Better understand the soil wet bulb formation with subsurface or aerial drip irrigation in viticulture

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Abstract

The gradual change in rainfall patterns experienced in the south of France vineyards, especially around the Mediterranean Sea, means that the vines are increasingly subject to summer drought. The winegrowers developed the use of irrigation techniques to ensure the maintenance of competitive yields in the production of wines under Protected Geographical Indication label. In practice, drip irrigation pipes can be installed above the ground or buried into the soil as well as at different distances from the vine row. The objective of this study was to examine the profiles of the wet bulbs of the soil obtained from two drip irrigation systems: aerial drip located under the vine row and subsurface drip placed in the middle of the inter-row. This experiment took place over two consecutive seasons (2020-2021) on a 3.4 ha Viognier plot in the Mediterranean (France). Capacitive soil water content probes were installed at different depths (20 - 40 - 60 - 80 cm) and at different lateral distance from the vine row (30 - 60 - 90 - 120 cm) to control the formation of the soil wet bulb during irrigation. The mapping and the analysis of the data allowed a better understanding and differentiation of the water percolation when irrigating with subsurface or aerial drip. For the same amount of water and without differences of vine water status, it is shown that in a subsurface drip irrigation situation, the size of the wet bulb formed is larger than in aerial drip irrigation system.

Introduction

The gradual change in rainfall patterns in southern France, particularly around the Mediterranean, means that the vines are regularly and stronger subject to water stress. It is shown that water stress significantly modifies the physiology of the vine and the berry (Scholash and Rienth, 2019). While the economic profitability of farms today requires an optimization of the quality of production in connection with the segmentation of products, the summer drought no longer allows the winegrower to perfectly control his production systems. Due to easy access to water winegrowers around the Mediterranean install irrigation system to limit the effects of strong vine water stress, (Romero et al., 2022). Aerial drip irrigation under the vine row is the most widely used but many studies have compared effects of surface and subsurface drip irrigation on vine and grape quality (Ma et al., 2020; Pischiotta et al., 2018). Results demonstrated that subsurface drip irrigation can reduce water use (Sharma et al., 2011). Under less water-limiting conditions, subsurface irrigation under the row or aerial irrigation does not demonstrate any gain in yield or grape quality (Miras-Avalos et al., 2017).
Many results related to irrigation focus mainly on vines physiology and grapes quality. Furthermore, few studies are concerned with subsurface irrigation placed in the middle of the inter-row. Santalucia et al., (2007) indicate that distributing subsurface water 1m20 away from the rows seems to stimulate higher reproductive activity than aerial water below the rows.
The objective of this study was to examine the profiles of wet bulbs of the soil obtain from 2 irrigation systems: aerial drip located under the vine row and subsurface drip located in the middle of the inter-row of vine.

Material and methods

The trial was set up for 2 years (2020-2021) at Domaine Saint-Paul (Maureilhan, France), in the Mediterranean Protected Geographical Indication (PGI) production area. The plot has been planted in 1996 with cv. Viognier B grape variety. Vines are trained in vertical shoot positioned system with a density of 4000 vines/ha (2.50 m x 1m). The soil was fully mechanically weeded from spring to harvest.The drip irrigation was installed on the plot in June 2019. Two irrigated treatments, aerial irrigation (AI) and subsurface irrigation (SI) are compared with a non-irrigated control (NI). AI and SI are irrigated identically.

Table 1. Treatments

Treatments	No Irrigation (NI)	Aerial Irrigation (AI)	Subsurface Irrigation (SI)
Position	-	Under the row	Middle Inter-row
System	-	Aerial 20 cm	Buried 40 cm
Dripper	-	1 per meter	1 per meter
Dripper flow	-	1,6 L/hour	1,6 L/hour

The soil texture is composed by sands (14% coarse and 25%<0.2 mm), clay (29%) and silts (coarse 10% and 22%<0.02 mm). The vines are irrigated between flowering and veraison to maintain a predawn leaf water potential greater than -0.3 MPa. 5 irrigations were scheduled for a total amount of 86mm in 2020 and 3 irrigations for an amount of 70mm in 2021. These allowed to monitor the soil moisture content.
Vine water status was measured with predawn leaf water potential by means of the pressure chamber technique (Scholander et al. 1964). Each measurement occurred on the same vines.
TEROS 11 volumetric soil moisture sensors from Meter Group were used to measure soil moisture. They provided continuous information on the relative humidity of the soil and its temperature. The sensor provided a percentage of humidity and data were recorded every hour on a datalogger. The first probes were buried in March 2020 and other sensors were installed in 2021 to complete this study. The position of the sensors allowed to establish links between the depth and the areas of water retention, the soil drying speediness and the size of the wet bulb after irrigation. The sensors were positioned at four depths, 20 – 40 – 60 – 80 cm and four widths: A (under vine row) – B (30 cm from vine row) –C (60 cm from vine row) –D (middle of the inter-row, 125 cm from vine row) (figure 1)

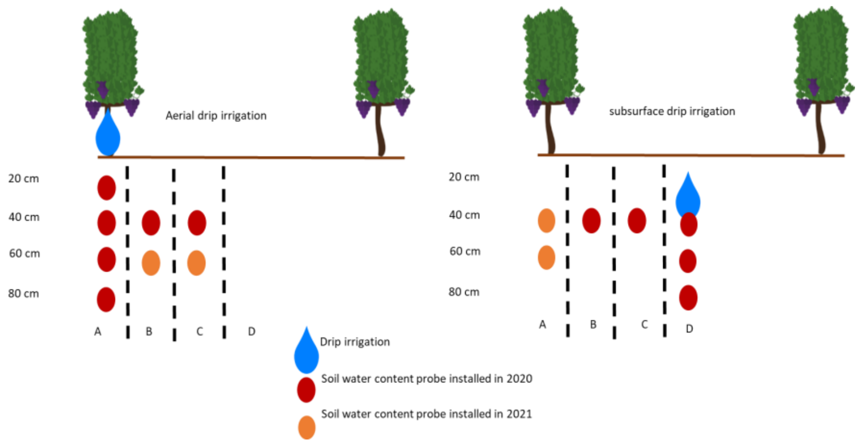

Figure 1. Capacitive probes positioning on Aerial Irrigation (AI) and Subsurface Irrigation (SI) treatments

Capacitive probes were also placed under the non-irrigated row control (NI) in zone A at 20 cm, 40 cm, 60 cm and 80 cm to measure the impact of rains on soil moisture content and monitor the water loading of the plot. Statistical analyses were made with XLSTAT of Addinsoft software for ANOVA treatments and Fisher test at 5% threshold for group sampling.

Results and discussion

Huglin Index showed that 2020 and 2021 are two hot vintages (IH+1) with 2580 degree.days in 2020 and 2469 in 2021. The annual rainfall was 591 mm in 2020 and only 415 mm in 2021. From June to September, rainfall does not exceed a total of 93 mm in 2020 and 58 mm in 2021.

Evolution of soil moisture

The evolution of soil moisture on non-irrigated control (NI) showed the drying kinetics of the soil in summer and its recharge during the winter. At a depth of 20 cm.in 2020, we could estimate the field reserve around 41% at the end of winter. It was only 32% in 2021, the winter of 2020-21 did not allow to optimize the soil water content. During the summer period, no significant water supply (rain) recharged the soil water reserve at any depths. We could therefore consider that the changes in soil moisture recorded on irrigated treatments were only due to irrigation.

Abrupt spikes in probe results were observed when water from irrigation reaches their area and confirmed the recharge of water in the soil. The results showed that the areas did not react in the same way but were reproducible over the two years of study.

On the Aerial Irrigation (AI): Each aerial drip irrigation generated an increase of soil moisture in zone A (under the row) at 20cm and 40 cm but weaker at 60 cm. At 80 cm under the row, irrigation water was very poorly available. On the other hand, the results clearly showed that zones B and C had an increase only at 60 cm (Figure 2).

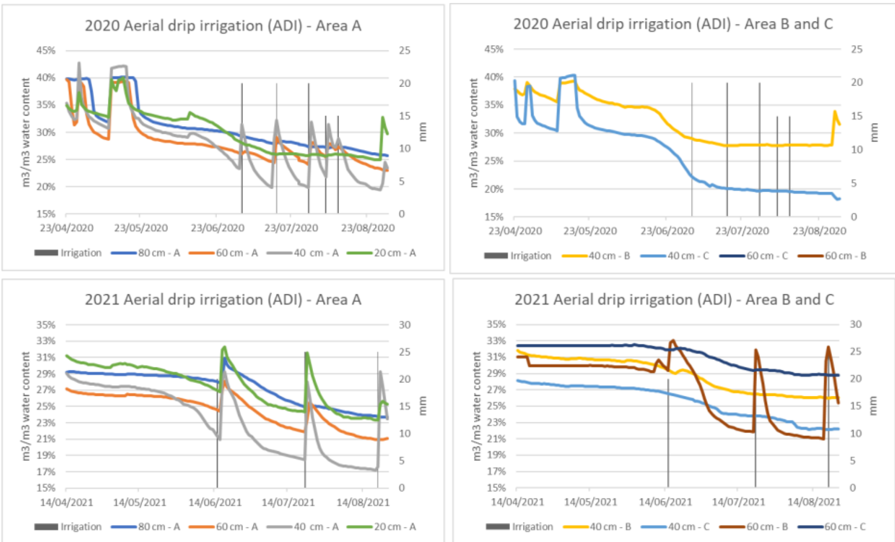

Figure 2: Variation of soil moisture on Aerial Irrigation (AI) at different depth

On the Subsurface Irrigation (SI): Irrigations systematically generated a response from the probes, regardless of the vintage. All areas showed an increase in their moisture, except in zone A, below the row of vines, furthest from the dripper (Figure 3).

Quantitative evolution of soil moisture

Beyond knowing the qualitative distribution in soil of the irrigation water, we calculated the increases in soil moisture after each irrigation. These increases were calculated based on the soil moisture on the day before irrigation. A gain in soil moisture was calculated 24 hours after irrigation.

The gain was measured on each location after the 8 irrigations (table 3). Aerial irrigation generated moisture gains only on zone A (below the row) and preferably to 40 cm then 20 and 60 cm. The water supply was ineffective at 80 cm below the row. It was also noticed that irrigation water did not percolate laterally. No increase was measured on zones B and C, excepted in C-60 cm where a slight humidification of the soil was recorded.

The results were different with subsurface irrigation in the inter-row. All areas of the soil showed an increase in moisture after each irrigation except zone A. The water thus appeared to percolate deeply and laterally in a consistent manner.

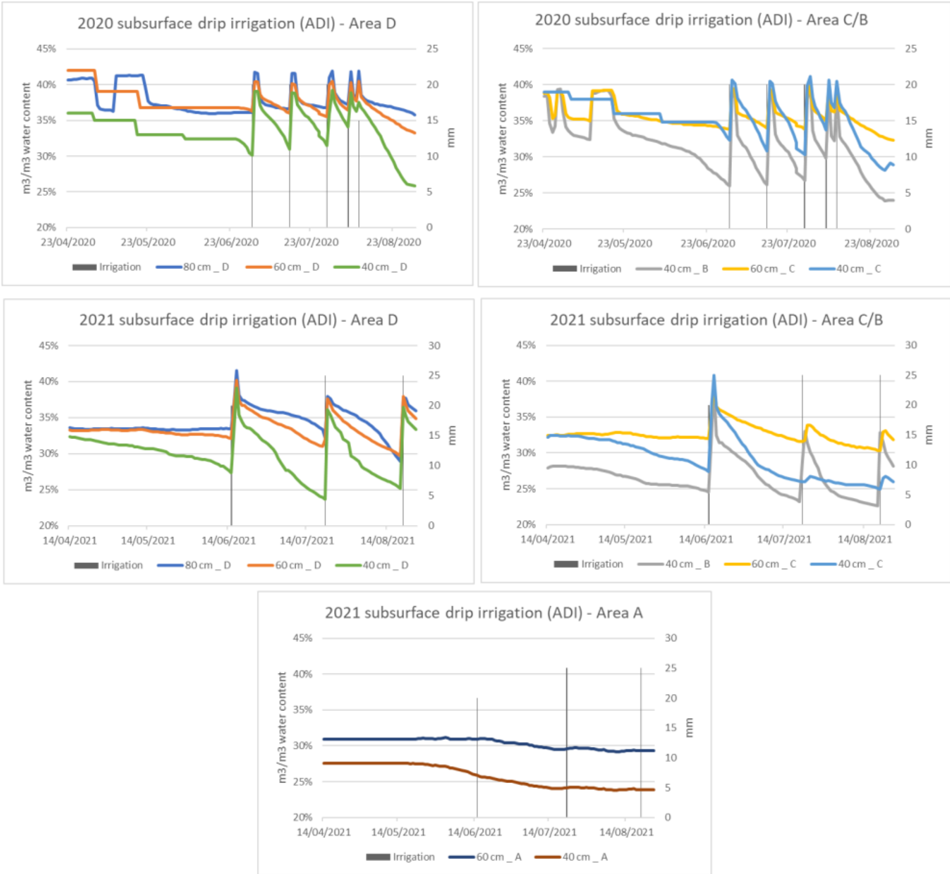

Figure 3. Variation of soil moisture on Subsurface Irrigation (SI) at different depth

Table 2. Increase of soil moisture after each irrigation according to the location of the probe - Aerial and subsurface irrigation

	Aerial Drip Irrigation							
Irrigation/Area	20 cm - A	40 cm - A	60 cm - A	80 cm - A	40 cm - B	60 cm - B	40 cm - C	60 cm - C
01/07/2020	-0,7%	35,2%	-0,8%	-0,7%	-0,3%		-2,6%	
15/07/2020	-0,4%	44,7%	-0,8%	-0,4%	-0,4%		-0,5%	
29/07/2020	0,8%	60,3%	16,6%	-0,7%	0,0%		0,5%	
06/08/2020	0,8%	44,5%	9,8%	-0,4%	0,0%		0,0%	
09/08/2020	-0,4%	6,2%	2,2%	0,0%	0,0%		-0,5%	
15/06/2021	19,3%	34,2%	11,1%	9,4%	-0,5%	11,6%	-0,3%	0,0%
21/07/2021	29,6%	51,3%	8,7%	0,0%	0,0%	-2,8%	-0,1%	0,0%
19/08/2021	8,3%	66,0%	-0,1%	-0,3%	-0,1%	5,6%	-0,1%	-0,2%
Average	**7,2%**	**42,8%**	**5,9%**	**0,9%**	**-0,2%**	**4,8%**	**-0,4%**	**-0,1%**

	Subsurface Drip Irrigation							
Irrigation/Area	60 cm _ A	40 cm _ A	40 cm _ B	60 cm _ C	40 cm _ C	40 cm _ D	60 cm _ D	80 cm _ D
01/07/2020			51,5%	16,9%	25,7%	29,6%	11,3%	15,5%
15/07/2020			50,2%	15,9%	31,5%	25,5%	11,4%	13,7%
29/07/2020			42,3%	13,9%	31,7%	14,0%	12,7%	11,4%
06/08/2020			31,9%	13,1%	20,5%	14,1%	10,7%	12,4%
09/08/2020			20,5%	8,3%	10,1%	3,3%	7,4%	10,3%
15/06/2021	0,2%	-0,7%	32,7%	11,8%	33,1%	23,6%	15,4%	11,6%
21/07/2021	0,4%	0,2%	14,1%	6,6%	1,3%	52,5%	17,8%	17,8%
19/08/2021	0,0%	-0,1%	45,3%	8,4%	-0,2%	44,5%	27,7%	30,2%
Average	**0,2%**	**-0,2%**	**36,1%**	**11,9%**	**19,2%**	**25,9%**	**14,3%**	**15,4%**

The graphic representation of the results (Figure 4) images circulation of the water in the soil after each irrigation according to the position of the drippers.
The simulation of the wet bulb profile clearly showed two different patterns depending on the positioning of the irrigation system. An aerial irrigation under the vine row generated a strait vertical bulb not diffused horizontally. On the other hand, subsurface irrigation in the middle of the inter-row produced both a large lateral (up to 95 cm) and vertical soilwater bulb (60 cm)

Figure 4. Box plot representation of soil moisture increases 24 hours after irrigation depending on the area and depth. 1: aerial drip irrigation, 2: subsurface drip irrigation.

Grapevine water status

Predawn water status measures have been carried out on the 3 treatments. There were significant differences between the non-irrigated control and the irrigated treatments in 2021 and in trend in 2020 (table 3). There was no difference between the two irrigation treatments.

Table 3. Effect of aerial (AI), subsurface (SI) and no (NI) irrigation on predawn leaf water potential.

	29/07/2020	18/08/2020	25/08/2020
AI	-0,32 a	-0,36 a	-0,46 a
SI	-0,34 a	-0,37 a	-0,45 a
NI	-0,29 a	-0,44 a	-0,53 a

	21/06/2021	12/07/2021	29/07/2021	10/08/2021	25/08/2021
AI	-0,11 a	-0,16 b	-0,34 b	-0,27 b	-0,25 b
SI	-0,10 a	-0,14 b	-0,31 c	-0,28 b	-0,25 b
NI	-0,13 a	-0,26 a	-0,69 a	-0,42 a	-0,55 a

Yield

Yields at harvest showed significant differences in 2020 and 2021 between treatments (Table 4). The non-irrigated vines produced significantly low yield than the irrigated treatments due to a lower bunch weight. No difference was observed between the 2 irrigation treatments.

Table 4. Effect of aerial (AI), subsurface (SI) and no (NI) irrigation on yield parameters.

	2020			2021		
	AI	SI	NI	AI	SI	NI
Nb bunch per vine	16,5 a	16,2 a	16,2 a	15,9 a	14,9 a	16,1 a
Yield per vine (kg)	3,610 b	3,322 b	2,608 a	3,181 b	3,017 b	1,940 a
Bunch weight (kg)	0,219 b	0,205 b	0,161 a	0,200 b	0,202 b	0,120 a

Conclusion

In this experiment, using capacitive probes in the soil, we demonstrated that subsurface irrigation (40 cm depth) in the middle of the row generated larger volumes of wet bulb, with vertical and lateral percolation of the water, than aerial drip irrigation system.
Subsurface irrigation in the inter-row did not modify the vines water status neither the yields comparing to aerial irrigation under the vine row.
During our trial, we also were able to visualize, without measurement, that the water from the subsurface irrigation reached the ground surface by capillarity. This irrigation system, still underdeveloped, could be a lever in dry areas to promote the establishment of plant cover in the inter-row, which is known for providing a set of sustainable services.

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