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

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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 not only on grapevine variety but also on environmental factors involved in the so-called "terroir" effect. By decomposing terroir into measurable climate and soil parameters, namely air temperature, radiation, nitrogen and water status, its impact on aromas and wine typicity can be better understood.

Decomposing terroir into quantifiable parameters

In addition to winemaking techniques, wine quality and typicity is linked to the place where the grapes are grown. This relationship between the wine's sensory attributes and its origin is referred to as « terroir expression »[1]. Climate, soil and the cultivar are major drivers of this terroir expression[2]. It can be assumed that the influence of climate and soil is expressed through the grapevine variety, which is mediated by the rootstock. To understand the role of climate and soil in grape and wine composition, it needs to be decomposed into measurable parameters. Climate influences on vine development and grape ripening are mainly associated with temperature, radiation and rainfall. Temperature drives phenology (the timing of developmental stages like budbreak, flowering and veraison) and grape ripening. Grape composition at ripeness is also temperature-dependent. Radiation (associated with sunlight) provides the energy for the process of photosynthesis and has a major impact on the accumulation of secondary metabolites (tanins which mainly accumulate prior to veraison; anthocyanins and aroma compounds which accumulate during grape ripening) in grapes. Soil influences are primarily associated with nitrogen supply and water availability. Vine nitrogen status acts on vigour, vegetative expression, yield and grape composition at ripeness. Vine water status - which is the result of the combined effect of rainfall, irrigation, reference evapotranspiration, soil water content and canopy architecture - drives shoot growth, yield and grape ripening, and has a major impact on grape composition at ripeness. Temperature, rainfall and radiation data can easily be acquired by the measurement devices of a weather station. Several techniques are available for assessing vine water and nitrogen status. The quantification of these major terroir factors opens the door to a better understanding of their impact on aromatic composition of wines (Figure 1).

The importance of aromas

The aromatic profile of wine (linked to typicity expression) is highly influenced by secondary metabolites, in particular aroma compounds. Hundreds of aroma compounds have been identified in grapes and wines and they can be classified according to the aromatic nuances they induce and the chemical family they belong to (Figure 1 and Table 1). Volatile compounds are rarely variety-specific. Although their concentration varies with the variety (e.g., Cabernet-Sauvignon produces more IBMP

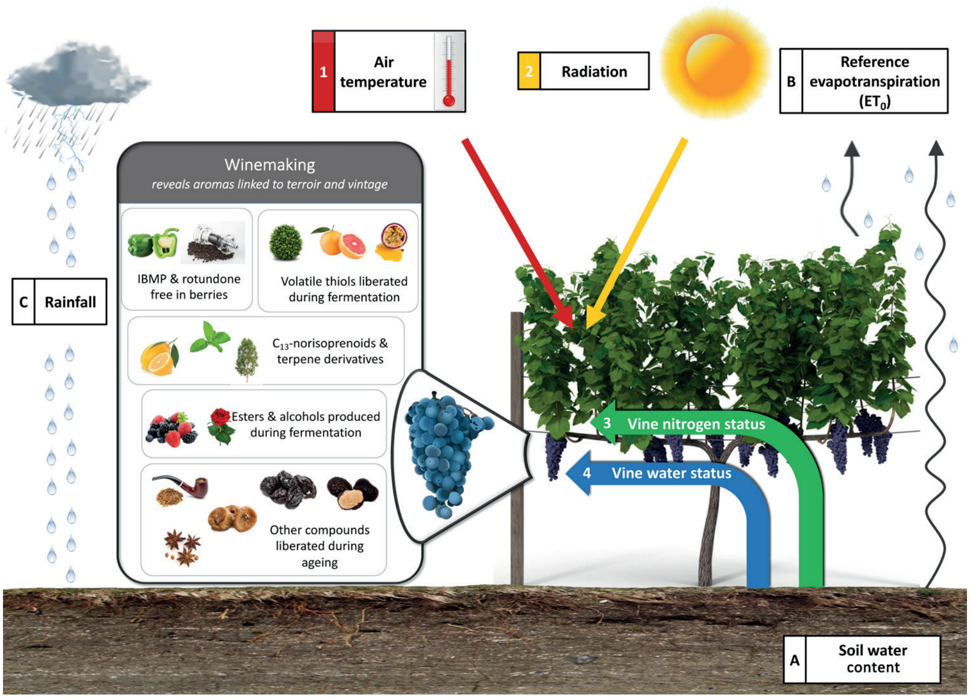

FIGURE 1. Overview of the terroir effect on aromas in grapes and wines.
Terroir expression is mainly mediated through (1) air temperature (climate), (2) radiation (climate), (3) vine nitrogen status (soil), and (4) vine water status, which results from (A) soil water content (soil), (B) reference evapotranspiration (climate), and (C) rainfall (climate). These four components related to soil and climate impact aroma composition and expression in grapes and wines.

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		Terroir factor			
	Aroma compound or family	Air temperature	Radiation	Vine nitrogen status	Vine water deficit
Green and peppery flavours	IBMP	decrease	decrease	no effect	decrease
	(-)-rotundone	decrease	increase	not yet investigated	decrease
	1,8-cineole	decrease	not yet investigated	not yet investigated but likely to increase	decrese
Other monoterpenes		variable effect	increase	decrease	variable effect
Volatile thiols and C_{13}-norisoprenoids	Volatile thiols	decrease	increase	increase	increase when moderate
	TDN	increase	increase	decrease	increase
	Tabanones	increase	not yet investigated	not yet investigated	increase
	Other C_{13}-norisoprenoids	no effect	increase	increase	increase
Dried fruit aromas		increase	increase	not yet investigated	possible increase through dehydration
Esters		not yet investigated	increase	increase	increase
Other compounds	DMS	increase	not yet investigated	increase	increase
	Red wine aging bouquet	likely to increase	not yet investigated	not yet investigated	increase
	o-aminoacetophenone	not yet investigated	increase	decrease	increase
	Glutatione	increase	decrease	increase	decrease
	Tanins	no consistent effect reported	increase	decrease	increase

TABLE 1. Effect of four terroir factors (air temperature, radiation, vine nitrogen status, and vine water deficit) on aroma compounds in grapes and wines. References can be found in van Leeuwen *et al.* (2020)[5].

than Merlot), they are also impacted by the environmental conditions of the vineyard (i.e., the terroir). It should be noted that wine typicity, in particular its aroma profile, is also influenced by grape harvest dates[3].

Impact of specific terroir parameters on aromas in grapes and wines

Air temperature

Cool growing conditions favour green aromas in grapes and wines, which can be induced by IBMP (bell pepper nuances) or 1,8-cineole (Table 1). High concentrations of IBMP are not desirable in red wine, but moderate levels of IBMP in Sauvignon blanc are appreciated, because they bring freshness to the wine. Syrah grown in cool climates have higher levels of (-)-rotundone (pepper nuances), which is considered, to a certain extent, as a quality factor. Volatile thiols (in particular 3-SH, grapefruit nuances) are negatively influenced by high temperatures, while Riesling grown in warm conditions contain more TDN (kerosene nuances). Moderately warm conditions favour DMS levels, which are implicated in the complexity of aged wines, while hot conditions trigger cooked fruit aromas, reducing the complexity and ageing potential of red wines.

Radiation (sunlight)

High levels of radiation decrease the concentration of IBMP in grapes and wines, while (-)-rotundone can be enhanced by exposure of the grapes to sun. High radiation has globally a positive effect on wine aromas, in particular on monoterpenes, volatile thiols (3-SH) and TDN. However, excessively high radiation may trigger the presence of ortho aminoacetophenone (AAP, nuances of atypical ageing) in white wine and cooked fruit aromas in red wine, which are putative factors driving premature ageing. In white grapes relying on volatile thiols for their aroma expression (in particular Sauvignon blanc) a side effect of high radiation is an increase in skin phenolics. These may be transformed into quinones during prefermentation operations, which can destroy a part of the precursors of volatile thiols or react with glutathione, a powerful antioxidant compound which has a preserving effect on these aromas.

Nitrogen

Although vine nitrogen status does not have a direct impact on the synthesis of IBMP, unlimited nitrogen uptake may increase vigour and create a cool and shaded microclimate in the bunch zone, indirectly reducing the degradation of green aromas. The synthesis of precursors of volatile thiols is enhanced by nitrogen, as is the production of esters during fermentation, leading to more fruity wines. The production of DMS is triggered by nitrogen, favouring the development of an attractive ageing bouquet. In Riesling, the concentration of TDN and AAP is reduced under increased nitrogen status. A side effect of nitrogen is that it reduces skin phenolics and increases must glutathione, limiting the risk of volatile thiol degradation through quinones. The absence of a limitation in nitrogen supply is globally favourable for aroma expression in wines, but excessive nitrogen should be avoided, because it promotes vigour and may induce *Botrytis cinerea* infection.

Water

Vine water status is the result of the combined effect of climate (rainfall and reference evapotranspiration), irrigation (if applied) and soil (soil water content). Water deficit is generally favourable for aroma expression in wines, because it reduces green aromas (in particular IBMP) and increases monoterpenes, C_{13}-norisoprenoids and volatile thiols (on the condition that the deficit is moderate). However, it is also known to decrease (-)-rotundone and therefore to affect the peppery typicity. When vines meet water deficit during the berry ripening period, the produced wines develop a more attractive ageing bouquet[4]. Severe water stress, however, promotes atypical ageing related to the development of AAP in Riesling, and may trigger cooked fruit aromas in red wines, probably as an indirect effect of berry shrivel. ■

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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