SOIL MANAGEMENT AS A KEY FACTOR ON VINEYARD BEHAVIOR UNDER SEMIARID CONDITIONS: EFFECTS ON SOIL BIOLOGICAL ACTIVITY, PLANT WATER AND NUTRIENT STATUS, AND GRAPE YIELD AND QUALITY

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Abstract

Aims: Viticulture practices linked with soil management, as cover crops and deficit irrigation, can help to regulate the vineyard behavior reducing in most cases plant vigor and modifying plant water and nutrient status, and as a consequence, grape yield and quality. Also, these practices can modify the soil biological activity mostly related to microbiome diversity and functionality. However, the overall effect of these agricultural practices depends on the soil water availability, the soil fertility, and the grape cultivar response. Under semiarid conditions, the intensity of competition for water and nutrients associated to cover crop practice can be a handicap for a regulation of grape yield and quality. Also, the effect of cover crops on soil biology under those conditions is poorly understood.

Methods and Results: In the present work we present results of a three year's experiment studying the effect of combining natural green cover and deficit irrigation on soil microbiome, plant water and nutritional status, and grape yield and quality, in two contrasting genotypes. Changes in functional diversity of microbiomes were mainly associated with soil moisture and also changed throughout the vegetative period. Nevertheless, organic matter decomposition assays determined that the maintenance of the cover implies not only a higher rate of decomposition of organic matter but also that a less fraction of it is degraded, favoring the accumulation of carbon in the soil. Under our experimental conditions, green cover reduced plant growth and yield due to an excess of competition for water regardless of genotype. However, the cover crop had a positive effect on grape quality increasing sugar and phenolic content.

Conclusions: The maintenance of cover crop in vineyards under semiarid areas such as the Mediterranean basin, generates a balance between positive effects such as the increase of organic C in the soil or the improvement of the quality of the grape and negative effects such as the decrease in the availability of water in the soil or the decline of yields.

Significance and Impact of the Study: This study has shown that more sustainable soil management practices can have clear positive effects on the environmental services of the agroecosystem and yield quality. These results open a window to explore this type of management in less studied environments such as the Mediterranean.

Keywords: Cover crop, microbiome, grapevine, ecosystem services

Introduction

The strategies involving soil tillage and the use of cover crops, a non-conventional soil management practice, is matter of debate and solutions are greatly linked to the concept of "terroir" (Pou *et al.,* 2011; Lopes *et al.,* 2011; Medrano *et al.,* 2014). The effects of cover crops on grapevine vigour, yield and berry composition depend on the "terroir", being either (i) beneficial to control vegetative growth and increase berry colour in the case of vigorous genotypes combined with high spring rainfall or (ii) detrimental, in case of low vigour genotypes/cultivars and/or of semi-arid and/or extreme environments because they can result in an excessive reduction in vigour and yield (Pou *et al.,* 2011; Costa *et al.,* 2016). On the other hand, the implementation of cover crops, have been promoted as management options for enhancing soil quality and health (Sharma *et al.,* 2018). Indeed, those practices are known to directly or indirectly affect populations of soil bacterial communities and their functional diversity, and contribute to the ecological intensification of crops, enhancing ecosystem services such as nutrient cycling, water management and increased biodiversity (Monteiro and Lopes, 2007). The present work analyzes the effects of two soil management systems, spontaneous cover crop *versus* traditional tillage, and applying two water treatments (water deficit irrigation and no irrigation), in soil water dynamics, soil biological activity and plant performance.

Material and Methods

The experiment was carried out in the experimental vineyard located on the UIB Campus. 10 years old plants of Tempranillo and Garnacha cv grafted in R-110 and conducted to a bilateral cordon with vertical positioned shoots. The row and vine spacing are 2.5m by 1 m. Two soil management systems were evaluated for three consecutive years: traditional tillage and spontaneous and permanent cover crop, and two irrigation regimes: deficit irrigation (0.3 ETo) applied from June to September by drip irrigation system and no irrigation. Cover crop was tilled two times along the year: at the end of fall and middle spring. Spontaneous over crop was analyzed in terms of diversity, biomass production and nutrient sequestration. Soil water dynamics and plant water status was monitored along vegetative period using FDR probes installed one-meter depth in the vine lines, and stomatal conductance as a reference parameter (Medrano *et al.,* 2002) respectively. During two years of experiment, the soil biological activity was determined by measuring the rate of soil CO_2 emission in the row and in the vine lines with a soil respiration chamber (Li-6400-09) directly connected to a portable gas exchange analyzer (Li-6400, LI-COR Biosciences, Lincoln, NE, USA). The diversity and functionality of the bacterial community of the rhizosphere and the adjacent soil was evaluated, at flowering, veraison and harvest, by using Ecoplates (Biolog®) technique (Baraza *et al.,* 2019). The organic material decomposition rate was estimate by the "tea bag index" method. Also, nutrients competence effect due to cover crop was analyzed by measuring nutrient extraction by cover crop and its biomass two times along the year in the two years of the experiment and nutritional status of the vineyard was measured in petioles at vearison. Finally, growth and plant yield components as well as grape quality was analyzed at harvest.

Results and Discussion

The cover crop diversity was analyzed considering four groups: G1. Species with bulbs/rhizomes, G2. Annual speciesG3. Perennial species and G4. Legumes. The total dry biomass of each functional group changes during the year and is highly dependent of soil water availability (Figure 1). In non-irrigated lines, the main group was annual and perennial species. However, under irrigation, only annual species was the predominant in both winter and spring times. Also, year by year effect was observed for most of the groups (Figure 1). The presence of cover crop do not affect significantly the plant nutrient status (data not shown).

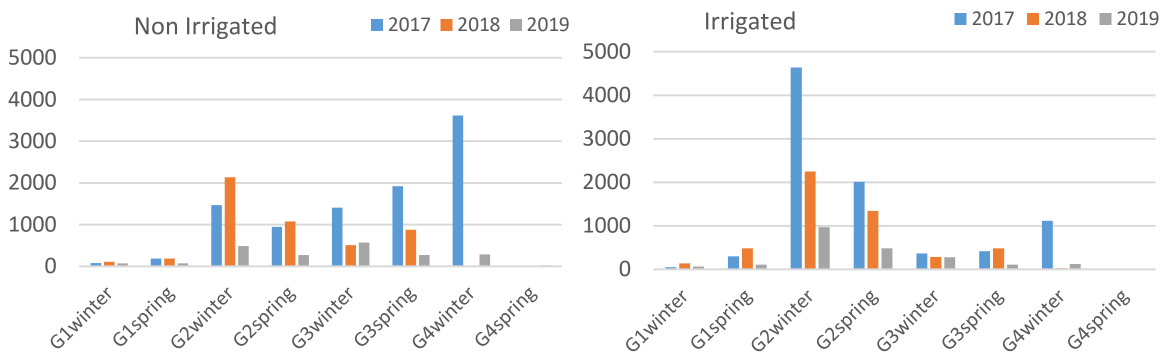

Figure 1: Total dry biomass of cover crop species grouped in four groups considered G1. Species with bulbs/rhizomes, G2. Annual speciesG3. Perennial species and G4. Legumes. Data correspond to the three years of experiment and two times of each year.

Soil management determined soil water availability and plant water status (Figure 2). The presence of cover crop clearly reduced the soil water moisture at 30 cm deep, even at the beginning of flowering, that confirm the relevant competition for water between the cover crop and the vineyard. This fact also was reflected in plant water status. Plants positioned in the cover crop plots, showed stomatal conductance values around 150 mmol H_2O $m^{-2}s^{-1}$, at flowering compared to 250-300 mmol H_2O $m^{-2}s^{-1}$ in tilled soil. These values were declining along vegetative period. The more affected cultivar by water deficit associated to green cover was Tempranillo (Figure 2). Although the cover crop does not affect the functionality of the microbiota, an increase in the degradation rate of organic matter and in the non-degraded fraction allowed a greater accumulation of organic C in the no-tilled soil (Capó -Bauçà *et al.,* 2019).

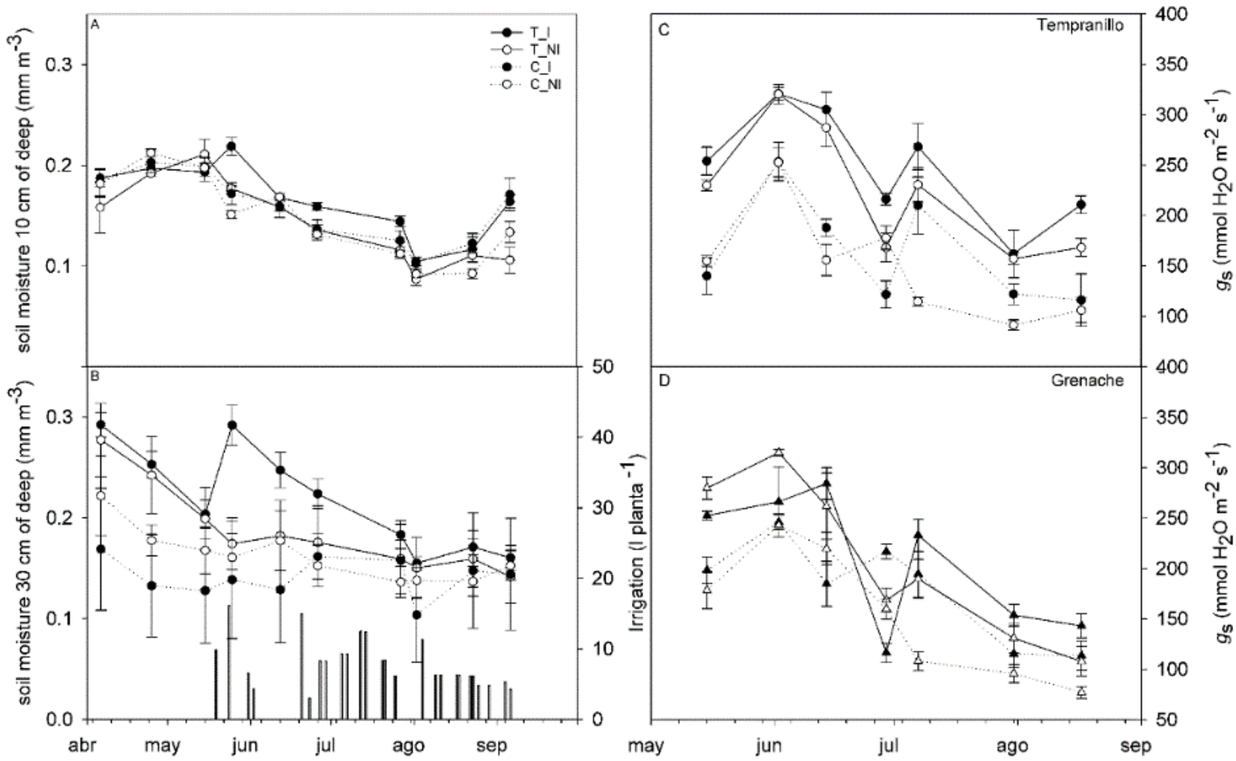

Figure 2: Soil moisture dynamics (A, B) and changes on stomatal conductance (C,D) along vegetative period for Tempranillo and Grenache plants submitted to irrigation and soil management treatments. Bars means the irrigation dosages per plant. Data correspond to 2017. n= 4.

Data of vegetative and productive parameters collected during the three years of the experiment were analyzed in order to evaluate the effect of the different variables considered in the study. First, the existence of cover crop caused a significant reduction about 50% on plant growth and yield (Table 1). However, the plants maintained a good balance between vigour and yield reflected by Ravaz index values. However, irrigation management only induced a light reduction in yield capacity but not on plant growth. For all studied parameters, non-significant effect of genotype was found. Similar results were in accordance with Pou *et al*. (2011) for Manto Negro cultivar. The analysis of grape quality parameters reflects significant effect of soil management and genotype on soluble sugar content on must and phenolic and a clear increase of grape anthocyanin content (Table 2). Those results are coincident with other experiments carried out in semiarid conditions (Lopes *et al.,* 2011; Pou *et al.,* 2011).

Conclusions

The maintenance of cover crop in vineyards, under semiarid climates such as the Mediterranean, generates a balance between positive effects such as the increase of organic C in the soil or the improvement of the quality of the grape and negative effects such as the decrease in the availability of water in the soil or the decline of the yields. Those effects can be minimized by using a good irrigation strategy and/or adjusting the cover crop management to the environmental conditions and selecting genotypes (rootstocks vs cultivar).

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Appendix

Table 1: Mean values of three years of experiment of plant vigor, productive parameters and Ravaz index. Different letters indicate significance at P<0.005.

Variable	Treatments	Number of clusters	Yield (Kg/plant)	Pruning weight (Kg)	Ravaz ndex
Soil manag.	Cover Crop	12.31 ±0.58a	1.44 ± 1.29 a	0.33 ± 0.18a	5.19 ± 4.01a
	Tilling	15.69 ± 0.42b	3.17 ± 1.5b	0.65 ± 0.35b	5.71 ± 2.95a
Irrigation	I	14.64 ± 0.49a	2.60 ± 1.60 a	0.50 ± 0.34a	6.24 ± 3.78a
	NI	13.36 ± 0.57a	2.03 ± 1.62 b	0.49 ± 0.30a	4.70± 3.11b
Cultivar	Tempranillo	13.38 ± 0.43a	2.36± 1.73 a	0.52 ± 0.36a	5.77 ± 4.05a
	Grenache	14.6 ± 0.62a	2.25± 1.57 a	0.46 ± 0.52 a	5.14 ± 2.91a
Year	2015	13.06 ± 0.46a	1.78 ± 0.15 a	0.34 ± 0.02a	6.09 ± 0.41a
	2016	12.63 ± 0.82a	3.28 ± 0.25b	0.64 ± 0.05b	5.51 ± 0.46ab
	2017	17.32 ± 0.69b	2.45 ± 0.21c	0.65 ± 0.05b	4.08 ± 0.3b

Table 2: Mean values of three years of experiment of grape quality parameters. Different letters indicate significance at P<0.005.

Variable	Treatments	TSS (º Baume)	TA (g Tart/L)	pH	IPT (A 280)	Total Antocy. (mg/L)	Total Tanins (g/L)
Soil manag.	CC	12.8±0.88a	3.21±0.59a	3.77±0.04a	81.7±23.9a	463.2±264.8a	2.51±0.27a
	T	12.3±1.15b	3.53±0.58b	3.67±0.04a	66.3±27.9b	388.1±211.4a	2.53±0.26a
Irrigation	I	12.2±1.07a	3.44±0.68a	3.71±0.04a	70.3±24.1a	373.3±205.5a	2.51±0.27a
	NI	12.92±0.9b	3.30±0.51a	3.72±0.03a	77.9±29.4a	478.1±264.3a	2.53±0.26a
Cultivar	Tempranillo	12.2±1.02a	3.15±0.63a	3.74±0.02a	95.5±17.3a	580.2±173.6a	2.89±0.26a
	Grenache	12.8±1.02b	3.57±0.46b	3.70±0.01a	53.6±15.9b	248.9±130.0b	2.16±0.26a
Year	2015	12.85±0.21a	3.44 ± 0.15a	3.54±0.01a	86.28 ±4.92a	547.64±55.0a	4.46±0.17a
	2016	12.82±0.17a	3.41 ± 0.09a	3.61±0.0a	61.34 ±4.31b	421.0±4.2ab	1.35±0.1b
	2017	12.2±0.12b	3.31 ± 0.08a	3.92±0.04b	74.62 ±6.1ab	308.1±45.0b	1.70±0.16b

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