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Girdling and gibberellic acid effects on yield and quality of a seedless red table grape for saving irrigation water supply

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ABSTRACT

Table grapes need of substantial water supply for achieving commercial requirements. Viticulture practices such as girdling (G) and gibberellic acid (GA) application, as well as water supply, can improve table grape quality. The study, which was conducted in two consecutive seasons (2010–2011), aimed to assess the counterbalance effect of these viticulture practices on yield and quality parameters and flavonoids composition in case of a significant and unusual irrigation water reduction (40%) applied to a table grape variety. The data from the two-way ANOVA and PCA analyses indicated that viticulture practices were clearly related to anthocyanins and flavonols variations whereas water management appeared mainly involved in the yield parameters variability. Specifically, the reduced water supply (RWS) decreased the grape yield (−20%) with respect to full water supply (FWS); by contrast GA, G, and G × GA treatments determined an increment of grape production ranging from 10 to 23%, independently from irrigation strategy. Moreover, G, in particular applied to RWS grapes, was able to improve the total soluble solids over titrable acidity (TSS/TA), a ratio strictly related to the quality perception by the consumer. Total anthocyanins were found positively linked to FWS whereas flavanols content was indifferent to water management. Instead viticulture practices seemed to have a greater impact on anthocyanin composition, considering that in RWS grapes under GA condition, higher contents of malvidin and peonidin (mainly responsible for the color stability of the skins) were revealed. Furtheremore, catechins and rutin appeared significantly enhanced by G and G × GA, and GA, respectively. From gathered findings, it can be concluded that suitable viticulture practices can allow a sensible reduction of water supply during table grape growth cycle without detrimental effects on yield and quality.

1. Introduction

Grapevines are very adjusted to semi-arid climate, for example, that of the Mediterranean, because of the extensive and profound root system and physiological mechanisms for shirking drought; on the other hand, the joined impact of dry spells, high air temperature, and high evaporative demand during summer in these zones is known to reduce grapevine productivity and berry quality (Chaves et al., 2007; Costa et al., 2007; Chaves et al., 2010). Therefore, the utilization of watering system in these situations emerges as an answer for balance harvest water deficits and thereby amplify grape production and quality with a specific end goal to expand benefits (Baiano et al., 2011). By contrast, the enhanced pressure on water resources increased the global perception of the need to reduce the "water footprint" for irrigated crops (Cominelli et al., 2009); this implies that the investigation of options permitting to enhance the grape general quality but saving irrigation water would be of most extreme significance.

In this context, viticulture practices, such as G and GA treatments, can be usefully integrated to irrigation management, because they have long been used to achieve the best commercial yield characteristics by increasing berry size of grapes (Ferrara et al., 2014). Since G effects on vine have accounted for reducing stomatal conductance of approximately 50% for a period of four weeks

Abbreviations: G, girdling; GA, gibberellic acid; G × GA, combination of girdling and gibberellic acid; T, control; RWS, reduced water supply; FWS, full water supply; TSS, total soluble solids; TA, titrable acidity; AT, total anthocyanins; PPT, total polyphenols; Pn-3-g, peonidin-3-glucoside; Pt-3-g, petunidin-3-glucoside; Mv-3-g, malvidin-3-glucoside; Dp-3-g, delphinidin-3-glucoside; Cy-3-g, cyanidin-3-glucoside; Ca, catechin; ECa, epicatechin; R, rutin; PB1, procyanidin B1; PB2, procyanidin B2.

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after treatment and the application of GA to the vine canopy has shown to mitigate the depressing effect of G on leaf gas exchange (Teszlák et al., 2013; Ferrara et al., 2014; Conesa et al., 2015), that results in less leaf transpiration and, therefore, a more favorable water status for vines (Williams et al., 2000), the adoption of G and GA practices can favor the water saving but improving the grape quality. In table grape, quality is related to characteristics such as appearance (including berry color, size, and uniformity), firmness, sweetness, acidity level, and phenolic content. Similarly, grape yield and berry dimension are very important features from a commercial point of view, as well as the consumer preference is strictly dependent from soluble solids concentration (TSS), titrable acidity (TA), and their ratio in grapes (Jayasena and Cameron, 2008). Furthermore, the presence of polyphenols is particularly appreaciated not only because they are related to the organoleptic quality (such as color or bitterness) but also because of their well known antioxidant and health-promoting properties (Baiano et al., 2011; Carrieri et al., 2013; Coletta et al., 2014).

Diverse water supplies, especially if applied during pre-veraison period but also in the veraison-harvest stage such as in the case of table grape (Williams et al., 2010), can actuate substantial modification in grapevine physiology providing a noteworthy effect on grape juice composition (Santos et al., 2007); in general, vines receiving no supplemental water or under mild water deficit will have less vegetative growth, smaller berries, and lower yields, conversely full irrigation of vines expands yield yet could be unfavorable for the overall quality (El-Ansary et al., 2005; Baiano et al., 2011; Faci et al., 2014). Moreover, the frequency and volume of water delivered to the grapevines can influence some qualitative and quantitative characteristics of table grapes such as lowering of acidity and accumulation of sugars (Santos et al., 2007; Castellarin et al., 2007). On the other hand, G and GA treatments have positively influenced yield and berry development during ripening as well as they have appeared to impact the accumulation of juice TSS and organic acids in mature table grapes (Pérez et al., 2000; Ferrara et al., 2014). In addition, even though anthocyanin and non-anthocyanin polyphenols biosynthesis and composition in the berry is genetically controlled (Gambetta et al., 2010), environmental factors as well as viticulture practices, such as pruning, girdling, and irrigation (Dokoozlian et al., 1995; Kounduras et al., 2006) are able to affect these components whose content can change more broadly than any other substances ordinarly measured in grapes (Esteban et al., 2002; Castellarin et al., 2007; Chaves et al., 2010).

Overall, seeking suitable viticulture practices which succeed in modulating the physiological and molecular responses of grapevine to water deficit could be a critical step to optimize the water supply administration; therefore, the objective of this study was to compare the effects of G and GA on grape yield, composition, and polyphenolic (anthocyanin and non-anthocyanin compounds) quality of "Early Red Seedless" table grape grown under RWS in a Mediterranean climatic condition (Apulia region).

2. Materials and methods

2.1. Plant material and growth conditions

The study was conducted in two seasons (2010 and 2011) on *Vitis vinifera* L. (cv. Early Red Seedless) eight-year-old vines located in the experimental field of the Research Unit for table grapes and wine growing in Mediterranean environment (Turi, Southern Italy, long. 40.56°E, lat. 17.12°N) at about 190 m on the sea level and on a sandy-clay soil (50% sand, 12% silt, and 38% clay) with a 0.7 m depth root zone. Vines were grafted onto *775 Paulsen (V. berlandieri x V. rupestris)* rootstocks, with a vine spacing of 2.5 m between rows and 2.5 m within a row; they were trained onto a "double tendone" trellis system, widely used in Apulian region and whose characteristics were carefully pointed out in an our previous report (Baiano et al., 2011), and were cane pruned (four canes every 12–15 buds per vines) with free-standing shoots (complete overhead canopy separated from fruit) in order to obtain an uniform bunch load per vine. Row orientation was North-South. Plant nutrition, pests and diseases control were carried out in accordance with local standards.

2.2. Irrigation and viticulture practices management

The climate of the region is Mediterranean semi-arid, characterized by hot dry summers (although short periods of heavy rainfall may occur) and mild rainy winters. The warmest month is August with a mean temperature of 24.9 °C, while the coldest one is January with a mean temperature of 6.3 °C. The mean annual rainfall is 640 mm, while the mean summer precipitation is 150 mm (Mattia et al., 2005). Two irrigation treatments, based upon a percentage of the net irrigation requirements (NIR = ETc − effective rainfall) from 15 days after flowering until harvest, were applied: FWS and RWS at 100% (2700 m^3 ha^{-1}) and 60% (1600 m^3 ha^{-1}) of NIR, respectively. The registered crop evapotranspiration (ETc) was slyghtly lower (15–20%) than the typical table grape vineyards and it was due to the moderate shading and wind reduction effect of antihail net (Kristal – Retilplast, Salerno, Italy) protection which is largely adopted in Apulia vineyards for its ameliorative effects on the yield (Rana et al., 2004). ETc was estimated using varying crop coefficients (kc) (ETc = ETo × kc) based on those proposed by FAO and adjusted for the Mediterranean area and ETo values. ETo was calculated weekly from the mean values of the preceding 6 years (2002–2008) using the daily climate data collected by a set of climatic sensors located 2.1 km far from the experimental vineyard and were extrapolated from the databank of the Ministry of Defence, Air Force weather station. The applied kc values were 0.35 in April, 0.45 in May, 0.5 in June, 0.75 in July to mid-August, and 0.60 in August to the end of September (Romero et al., 2010). The vines (FWS and RWS) were drip-irrigated by means of irrigation lines installed 180 cm above the soil surface with drippers spaced 70 cm apart and set to supply water at a constant pressure with two 8 L h^{-1} drippers per vine. The time between irrigation cycles was approximately 15 days (Table 1).

Moreover, vines were cane-girdled with a double-bladed 4.8-mm knife and rechecked for completeness when berry size reached 3–4 mm diameter. Over the two years of trial, in order to better evaluate the effect of G on yield, the clusters, located along the canes and before the cut of girdling, were not removed. Then, starting from the onset of cell enlargement stage GA (BERELEX® – SYNGENTA ITALIA, Milan, Italy) was applied on vines at different concentration on the basis of berry diameter (mm): 30 mg L^{-1} (4–5 mm), 30 mg L^{-1} (6–7 mm), 10 mg L^{-1} (9–10 mm), respectively. GA treatment was performed near the night and in absence of wind by means of an electrical knapsack power sprayer set to very low exercise pressure, making sure that it was directly applied to clusters to ensure full coverage of bunches untill runoff and at the same time to minimize derive effects of treatment.

2.3. Plant water status

To check the effective water status differences induced on vines by the two water managements, in the two years of study (2010 and 2011) from the beginning of June to harvest, the midday stem water potential (ψ_s) at pre- and post-irrigation stage was measured. For each stage the ψ_s mean value of the two years (Table 1) was calculated. The ψ_s values (Coletta et al., 2014) were measured on two mature and non-transpiring leaves per vine which had been bagged with plastic sheets embedded into aluminum foil no less than 1 h