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On-vine grape drying combined with irrigation allows to produce red wines with enhanced phenolic and rotundone concentrations

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ABSTRACT

Rotundone, the compound responsible for peppery aroma in red wines is positively correlated with the absence of water deficit during ripening which can make it problematic to produce red wines combining both superior concentrations in rotundone and phenolic compounds. To reach this double objective, on-vine drying with cutting of the fruit bearing cane or "Passerillage Éclaircissage sur Souche" (PES), a technique that consists in cutting the cane 2–3 weeks prior to harvest on a Guyot-trained vineyard was investigated combined or not with irrigation. We showed that PES had a limited impact on rotundone in wine. As the PES technique leads to an interruption of the sap flow, our results suggest that rotundone is synthesized in the berries and not translocated. A viticultural system combining irrigation and then PES induced significant gains in rotundone, in sugar concentration, in anthocyanins and in Total Phenolic Index in wine, and in skin to juice ratio. Measurements of bunch surface temperature indicate that the enhancement of rotundone production induced by irrigation is likely to be due to a direct rather than to an indirect effect through an increase in leaf area leading to a cooler bunch microclimate.

1. Introduction

Rotundone is the main compound responsible for peppery aroma in red wines which was discovered in 2008 in Australian Shiraz wine and grapes (Wood et al., 2008). It has been identified in Pinot Noir, Durif, Graciano, Riesling (Herderich et al., 2012) and more recently in other cultivars such as Duras (Geffroy et al., 2014), Gamay (Geffroy et al., 2016), and Malbec, Abouriou (Cullere et al., 2016) grown in France under cool or Atlantic climate conditions. Differences in rotundone concentrations in wines made from four Duras certified clones suggest that rotundone was involved in the vine's natural response to powdery mildew attacks (Geffroy et al., 2015b). While leaf removal strongly reduces rotundone, irrigation enhances its accumulation in berries (Geffroy et al., 2014). Other researches have highlighted large spatial variations in berry and wine rotundone concentrations within a single vineyard (Geffroy et al., 2014; Scarlett et al., 2014 Zhang et al., 2015a). In most cases, this variability was associated with variation in the land underlying the vineyard and was linked with vine water status. The highest rotundone concentrations were found in wines made from vines experiencing low water deficit within the same vineyard (Geffroy et al., 2014). Other works showed that rotundone concentration was positively correlated with vineyard water balance in wines produced from 15 vintages and from the same Shiraz vineyard (Zhang et al., 2015b).

Water deficit during ripening is known to reduce berry weight and increase the concentration of anthocyanins and tannins in wines (Bucchetti et al., 2011; Ojeda et al., 2002). Indeed, in addition to the indirect increase of phenolic compounds due to berry size reduction, the expression of genes coding for flavonoid and anthocyanin biosynthetic enzymes is strongly enhanced in berries grown under drought conditions (Castellarin et al., 2007). In most cases and especially in vineyards under oceanic or cool climatic influence experiencing low water deficit, it can be problematic to produce red wines combining both superior concentration in peppery compound and phenolic richness.

On-vine grape drying with cutting of the fruit bearing cane, also known in French as "Passerillage-Éclaircissage sur Souche" (PES) or "double maturation raisonnée" (DMR), is a viticultural technique still little known worldwide. PES consists of cutting the cane 2–3 weeks prior to harvest on a Guyot-trained vineyard. Studies carried out since 1992 in Italy (Garofolo et al., 1993), Croatia (Peršurić et al., 1998), Switzerland (Rösti et al., 2011) and France (Serrano et al., 2007), showed that this technique implemented on red or white cultivars, caused some reduction in yield and allowed for

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improving the overall wine quality by increasing sugar and phenolic concentrations in the berries due to dehydration. Corso et al. (2013) showed that PES induced flavonol and depressed catechin accumulation respectively which led to brighter colored wine with lower astringency. Cutting the cane produces two bunch populations: the first one for which the connection with the trunk is still active and the second for which any connection with the trunk is severed. Seven to eight hours of manual work per hectare were necessary to perform the cutting in the South West of France (Serrano et al., 2007). Results from the same research work showed that the technique was suitable for mechanical harvesting and that the cutting of fruit cane had no impact on the quantity of waste (i.e. leaves, petioles and stems) or on the harvesting rate. However, PES induced a 3-fold increase of losses due to the fall of grapes and canes onto the ground.

Rotundone was reported in grape leaves and stems (Capone et al., 2012) and more recently in Shiraz flower caps at pre-veraison (Zhang et al., 2016). It has been reported that some monoterpene derivatives could be translocated via phloem transportation in other plants (Turgeon and Medville, 2004). Therefore, PES that leads to an interruption of the sap flow is susceptible to impact rotundone which could be translocated from vegetative tissues to grape berries.

The aims of this study were to apply PES and to assess its impact on rotundone in wine. A two-year study was conducted in 2013 and in 2014 on Duras, a grape variety grown in the Protected Designation of Origin Gaillac in the south-west of France. Following on from a PES only experiment in 2013, a viticultural system combining five irrigations and PES was implemented in 2014. As irrigation is known to enhance rotundone accumulation (Geffroy et al., 2014) and, in most cases, increases berry size and dilution of the skin compounds (Ojeda et al., 2002), this viticultural system was intended to increase rotundone concentrations while mitigating, through PES, the negative effects of irrigation on phenolic concentration of wines.

2. Material and methods

2.1. Experimental site and design

Two separate experiments, the first one concerning only PES (2013 and 2014) and the second one a viticultural system consisting of five irrigations, each one equivalent to 14 mm of rain, and then PES (2014), were established in two separate parts of the same vineyard. The 0.60-ha vineyard, located in the heart of the Gaillac region (lat. 43° 50′ 21″ N; long. 01° 51′ 01″ E) and typical of the area with 2.20 m × 1 m vine spacing, was planted in 2001 with Duras (clone designated number 554) grafted on Gravesac rootstock. Orientation of the vine rows was north-east to south-west, and vines were trained with vertical shoot positioning on a single Guyot pruning system. The soil was managed by chemical weed control under the vines and by grass cover in the inter-row area. The experimental unit presented with a slope of 6%. Despite the apparent homogeneity of the plot, trunk circumference (TC) measurements were carried out in order to detect any source of variability. Previously, studies showed a link existed between TC – an index of vine vigor well correlated to apparent electrical conductivity of the soil (ECa) – and rotundone, and that TC could be used to approach rotundone spatial distribution (Geffroy et al., 2015a). Therefore, just before budburst, in April 2013 and in April 2014 for the PES and viticultural system experiments respectively, TC was determined for every vine within each experimental unit as the average value measured at three different heights (just above the graft; 10 cm under the trellis wire; and half way between the two first points of measurement) and confirmed the homogeneity of the plot. Consequently, the two experiments were undertaken using a completely randomized design with four replications. For both experiments, the experimental site was established on four consecutive rows with each row containing two experimental units of 26.4 m^2 composed of 12 continuous vines.

2.2. Weather measurements

In 2013 and 2014, rainfall and air temperature (minima, maxima and mean values) were monitored daily by a CimAGRO weather station (Cimel Electronique, Paris, France) placed within 400 m of the experimental site. In order to characterize the two vintages, several indices proposed by Tonietto and Carbonneau (2002) were calculated for the PES experiment: Huglin index or heliothermal index over the period of 1 April to 30 September, the cool night index (FNv-r), the mean air temperature (Tv-r), the maximal air temperature (Txv-r), and the thermal amplitude (Av-r) indices over the veraison–harvest period. Cumulative rainfalls over the whole calendar year, the budburst– veraison, veraison – harvest and cutting – harvest periods were also calculated for the PES experiment.

2.3. PES experiment (2013 and 2014)

On 4 out of 8 experimental units, the fruit cane was cut beyond the first growing shoot from the trunk using a manual pruning shear on 26 September in 2013 and on 11 September in 2014, which corresponds to 30 days after mid-veraison. Mid-veraison (50% of colored berries) was determined by collecting 100 berries on the experimental site and by counting the number of colored berries every third day from the end of July to the middle of August. Harvest took place exactly 48 days after mid-veraison on 14 October in 2013 and on 29 September in 2014. In order to get a better understanding of the impact of the technique on rotundone and classical enological parameters, the bunch population still connected with the trunk (Spur) and the disconnected one (Cane), were monitored separately (Fig. 1) and compared with a control treatment (Control).

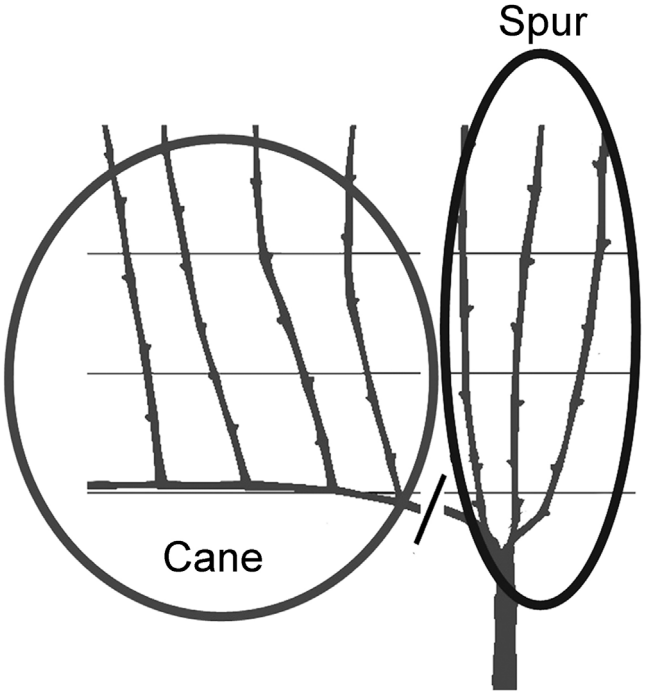

Fig. 1. Principle of on-vine grape drying with the cutting of the fruit bearing cane or "Passerillage Éclaircissage sur Souche" (PES). The spur bunch population is still connected with the trunk while the cane bunch is completely disconnected.