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Applied water and mechanical canopy management affect berry and wine phenolic and aroma composition of grapevine (*Vitis vinifera* L., cv. Syrah) in Central California

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ABSTRACT

A field study was conducted in north-central San Joaquin Valley of California to deduce the interactive effects of irrigation and mechanical canopy management on the phenolic composition of grape and wine, and volatile compounds of the wines produced from Syrah (*Vitis vinifera* L.). The irrigation treatments consisted of a grower control of 70% crop evapotranspiration (ET_c) replacement (IRR-I) from anthesis to harvest, compared to a stronger plant water stress between fruit set and veraison with 50% ET_c replacement, otherwise 70% ET_c replacement rest of the season (IRR-II). Four canopy management treatments were crossed with the irrigation design. A control treatment was pruned by hand to 22 two-node spurs (C) with no further manipulation. Experimental canopy management treatments (CM) consisted in mechanically box pruning the vines to a 0.10 m hedge combined with 3 levels of mechanically shoot thinning: heavy shoot thinning (M1), light shoot thinning (M2) and no shoot thinning (M3). In this two-year study, the irrigation treatments had no impact on the canopy architecture, but mechanization treatments were effective. However, this study reports sensitivity of canopy management to weather conditions in previous and current year, therefore to vintage effect. The irrigation treatments affected berry composition more than mechanization, and the effect was insensitive of the vintage effect. The IRR-II reduced berry weight, resulting in reduced yield and crop load in both years but greater berry anthocyanins, tannins and total phenolics. For anthocyanins, this result was also confirmed on wine. One year was characterized by higher amount of precipitation at fruit set, and in this year the concentration in 3-isobutyl-2-methoxypyrazine was higher, but the concentration of terpenes and norisoprenoids was lower, with the exception of β-damascenone that was stable between years but increased with IRR-II. In typical years, where no precipitation is received in the San Joaquin Valley from fruit set to veraison, the M2 and IRR-II method may contribute to improve berry skin and wine phenolics as well as to reducing IBMP in wine while achieving high yields. This trial showed that precipitation can modulate the impact of cultural practices on grape and wine composition, and that lower irrigation amounts do not correspond to reduced wine quality even in the semi-arid and warm conditions of Central California.

1. Introduction

The San Joaquin Valley of California is the leading producer of wine grapes in the United States (CDFA, 2016). In this region the majority of wine grapes are grown for bulk wine production, they have low anthocyanin and tannin content but more herbaceous aroma. This is mostly due to the hot climate of this region compared to premium wine regions (Jones, 2006), but also due to vine imbalance, either too much fruit for the leaf area retained (Terry and Kurtural, 2011), or vice versa (Geller and Kurtural, 2013; Wessner and Kurtural, 2013). In previous works, we studied mechanical cultural practices such as dormant pruning in Cabernet Sauvignon (Kurtural et al., 2012), shoot thinning in Pinot gris and Syrah (Geller and Kurtural, 2013; Terry and Kurtural, 2011), and leaf removal in Merlot, Pinot gris and Syrah (Cook et al., 2015; Geller and Kurtural, 2013; Wessner and Kurtural, 2013) coupled to irrigation trials (Cook et al., 2015; Terry and Kurtural, 2011; Williams, 2012) to achieve an optimum crop load as the ratio of vegetative and fruit production (assessed with Ravaz Index, RI). However, the precise effects of mechanical canopy management (CM) and restricting irrigation application at key grapevine phenological stages on resultant wine composition have not been addressed.

Flavonoids are important constituents of wine because of their

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contribution to appearance (color), taste (bitterness) or mouthfeel (astringency) (Tarara et al., 2008). Grapes are non-climacteric fruits and have two stages of berry growth separated by a lag phase concomitant to changes in berry consistency and composition (i.e. veraison). Flavonoids typically have a consistent pattern in their concentration where proanthocyanidins and flavan-3-ol monomers tend to accumulate before veraison and decrease as grapes mature, while flavonols accumulate predominantly after veraison, and anthocyanins accumulate only after veraison (Bogs et al., 2005; Martínez-Lüscher et al., 2014; Matus et al., 2009). Among environmental factors, cluster exposure to the sun is one of the most influential factors affecting the flavonoid composition in grape berries (Martínez-Lüscher et al., 2014; Yu et al., 2016), and this can be easily modified by canopy management practices (Matus et al., 2009). However, solar radiation can have a beneficial effect on wine grapes composition, as long as certain temperature threshold is not reached (Cook et al., 2015; Spayd et al., 2002).

Grape aromas are responsible for part of wine aroma, but not all the compounds found in are associated with pleasant notes. Herbaceous aromas negatively affect consumer perceptions in some red wines and they are not desired, while floral and fruity notes are (Bindon et al., 2014). Two main classes of compounds having herbaceous notes, methoxypyrazines and C_6-alcohol/aldehydes, have been observed to be significant negative quality indicators (Mendez-Costabel et al., 2013). Methoxypyrazines, such as the bell-pepper like aroma of 3-isobuytly-2-methoxypyrazine (IBMP) are mainly related to grape ripening stage, because accumulates in the grape berry from fruit set to veraison and degrades rapidly under good sun exposure (Koch et al., 2012; Ryona et al., 2008). Contrarily, the presence of C_6 compounds, such as *cis*-3-hexen-1-ol, is related to fresh grape processing, as these compounds are resulting from enzymatic degradation of grape cell membrane lipids rather than cultural practices (López et al., 1999).

Norisoprenoids, such as β-damascenone and β-ionone, and terpenes, such as linalool and geraniol are responsible of floral and fruity aromas, especially abundant in both black and white muscat-flavored varieties. The formation of norisoprenoids is a result of carotenoid degradation, followed by enzymatic conversion to the aroma precursor (e.g. glycosylated or other polar intermediate), and finally, the acid-catalyzed conversion to the aroma-active compound (Gerdes et al., 2002). Once formed, these compounds are then subject to further acid-catalysis reaction during wine aging (Skouroumounis and Sefton, 2000).

Concentration and profile of aroma compounds in grapes and wines can be greatly affected by the cultural practices (González-Barreiro et al., 2015; Helwi et al., 2016), the growing site (Scarlett et al., 2014), and the wine making process (Ilc et al., 2016). The first effect of cultural practices on volatile compounds is related to sunlight exposure of vines and cluster, but also water availability (González-Barreiro et al., 2015). High IBMP concentrations, have been related to rapid shoot extension, high water availability, poor cluster exposure, and cool temperature (Scheiner et al., 2012). However, even in warm climate conditions, high water availability due to excessive irrigation or high precipitation may cause rapid canopy filling due to lateral extension from fruit set to veraison, and result in similar or higher levels of IBMP at harvest than vineyards located in cooler regions (Mendez-Costabel et al., 2013).

The objective of this work was to investigate the interactive effects of mechanical canopy management and applied water amount on the accumulation of phenolic and aroma compounds of grapes and wines under the warm and semi-arid growing conditions of the San Joaquin Valley of California.

2. Materials and methods

2.1. Site description, soil and weather data

This study was conducted from 2009 to 2011 at a commercial vineyard, planted with Syrah (*Vitis vinifera* L.), Foundation Plant Services clone 05, vines grafted on 1103 Paulsen (*Vitis berlandieri* Planch. × *Vitis rupestris* Scheele) at 2.12 m × 3.35 m (vine × row) spacing. The research site was located in Merced Co., CA (lat. 37.1°N – long. 120.2°W; 70 m asl). The vines were planted in 1999 on a Borden Fine Sandy Loam soil, a fine-loamy, mixed active thermic Typic Haploxeralfs (Soil Survey Staff, Natural Resources Conservation Service, USDA). The vines were trained to a bi-lateral cordon at 1.4 m with two foliage support wires at 1.7 m with a 0.2 m t-top trellis. The vineyard was drip-irrigated with pressure compensating emitters spaced at 1.06 m, two emitters per vine totally delivering 3.8 L/h per vine. All cultural practices (except irrigation and CM treatments) were carried out according to commercial industry standards for that area.

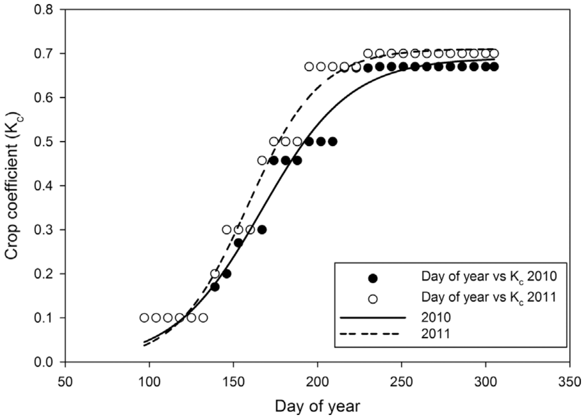

Fig. 1. Seasonal crop coefficient (K_c) for a California sprawl canopy on 3.35 m rows as a function of Julian days in 2010 and 2011. The individual K_c s are derived from the percent shaded area measured weekly using the following equation. $K_c = 0.017 \times$ percent shaded area.

Rainfall, reference evapotranspiration (ET_o) and temperature, were obtained from the California Irrigation Management Information System (CIMIS, California Department of Water Resources), weather station in Merced, CA. The amount of precipitation received, and the additional irrigation amounts were recorded weekly. The growing degree days (GDD) were calculated with a threshold of 10 °C.

2.2. Experimental design

The experiment was a four (canopy management) × two (irrigation replacement) factorial design with four replicated blocks. Three rows of 380 vines each comprised one block and one guard row separated each block. The irrigation treatments were applied randomly as main-plot to every three rows, separated by the guard row. The canopy management treatments were randomly applied as sub-plot to every 80 vines within each row separated by 15 guard vines, which composed the treatment replicates (80 × 4). In each treatment replicate a total of 8 plants was measured, sampled or harvested, at fixed distance (every 10 vines), having therefore a total of 32 plants per treatment. The field treatments were applied beginning in 2009, but measurements were collected starting in 2010 to allow for the vineyard to adjust to mechanized pruning and canopy management treatments.

2.2.1. Canopy management treatments

Four treatments were applied. A control treatment consisting of hand pruning (C) to 3 spurs per 0.3 m of row (22 spurs per vine) with two nodes each was applied. All mechanical canopy management (CM) treatments were initially machine box-pruned to a 0.1 m hedge, using a 0.6 m double, sprawl-pruner head (model 63700; V-Mech., Clovis, CA) mounted onto a V-Mech 1210 single-row, tractor-mounted tool carrier. All treatments were applied at modified Eichhorn-Lorenz (E-L; Lorenz et al. (1995)) scale stage 17 (pre-bloom: 12 leaves separated, inflorescence well developed, single flowers separated) with a rotary-paddle shoot thinner that had a rotary brush attachment (model 62731;