MINIMAL PRUNING INCREASES THE CONCENTRATION OF AROMATIC PRECURSORS IN VIOGNIER GRAPES

LA TAILLE MINIMALE AUGMENTE LA CONCENTRATION DE PRECURSEURS AROMATIQUES DANS LES RAISINS DE VIOGNIER

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Abstract

Aromatic composition of grapes is essential to wine quality. A study was conducted over four years, under Mediterranean conditions in southern France, to assess the impact of different training systems on aromatic precursors in fruit of Viognier B. grapevines. Two training systems [vertical shoot positioning (VSP) and minimal pruning (MP)] were investigated during the 2010, 2011, 2013 and 2014 seasons. At harvest, 18 different compounds corresponding to 4 families of grape aromatic glycoside precursors were quantified in grapes and musts by Gas Chromatography with flame ionization detector (GC-FID): monoterpenes, C6 compounds, aromatic alcohols and C_{13}-norisoprenoids (the latter only analysed in 2013 and 2014). MP significantly increased grape aromatic glycoside precursors concentrations, expressed in µg of 4 nonanol per kg of grapes, of C6 compounds (+38%), aromatic alcohols (+46%) and C_{13}-norisoprenoids (+133%). The differences between MP and VSP were greater in 2014, a year with diminished potential of aromatic glycoside precursors (2014 < 2010 <2013< 2011). This difference between years was negatively correlated with the Cool night index (CI). This study confirms that the MP training system presented a greater aroma potential of grapes than VSP, mainly due to a positive effect on the concentration of aromatic glycoside precursors by a reduction in berry size. In fact, biosynthesis of aromatic precursors, expressed in nanograms of 4 nonanol per berry, was similar for both training systems.

Keywords : *Viognier, aroma precursor, training system, grape quality.*

Résumé

La composition aromatique des raisins est essentielle pour la qualité du vin. Une étude a été menée sur quatre années, en zone méditerranéenne du sud de la France, pour évaluer l'impact de différents systèmes de conduite sur les précurseurs d'arômes dans les baies de Viognier B. Deux systèmes de conduite [espalier (VSP) et taille minimale (MP)] ont été étudiés au cours des millésimes 2010, 2011, 2013 et 2014. A la vendange, 18 composés différents correspondant aux quatre familles de précurseurs glycosidiques ont été quantifiés dans les moûts issus des baies par chromatographie en phase gazeuse couplée à un détecteur à ionisation de flamme (GC-FID): monoterpènes, composés C6, alcools aromatiques et C_{13}-norisoprénoïdes (analysé seulement en 2013 et 2014 pour ce dernier). Les résultats obtenus montre que MP augmente significativement la concentration dans les raisins, exprimée en µg de 4 nonanol par kg de raisin, des composés C6 (+ 38%), des alcools aromatiques (+ 46%) et des C_{13}-norisoprénoïdes (+ 133%). Ces différences entre MP et VSP ont été plus importantes en 2014, année où le potentiel de précurseurs glycosidiques a été le plus faible *(2014 < 2010 <2013< 2011)*. Cette différence entre les années a été négativement corrélée avec l'indice de fraîcheur des nuits (IF). Cette étude confirme que le système de conduite MP induit un potentiel aromatique du raisin plus important que VSP en raison, principalement, d'un effet positif sur la concentration des précurseurs glycosidiques par une réduction de la taille des baies. En effet, la biosynthèse des précurseurs aromatiques, exprimée en nanogrammes de 4 nonanol par baie, a été similaire pour les deux systèmes de conduite.

Mots-clés: Viognier, précurseurs d'arômes, système de conduite, qualité du raisin.

1. Introduction

In the wine-producing regions of southern France, characterized by a relatively warm and dry climate, a progressive increase in grape pH, often from 0.2 to 0.4 points at harvest, and a decrease in the acidity of musts and wines have been observed over the past 20 years. This situation is concomitant with a rise in annual temperatures and a progressive increase in drought conditions and increasingly early harvest dates of up to three weeks (Laget *et al*., 2008; Dubernet, 2008). MP (or Minimal Pruned Cordon-Trained vines - MPCT) is a training system developed in Australia, mainly focused on significantly reducing grape production costs per hectare (Clingeleffer, 1984, 1992). Trials carried out in the Languedoc-Roussillon region of France over the past ten years on different grape varieties have shown that MP is an interesting agronomic tool for differentiating and diversifying wine quality and style, significantly reducing the pH and concentration of K^+ in grapes and in musts, in comparison to vertical shoot positioning (VSP) (Deloire *et al*., 2004; Rousseau, 2006; Ojeda *et al*., 2007). However, limited information is available regarding the relationship between MP and the aromatic composition of grapes and wines. The presence of aromatic compounds in either, free or bound forms as glycosides in grapes is well documented (Gunata *et al*., 1985; Strauss *et al*., 1986). In general, aroma compounds occur in grapes at low concentrations and are mainly found in the form of non-odorant glycosylated precursors.

Among secondary metabolites with sensory significance, monoterpenes, C13-norisoprenoids, and volatile phenols have increasing trends with grape maturity (Fang and Qian, 2006), rising more rapidly during the advanced stages of grape ripening (Coombe and McCarthy 1997). In general climate is considered to have a decisive impact on secondary metabolites (Jackson and Lombard, 1993). Many of these compounds have been linked to the distinctive varietal aroma of various varieties (Razungles *et al.*, 1993; Guth, 1997). Although the direct relationship between aromatic glycoside concentration and wine sensory properties has not been fully established, glycosides are considered an indicator of aromatic potential (Williams *et al.*, 1995). It has been envisaged that the quantification of aromatic glycosides could prove to be a useful tool in optimising viticultural and oenological practices (Rocha *et al.*, 2010). This study set out to describe the aromatic precursors of *Vitis vinifera L.* cv. Viognier B. as influenced by training system; minimal pruning (MP) and vertical shoot positioning (VSP) in Mediterranean conditions.

2. Material and methods

Vineyard Characteristics

The study was conducted during four seasons (2010, 2011, 2013 and 2014) on cv. Viognier B. (*Vitis vinifera* L.) grafted onto SO4 (*Vitis berlandieri* x *Vitis riparia*), planted in 1996 at experimental vineyard INRA UE Pech Rouge in Gruissan, France (latitude 43°08'35''N; longitude 3°7'59''E). The soil is described as a sandy loam located on a coastal plain with a fluctuating saline water table during winter. Vines were trained on two [vertical shoot positioning (VSP) and minimal pruning (MP)] systems. Rows are orientated Northeast Southwest and vines spaced 1 x 2.5 m in VSP, and 1 x 3.5 m in MP. Drip irrigation lines with drippers spaced 1m apart with a capacity of 1.6 L/h were installed in every row, 30 cm above the ground. VSP was pruned as bilateral cordon and MP received no winter or summer pruning. The VSP vines were subject to a shoot positioning action, without the removal of water shoots and one hedge trimming (berry pea-size) during the years of the trial. A standard phyto-sanitary spray program was applied to all treatments.

Measurements

Climatic Parameters : Climatic data on a meso-climate scale were obtained from a weather station (CIMEL ™ 516i) from the INRA-Agroclim network, located 50m from the experimental vineyard.

Grapevine Water Status and Irrigation : Water status was determined by the predawn leaf water potential (Ψ_{pd}) measured by the pressure chamber technique (Scholander *et al.* 1965). For each measurement, 3 fully expanded leaves from 3 different plants per replicate (9 plants per treatment) were chosen in the center of the canopy. Measurements were taken on a weekly basis from the berry pea size stage (7 mm diameter) to harvest. Irrigation was individually applied to each treatment to maintain water potential values above -0,5 MPa throughout the season. Irrigation was supplied in 5mm applications.

Berry sampling and must analysis : One day before harvest, 250 berries per replicate were sampled for must composition and berry characteristics and 500 g of berries were frozen for analysis of aroma precursor content.

Sample preparation, extraction and analysis of aroma precursor content : Extraction and analysis of fruit glycoside compounds were based on the methods described by Martinez-Gil *et al.* (2013). At harvest, 18 different compounds corresponding to 4 families of grape aromatic glycoside precursors were quantified in grapes and musts by Gas Chromatography with flame ionization detector (GC-FID): monoterpenes, C6 compounds, aromatic alcohols and C13-norisoprenoids (the latter only analysed in 2013 and 2014) (Table 1).

Statistical Analysis : Data were subjected to analysis of variance (ANOVA). Mean comparisons were performed using Fisher's least significant difference (LSD) test; significance was set at $p \leq 0.05$ and $p \leq 0.01$(Software Statistica® vs. 10).

Table 1. *Different compounds corresponding to 4 families of grape aromatic glycoside precursors quantified in grapes*

Family of compounds	Glycoside compounds analyzed	Vintages analyzed
C6 Compounds	hexanal, 2 hexanal, hexanol, 3 hexen-1-ol	2010, 2011, 2013, 2014
Monoterpenes	linalool, nerol, geraniol, geranic acid, p-Menthane-3,8-diol	2010, 2011, 2013, 2014
Aromatic alcohols	benzyl alcohol, 2 phenyl EtOH, isoamyl alcohol, isobutanol, 2 pentanol, 1 butanol, 2 heptanol, 1 octanol	2010, 2011, 2013, 2014
C13-norisoprenoids	3-Hydroxy-ß-damascenon	2013, 2014

3. Results and discussion

Minimal pruning is based on the principle that a minimally pruned vine may become self-regulating in term of balance between the vegetative growth and the yield. This training system, that permits the elimination of pre-pruning, pruning, and the majority of green operations in vineyards, allows a reduction in production costs close to 20% (Rousseau, 2006; Rousseau *et al.*, 2006). During the 4 seasons of this study, on average with respect to VSP, MP increased yields (+ 28%), with greater number of clusters per plant (+255%) and less berries per cluster (-32%) (data not shown). Berry size in MP is significantly lower (-31%) (Figure 1A) and this is perhaps the main factor to explain the effect on the aromatic precursor composition. Certainly, the concentration of aroma precursors, expressed in μg of 4 nonanol equivalent / kg of grape, increases with decreasing berry size (Figure 1B).

Thus, grapes from MP are generally richer in most compounds tested, mainly those from the group of C13-norisprenoids, C6 compound and aromatic alcohols (Figure 2A). However, the total amount of berry aroma precursors, expressed in nanograms of 4 nonanol per berry, remains unchanged (Figure 2B), indicating no influence of MP on the biosynthesis of these precursors. The amount of precursors per berry was very different depending on the vintage *(2011> 2013 >2010> 2014)* showing that vintage was the main factor determining the aromatic potential of grapes, regardless of training systems. This vintage effect was not due to water status of plants because pre-dawn leaf water potential was measured weekly during the growing season and water was applied by drip irrigation to achieve a similar level of plant water status in all seasons (data not shown). The potential of the year compared to the amount of aroma precursors is mainly explained by the thermal conditions; in this case ripening conditions expressed with the Cold night index (CI, Tonietto and Carbonneau 2004) indicated a positive effect of low night temperatures during the last month before harvest on aroma precursors (Figure 3).

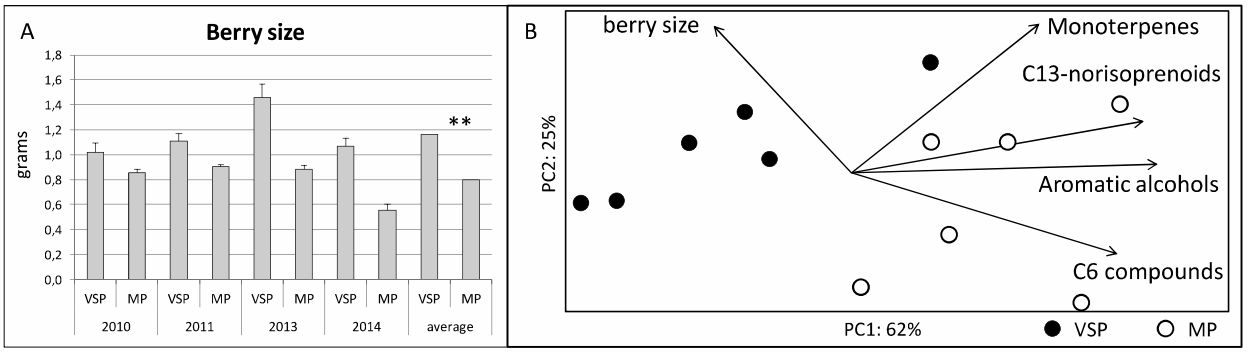

Figure 1. (A) *Berry size of Viognier B. grapevines with two training systems [vertical shoot positioning (VSP) and minimal pruning (MP)].* ***(B)*** *Principal component analysis with values corresponding of aromatic glycoside precursors content and berry size during 2013 and 2014 seasons. Vertical bars indicate standard deviation. (*) and (**) significance level at $p \leq 0.05$ and $p \leq 0.01$ respectively, (ns) no significant differences*

Figure 1. **(A)** Taille des baies de vignes de Viognier B. avec deux systèmes de conduite [espalier (VSP) et taille minimale (MP)]. **(B)** Analyse des Composantes Principales avec les variables correspondantes aux précurseurs glycosidiques d'arômes et la taille des baies pendant les saisons 2013 et 2014. Les bars verticaux indiquent l'ecartype. (*) et (**) différences significatives au $p \leq 0.05$ et $p \leq 0.01$, (ns) différences non significatives

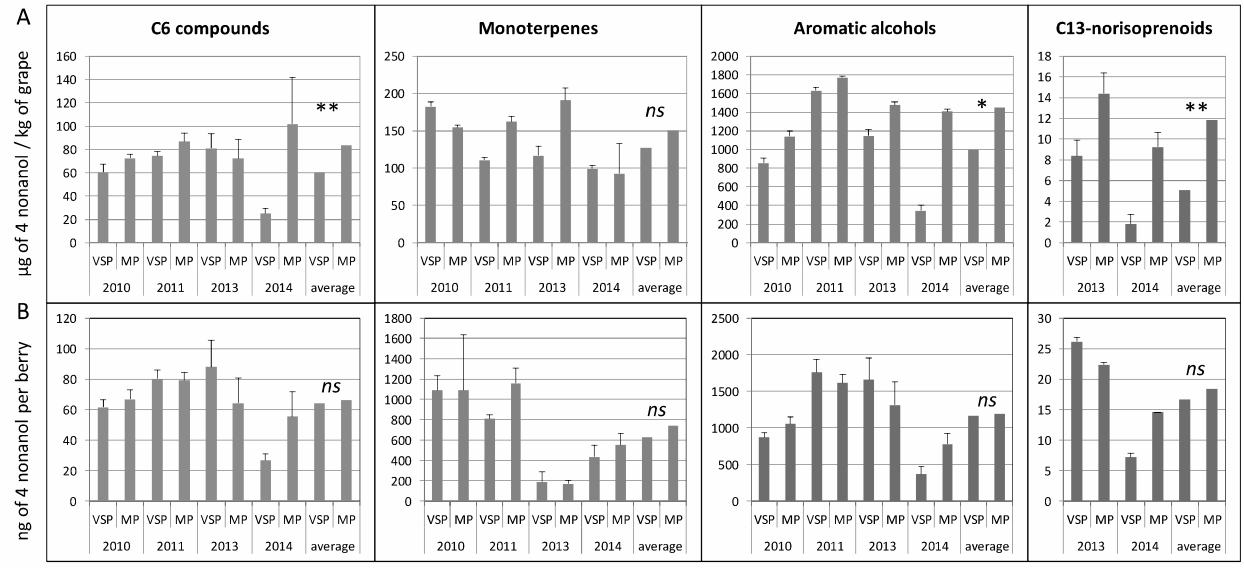

Figure 2. *Grape aromatic glycoside precursors content, expressed in µg of 4 nonanol equivalent:* ***(A)*** *per kg of grape;* ***(B)*** *per berry, corresponding to 4 families (C6 compounds, aromatics alcohols, Monoterpenes, and C_{13}-norisoprenoids) in fruit of Viognier B. grapevines with two training systems [vertical shoot positioning (VSP) and minimal pruning (MP)]. Vertical bars indicate standard deviation. (*)and (**) significance level at $p \leq 0.05$ and $p \leq 0.01$ respectively, (ns) no significant differences.*

Figure 2. Précurseurs glycosidiques d'arômes de raisins, exprimes en équivalent de µg de nonanol : **(A)** par kg de raisin ; **(B)** par baie, correspondants à 4 groupes (C6 compounds, aromatics alcohols, Monoterpenes, and C_{13}-norisoprenoids) en vignes de Viognier B. avec deux systèmes de conduite [espalier (VSP) et taille minimale (MP)]. Les bars indiquent l'ecartype. (*) et (**) différences significatives au $p \leq 0.05$ et $p \leq 0.01$, (ns) différences non significatives

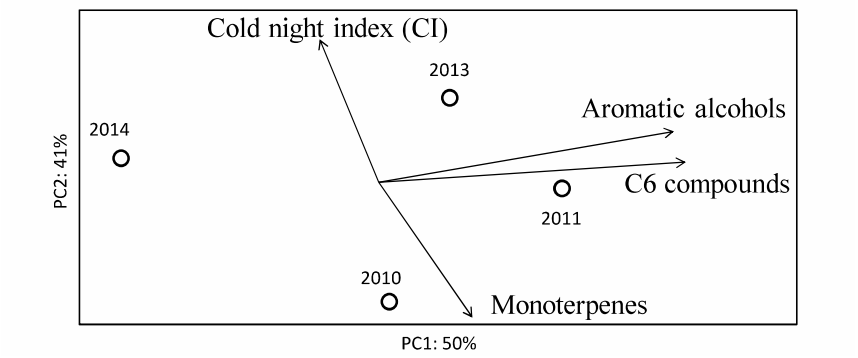

Figure 3. *Principal component analysis with values corresponding of aromatic glycoside precursors content and Cold night index (CI, Tonietto and Carbonneau 2004). Each point corresponds to the mean of each one of four seasons studied for each group of aroma precursors.*

Figure 3. Analyse des Composantes Principales avec les variables correspondantes aux précurseurs glycosidiques d'arômes et l'Index de fraîcheur des nuits (CI, Tonietto and Carbonneau 2004). Chaque point correspond à la moyenne de chaque année pour chaque groupe de précurseur d'arôme.

4. Conclusion

MP increased grape aromatic glycoside precursors concentrations, expressed in μg of 4 nonanol per kg of grapes, principally due to berry size reduction. Climatic conditions of the year determine the potential of aromatic glycoside precursors. The highest content of precursors was positively correlated with low night temperatures during the month prior to harvest (Cool night index).

5. Acknowledgements

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