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How terroir shapes aromatic typicity in grapes and wines (Part II)

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Over the past decades, great progress has been accomplished in the understanding of the molecular basis of aromas in grapes and wines. These aromas depend on the grapevine variety, but also on environmental factors involved in the so-called « terroir » effect. In the first part of this review, it was shown how the terroir effect can be decomposed in measurable climate and soil parameters, namely air temperature, radiation, nitrogen and water status. Their impact on aromas and wine typicity is well documented in the scientific literature. In the second part of this review, examples are provided about the terroir effect for three major red varieties (Merlot, Cabernet-Sauvignon and Syrah) and two white varieties (Sauvignon blanc and Riesling). How wine aromas can be optimized through vineyard management practices is also discussed.

Examples of aroma profiles related to specific terroirs

Sauvignon blanc is grown under a wide range of climatic conditions and soil types. Typical cool climate Sauvignon blanc is produced in Marlborough (New Zealand), the Elgin region (South-Africa) and Sancerre (France). Its aroma nuances are shaped by a delicate balance between green aromas (bell pepper induced by IBMP and boxwood by 4-MSP) and fruity aromas (grapefruit induced by 3-SH and passion fruit by 3-SHA). Examples of warm climate Sauvignon blanc can be found in California and Australia. The aroma profile of these is dominated by passion fruit or, if the region is really hot, by a lack of aromatic expression. The archetype of cool climate Sauvignon blanc is produced in the Awatere valley (a sub region of Marlborough, New Zealand). The aroma profile is dominated by green aromas (asparagus, boxtree), associated to grapefruit. Bordeaux is a major winegrowing area for Sauvignon blanc where the climate is temperate. The most expressive Sauvignon blanc is produced in the cooler parts of the Bordeaux area, on soils with medium to high water holding capacity and medium to high in nitrogen supply.

Merlot and Cabernet-Sauvignon grown in cool climates, or with low radiation, can be green, because of the presence of IBMP. An excess of IBMP is generally not appreciated, although some green aromas, like 1,8-cineole, can provide minty freshness in the aroma expression. Merlot and Cabernet-Sauvignon grown in temperate climates express fruity flavours and develop a complex ageing bouquet after a few years of bottle storage. These positive characters are induced by a wide range of compounds, including substituted esters, volatile thiols (in particular 3-SH) and DMS. Aroma expression after bottle ageing is enhanced when wines are produced by vines facing water deficits[1]. It has been shown that these wines contain more DMS and tabanones. Under warm climates, wines from the above mentioned varieties can express dried fruit aromas, in particular when produced from Merlot. Some of the finest wines from Cabernet-Sauvignon are produced in Margaux, Saint-Julien, Pauillac and Saint-Estèphe (Bordeaux, France). In the Bordeaux area, Cabernet-Sauvignon ripens late in the season, when temperatures are decreasing, eliminating any possible risk of dried fruit aromas. The gravel soils of these appellations induce an interesting combination of moderate to severe water deficit and unlimited nitrogen supply to the vines. This combination of cool climate, water deficit, and unlimited nitrogen can shape beautiful ageing bouquets.

Syrah can express different aromatic identities depending on the climate. In cool climate vineyards, such as those from the northern Rhone valley in France, the Victoria's Grampians region in Australia, or the Hawke's Bay area in New Zealand, Syrah expresses very intense peppery aromas, induced by the presence of (-)-rotundone. In warmer climates (i.e., unirrigated vineyards in the coastal parts of the Languedoc area or southern Rhone valley in France, Barossa valley in Australia), Syrah is rather marked by the expression of ripe and dried fruit, and black olive aromas. DMS has been identified as a major contributor to these notes.

The typicity of Riesling wines is shaped by various aromatic nuances, which reflect growing conditions, in particular temperature and vine water status. Typical cool climate Riesling wines, as grown in Europe (e.g., Germany, Alsace, Austria), are marked by the fruity aromas induced by volatile thiols, among other compounds, although this expression may change with increasing temperatures. Bottle aged bouquet, especially in Riesling wines from warmer climates, like Australia or South-Africa, but also from United States or Canada, contains more kerosene-like aromas as a result of the presence of TDN. When Riesling is grown under high radiation and water deficits, the presence of ortho aminoacetophenone (AAP) can lead to atypical ageing, in particular when vine nitrogen status is low.

Managing terroir-induced aroma expression in the vineyard

Terroir factors (temperature, radiation, water, nitrogen) induce specific aromatic typicities. The choice of plant material and vineyard operations can, however, modulate this expression. The excessive presence of green aromas is generally not appreciated in red wines. They are often the result of low temperatures during grape ripening, low light intensity, unlimited water supply and/or unlimited nitrogen supply. The presence of green flavours can be reduced by planting early ripening varieties (Merlot instead of Cabernet-Sauvignon). Another option is reducing nitrogen availability by planting cover crop or increasing exposure to light by leaf removal (which will also

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TABLE 1. The effects of varietal choices and management practices to modulate aroma expression linked to terroir. References can be found in van Leeuwen *et al.*, 2020[6].

Management practices and plant material choices	Impact on green aromas (IBMP)	Impact on boxtree, grapefruit and passion fruit nuances (volatile thiols)	Impact on cooked fruit and oxidized prune aromas	Impact on atypical ageing in white wine (AAP)
Leaf removal	Practice early leaf removal in cool and wet climates to reduce green aromas		Limit leaf removal to avoid excessive bunch exposure in warm climates which favours cooked fruit and oxidized prune aromas	Excessive exposure of bunches to direct sunlight can favour atypical ageaing of white wines, in particular under warm and sunny climates
Training systems	Use training systems that favour open canopies (VSP, Smart-Dyson, Lyre trellis) in cool and wet climates		Use training systems that favour some amount of bunch shading (globlet bushvines, pergola, VSP without leaf removal) to limit cooked fruit and oxidized prune aromas in warm climates	
Water management	Water deficits reduce green aromas in cool climates. Full irrigation favours excessive vigour which may lead to green aromas in cool and warm climates trough excessive bunch shading and late shoot growth cessation	Moderate water deficit favours the development of volatile thiol precursors in grapes, while severe water deficit is detrimental	Avoid late-season severe water deficits in warm climates, which may lead to berry shrivel and enhance cooked fruit and oxidized prune aromas	Water deficit increases the risk of atypical ageing in white wine
Nitrogen fertilisation	Excessive nitrogen fertilisation leads to high vigour and favours green aromas through bunch shading, in cool and warm climates	Increasing vine nitrogen status through fertilisation enhances the synthesis of volatile thiol precursors in grapes and promotes the production of glutathion, a natural preservative of volatile thiols in wines	Nitrogen deficiency leads to low vigour and excessive bunch exposure that favours cooked fruit and oxidized prune aromas in warm climates	Nitrogen fertilisation limits the risk of atypical ageing in white wine
Cover cropping	Cover cropping reduces vigour, improves bunch exposure and limits green aromas in cool and warm climates	Cover cropping reduces vine nitrogen status (except when legumes are involved), which limits the synsthesis of volatile thiol precursors in grapes	Avoid low vine nitrogen status through competitive cover cropping in warm climates, because it enhances the development of cooked fruit and oxidized prune aromas through excessive bunch exposure	Avoid low vine nitrogen status through competitive cover cropping in warm climates, because it enhances the development of atypical ageing in white wine through excessive bunch exposure
Variety choices	Use early ripening varieties in cool climates to avoid green aromas	Levels of volatile thiol precursors are variety dependant. Sauvignon blanc and Riesling (among others) contain high levels	Use late ripening varieties in warm climates to limit de development of cooked fruit and oxidized prune aromas	Riesling is particularly prone to the development of o-aminoacetophenone (AAP)
Rootstock choices	Use low to medium vigour rootstocks in cool and wet climates to limit green aromas through improved bunch exposure		Use medium to high vigour rootstocks in warm climates to reduce bunch exposure and delay maturity in order to limit cooked fruit and oxidized prune aromas	Any rootstock limiting water stress and inducing moderately high vigour limits the risk of atypical ageaing

increase the temperature in the bunch zone). Under warm climates there is a risk to produce red wines that are excessively marked by overriding and "trivial" dried fruit aromas, which reduces freshness and aromatic complexity. These can be limited by planting later ripening varieties (Cabernet-Sauvignon instead of Merlot). Other options are earlier harvest dates or increased vegetative expression and vigour to expose bunches to less direct sunlight.In Sauvignon blanc, grapefruit expression can easily be enhanced by nitrogen fertilization (when soil N supply is limited), either through foliar application or additions on the soil[2,3]. In warm climates, or on soils inducing moderate to severe water deficits, red varieties should be preferred over Sauvignon blanc or other early ripening white varieties for the production of high-quality wines. Berry temperature and light can be manipulated through canopy management and leaf removal. The effects of varietal choices and management practices to modulate aroma expression linked to terroir are summarized in table 1. Harvest date also has an important impact on wine typicity[4]. An extensive review on the effect of management practices on aroma compounds in grapes and wines can be found in Alem *et al.*, 2019[5].

Conclusion

Wine typicity in relation to terroir is largely shaped by odorous compounds. Over the past decades, a wide body of literature is published on the molecular basis of wine aromas. Many of these studies relate cultivar specific aroma profiles and how these are influenced by environmental factors and management practices. Major factors of terroir expression are air temperature, radiation, water supply to the vines and vine nitrogen status. Reviewing the effect of these factors on aroma compounds provides a better understanding of how terroir shapes aromatic typicities. Based on this knowledge, aroma expression can be optimized through varietal choices or management practices. ■

Sourced from the research article: "Recent advancements in understanding the terroir effect on aromas in grapes and wines" (OENO One, 2020).

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