation in the inter row access tubes and R the rainfall, assuming that no runoff or deep percolation and capillary rise of groundwater has occurred (Wang et al. 2011).

Table 1 shows that up to 1.5 m depth, the water used by RV treatment was significantly higher than that of ST treatment during the budburst–flowering period, whereas in the following period (flowering–veraison) the reverse was found. During the veraison–harvest period the extraction pattern was similar to the previous period but there were no significant differences between treatments. When considering the entire growth period (budburst–harvest) no significant differences were detected between soil management practices. These results are similar to those obtained by Monteiro and Lopes (2007) in a research conducted at the Lisbon winegrowing region with the variety "Cabernet Sauvignon". The same authors suggested that the higher water consumption in the ST treatment during the ripening period may be explained by the combined effect of a higher grapevine leaf area, greater soil water availability and by the increased evaporation rate of the bare soil.

Figure 2 presents the soil water storage variation for five 0.30 m soil layers. From budburst to flowering soil water depletion has occurred mainly in the first three soil layers (0 to 0.9 m) with the RV treatment presenting significantly higher values than those of ST treatment (Fig. 2A). During the flowering–veraison period there was a progressive tendency for an increase in water depletion from deeper layers (0.9 – 1.5 m) and the relative situation between treatments was reversed (Fig. 2B). During the ripening period water extraction values were very low throughout the entire profile in all treatments (data not shown), however extraction below 1.5 m depth (not monitored) might have occurred as observed by Rodrigues (2011) in a study carried out in a vineyard plot adjacent to the current experiment.

Table 1: Effect of soil management practices on the estimated average soil water use over the main grapevine growth periods, from 0 to 1.5 m soil depth. Touriga Nacional, Nelas, 2013.

		Daily water use (mm day^{-1})			
		Budburst / flowering	Flowering / Verasion	Verasion / Harvest	Budburst / Harvest
Inter-row					
	ST	2.33	1.85	0.78	1.83
	RV	2.74	1.46	0.67	1.82
	Sig	*	*	ns	ns
Undervine					
	Her	2.51	1.57	0.74	1.78
	Mul	2.55	1.74	0.72	1.86
	Sig	ns	ns	ns	ns
Interaction		ns	Ns	ns	ns
Rainfall (mm)		63.8	35.2	14.9	113.9

ST: soil tillage in the inter-row; RV: inter-row resident vegetation; Her: undervine herbicide strip; Mul: undervine mulch strip. Sig - level of significance; ns - no significant differences; * - significant at P <0.05.
(1) Data obtained from the sum of the rainfall with soil water depletion from 0 to 1.50 m soil depth. Runoff, deep percolation and capillary rise of groundwater were assumed to be negligible.

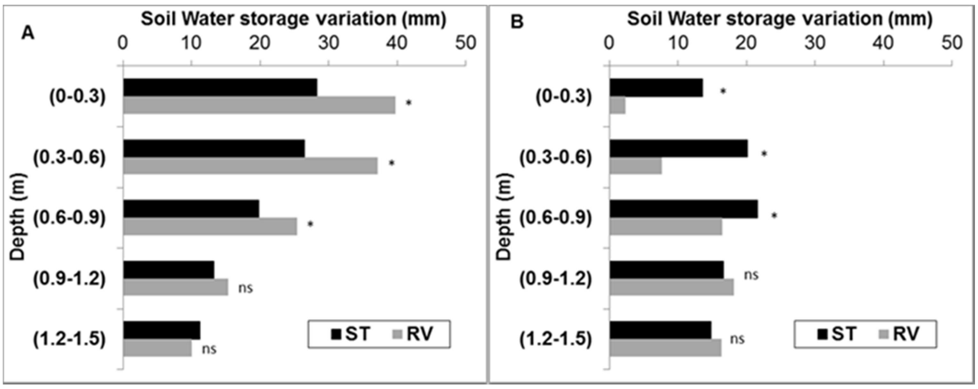

Figure 2: Effects of soil management practices on estimated mean soil water storage variation ($\Delta S=S_z(t1)-S_z(t2)$; $S_z(t)$ is the soil water storage at time t and depth z) for 5 layers during 2013 growing season (access tubes installed in the middle of the inter-row). (A) Period budburst–flowering and (B) period flowering–veraison. ST: Soil tillage in the inter-row; RV: permanent resident vegetation in the inter-row. Sig - level of significance; ns - no significant differences; * - Significant at P <0.05.

The stem water potential values showed no significant differences between treatments on all the measurement dates (data not shown). At the end of the ripening period, before the first rainfall, the stem water potential values obtained (ST: -1.37 MPa; RV: -1.32 MPa; Her: -1.35 MPa and Mul: -1.34 MPa) indicate a moderate to severe water stress situation (Ojeda 2008).

Although some authors have reported significant reductions in yield as a result of the use of cover crops (Afonso et al. 2003 and Lopes et al. 2011), our results show that neither yield per vine nor cluster weight were significantly affected by soil management techniques (Table 2). These results are similar to those reported by Lopes et al. (2008) in an experiment carried out at Lisbon winegrowing region.

No significant effects of the soil management practices were detected on berry composition as also observed by Lopes et al. (2011) in a similar experiment at Alentejo winegrowing region of Portugal with the variety Aragonez (syn Tempranillo). Despite a slightly higher pruning and shoot weight presented by ST treatment no significant differences were detected between treatments. This results differ from other reports that have showed significant reductions in the pruning weight due to cover crops competition for water as compared to soil tillage (Lopes et al. 2008, Lopes et al. 2011, Trigo-Córdoba et al. 2015, Beslic et al. 2015) and seems to indicate that in this terroir the water competition by the cover crops was not severe enough to induce differences in grapevine vegetative growth.

Table 2: Effects of soil management practices on yield and yield components, berry composition and pruning weight. Touriga Nacional, Nelas, 2013. TSS- total soluble sugars; TA – titratable acidity.

Treat	**Clusters/ vine**	**Yield (kg/vine)**	**Cluster wt (g/cluster)**	**TSS (ºBrix)**	**TA (g tart ac./L)**	**Antocyanins (mg/L)**	**Pruning wt (kg/vine)**	**Shoot wt (g/shoot)**
Inter row								
ST	18.3	1.77	97.1	21.7	7.60	669.6	0.46	36.9
RV	19.3	1.66	85.9	21.8	7.66	716.6	0.41	33.3
Sig	ns	Ns	ns	ns	ns	Ns	ns	ns
Undervine								
Her	18.1	1.68	93.1	22.3	7.55	704.8	0.41	33.5
Mul	19.4	1.74	89.8	21.3	7.70	681.4	0.45	36.7
Sig	ns	ns	ns	ns	ns	Ns	ns	ns
Interaction								
Sig	ns	ns	ns	ns	ns	Ns	ns	ns

ST: Soil tillage in the inter-row; RV: inter-row resident vegetation; Her: under-trellis herbicide strip; Mul: under-trellis mulch strip. Sig - level of significance; ns - no significant differences at $P < 0.05$.

4 CONCLUSIONS

Our preliminary results indicate that under the ecological conditions of the Dão terroir, the use of resident vegetation seems to be a useful technique to substitute inter-row tilling since water competition observed in the spring did not negatively affected grapevine performance. Furthermore, as no significant differences between the two under-trellis floor management treatments were detected, the choice between herbicide or organic mulches should be decided according to economic and environmental constraints.

These conclusions should be taken with care as they are based only on data from one growing season. More robust conclusions should be made only after the analysis of the 5 seasons of this experiment, which is under progress.

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