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Response of grapevine (Cabernet Sauvignon cv) to above ground and subsurface drip irrigation under arid conditions

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ABSTRACT

The response of wine grapes to irrigation systems was investigated in a Cabernet Sauvignon/140 Ru vineyard in sandy loam soil in Sicily during a two-year study. Two different drip irrigation systems were evaluated: one surface drip and two subsurface drip irrigation systems, with the trickle line located at different distances from vine trunks. Vegetative and quantitative parameters, must quality and root distribution were compared among irrigation treatments. During the two study years, irrigation of grapevines via a subsurface drip system resulted in greater water use efficiency without affecting must composition. Establishing the trickle line near the trunk positively influenced trunk growth and total root contact while establishing the trickle line 1.20 m from the trunk increased yield. Dry mass partitioning was modified in subsurface irrigation treatments in favour of reproductive organs. We conclude that subsurface drip irrigation under the trunk can be successfully used under water deficit irrigation management, even in sandy loam soil and in the hot climate conditions of the Mediterranean vineyard. Some aspects of management deserve further investigation and further studies may better define the optimum conditions for the successful utilization of the SDI 120 irrigation strategy.

1. Introduction

Sicily is a region in southern Italy with a history of wine production. The climate is warm and arid, and farmers are thus faced with the problem of achieving high grape yields and good grape quality with limited water supply. Water use efficiency plays an important role in irrigation strategies, particularly considering the water scarcity in Mediterranean areas as a consequence of climate change (Tomás et al., 2014).

Irrigation method significantly affects yield, vegetative, quality components and root development as well as water use efficiency. Irrigation system choice by grape farmers should also include consideration of many variables, such as type, depth and uniformity of soil, rooting zone, availability and quality of water, and total cost (Myburgh, 2012).

The advantages of drip irrigation over sprinklers and other conventional irrigation systems (Van Zyl, 1988) for vegetative, reproductive and qualitative parameters in *Vitis vinifera* are well known but only in subsurface system (Striegel et al., 1996; Sharma et al., 2005; Myburgh, 2007a,b; Sharma and Upadhyay, 2011), and more in-depth investigations are required. Many researchers define subsurface drip irrigation as a method of dispensing water below the soil surface with the same emitters and discharge rates range as surface drip irrigation (Davis and Nelson, 1970; Camp and Lamn, 2003). Subsurface systems are an important component of lower pressure systems, although the literature present contrasting results of subsurface drip irrigation. Major issues mainly involve irrigation management, and more specifically as in all irrigation systems, establishing the optimal water dose and drip line depth and distance from the row for different crops (Ayars et al., 2015). The choice of the appropriate drip line depth is influenced by crop, soil and climate characteristics. Soil hydraulic properties and emitters discharge affect vertical water movement in the soil and thus are factors that should be considered in the choice of dripline depth. For perennial crops (trees and grapes), the dripline is typically installed at a depth of 12–20 inches; sandy soils allow shallower installation depth and regardeless of soil type, the dripline should be positioned in the upper portion of the root zone to prevent excessive drainage, among other effects (Lamm, 2009). Myburgh (2007a,b), in studies of a subsurface drip irrigation system in a layered alluvial soil, showed a lower concentration of roots around the drip lines located at depth of 15 cm compared with those at 30 and 45 cm, but without negatively influencing grape production and quality.

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Gaiotti (2010) in on a four-year old Merlot/161-49 vineyard, found that roots were deeper and better developed when the trickle line was positioned at 1.35 m from the vine row, whereas when positioned at 0.4 m, growth was shallower and denser, similar to that of surface drip irrigation, and resulted in higher grape production and vigour.

Subsurface drip irrigation is a system designed to improve water use efficiency (WUE) compared with surface drip irrigation systems. The usage of subsurface drip irrigation has always lead to an enhancement of crop yield and quality, a decreased water requirement and decreased costs for other cultural practices in annual crops (e.g., tomato, cotton, sweet corn, cantaloupe, garlic, broccoli, pepper, and lettuce) (Ayars et al., 1999) as well as in fruit crops and in some cases, nut crops. Long term research of subsurface drip irrigation needed, especially to better understand the potential uses in nut crops, fruit trees and vines as acknowledged by Ayars et al. (2015).

For nut crops such as almond and pistachio, subirrigation system are considered especially useful due to potential for water and energy savings, enhancement of pest management, and ultimately increased production and nut quality (Ayars et al., 2015). Moreover, in French prune orchards in the northern Sacramento Valley (CA), the subirrigation method is used to better support water infiltration in clay and silt loam soils compared to surface drip irrigation (Ayars et al., 2015).

Considering that Sicily is a region with a warm, arid climate and limited water supply, a change in irrigation strategy may become essential to save water in viticulture without reducing the profitability of grapevines. For this reason, the objectives of this study were to 1) investigate as an alternative the subsurface irrigation system, and to compare results to the standard surface drip irrigation system, the most common method in Sicily and 2) compare trickle line positioning at two different distances from the vine row within a subsurface drip irrigation system, placed under the vine row and in the middle of the interrow. The choice of distances of trickle line from vine row in subsurface drip irrigation was established to ensure the uniformity of root development on both side of the rows maintaining only one trickle line.

2. Materials and methods

2.1. Field conditions, plant material and irrigation treatments

The response of grapevines to two different irrigation systems was investigated during the 2004 and 2005 vegetative seasons in a nine-year old Cabernet Sauvignon/140 Ru experimental vineyard, planted in 1996. Planting distance was 2.4 × 0.95 m, row orientation was north-south, and vines were trellised in a vertical shoot-positioned system and, cane pruned (8 buds per cane and 2 buds per spur). The vineyard was located in Western Sicily (Mazara del Vallo area, 37°36′10.93″ N – 12°39′15.26″ E, 34 m a.s.l.) in 80 cm deep soil characterized by 10% gravel, 20.8% clay, 35.2% silt and 44% sand. Soil management practices included a cover crop (*Vicia Faba*) during winter and incorporating the biomass into the soil in April by ploughing. Three shallow tillages (10–12 cm deep) from spring to summer were adopted to control weeds and prevent soil cracking (Crescimanno and Garofalo, 2006). During the two years of this trial, weather data were collected through an automated weather station at the Servizio Informativo Agrometeorologico Siciliano, 2017 (www.sias.regione.sicilia.it) located near the vineyard.

Three irrigation treatments with the same drip line emitter configuration, were investigated:

1 Surface drip irrigation (DR) with one drip line at 0 cm from the vine row and 50 cm above the soil, fixed on a dedicated wire below the cane;
2 Subsurface drip irrigation with one drip line at 0 cm from the vine row (under the vine) and 0.35 m deep (SDI 0);
3 Subsurface drip irrigation with one drip line at 1.20 m, positioned equidistantly between adjacent vine rows and 0.35 m deep (SDI 120).

The drip line was mechanically installed before vineyard establishment, deep enough (0.35 m) to prevent damage by tillage, but sufficiently shallow to supply water to the root zone (Van Huyssteen and Weber, 1980) without wetting the soil surface (Camp and Lamn, 2003).

Surface and subsurface methods entailed a drip line irrigation system with pressure compensating emitters with a flow rate of 4 L/hour were located one metre apart. The amount of water applied in each treatment was measured using flow meters.

2.2. Irrigation scheduling

The time of irrigation was determined physiologically by measuring plant water status through leaf water potential at various stages during the trial, including the harvest stage. These measures were taken at predawn using a Scholander pressure chamber (model 3115 Soilmoisture Equipment Corp. Santa Barbara, CA) on 3 fully expanded leaves from primary stems per block and treatment.

Irrigation for all treatments was managed by using a threshold predawn leaf water potential (ψ_{pd}) of −0.4 MPa from berry set to the end of veraison and −0.6 MPa from the end of veraison (Di Lorenzo et al., 2005). In both years, irrigation was stopped 15 days before the probable harvest date.

Optimum irrigation volumes were calculated based on data gathered in the same vineyard from an experimental trial performed in parallel to this experiment, aimed characterizing soil moisture profiles using FDR probes (Provenzano et al., 2016). In particular, at each irrigation date, the volumes of water administered were regulated to reach field capacity within soil zone wetted by the emitters and the soil layers most populated by roots while avoiding deep percolation. Field capacity and wilting point were determined using Richard's plates (Richards, 1947). The amount of water was reduced by 20% in SDI treatments to account for the lower evaporation from the soil (Allen et al., 1998). This latter term was calculated as the ratio between f_w (fraction of the surface wetted) and f_c (fraction of ground surface coverage), with $f_c = 0.20$ and $f_w = 0.04$, considering a diameter of the wetted zone under the emitters equal to 0.23 m. Therefore, irrigation volume at each event was 75 m^3/ha in DR and 60 m^3/ha in SDI. ψ_{pd} was considered as a stress indicator and fluctuation of this variable between irrigations for all treatments, was measured in 2004 at +1, +3, +5 and +7 days after irrigation in two periods, once from fruit set to veraison and once from the end of veraison to harvest.

2.3. Experimental design

The experimental design consisted of three randomized complete-blocks, each with 9 rows 95 m in length with 100 vines. Within each block, each irrigation treatment was imposed on 3 contiguous rows. For each treatment and block, observations were performed on 15 vines of the central row, leaving the other two as buffer rows, to separate irrigation treatments.

2.4. Phenology

Data on the occurrence of budburst, flowering, beginning of veraison (20%), end of veraison and harvest dates for all treatments in 2004 and 2005 were recorded (Baggiolini, 1952). The budburst (stage C) and flowering stages (I) were considered to occur when