CERTIFIED CLONE AND POWDERY MILDEW IMPLICATES ROTUNDONE IN DURAS WINES

Few recent studies have been investigating the effect of clone on aroma compounds. The aim of this research work was to study the impact of certified clones from *Vitis vinifera* L. cv. Duras N - a grape variety grown in the South West of France - on grape quality and rotundone, a sesquiterpene responsible for peppery aroma which has been reported recently in red wines made from this cultivar.

**MATERIAL AND METHODS**

- **Experimental site and design:** The experimental site consisted of four consecutive rows, each row planted with one of the four certified clones of Duras N (554, 555, 627 and 654). For each clone, measurements were replicated on three experimental units of twelve continuous vines per row.
- **Homogeneity control of the plot:** Controls carried out on the plot using trunk circumference, a variable correlated to rotundone (1), δ13C measured on grapes at harvest, and iii) NDVI mapping confirmed the absence of variability, especially between the rows.
- **Measurements on vines and evaluation of powdery mildew severity:** At harvest, number of clusters per vine and yield (kg/vine) were monitored.

**RESULTS AND DISCUSSION**

- **Effect of clone on TC, δ13C, classical laboratory analysis and production aptitude**

  While differences were observed in 2013 between the four clones for most of the measured variables, few analytical data allowed discrimination of the clones in 2014. In 2014, the severity of powdery infections might have brought some perturbation and variability in the data set. In 2013, clone 554 showed better qualitative performances (i.e. higher sugar concentration, TPI and anthocyanins) in comparison with the other clones and especially clone 555. Neither the number of clusters per vine nor yields (kg per vine) at harvest were impacted in 2013 and 2014 by clone type. As significant differences in severity of PM on grapes at harvest were observed between the clones in 2014 and PM infection leads to lightening bunch weight, differences in yields could have been expected. To our knowledge, this is the first time that clonal differences in powdery mildew susceptibility have been observed. Indeed, the differences observed could reflect variations in quality of the phytosanitary treatment targeted against PM in relation with the spraying equipment.

- **Rotundone in wines**

  Concentrations of rotundone were significantly higher in wines from clones 554 and 654 in comparison with clone 555, while clone 627 showed an intermediate level. Rotundone concentrations observed in 2014 (more than 300 ng/L on average for three of the studied clones), are well above the aroma threshold of this compound established at 16ng/L in red wine (2) and are among the highest ever reported which deserves further discussion. The 2013 vintage was cooler and the two vintages were characterized by a similar water deficit as reflected by δ13C measurements. Therefore, in accordance with previous results (3), higher rotundone concentrations were expected in 2013. Our results suggest that another mechanism is involved. On the experimental site, a correlation (r2 = 0.58) was observed between the rotundone concentration in experimental wine and PM severity. As experimental site, a correlation (r2 = 0.58) was observed between the rotundone concentration in experimental wine and PM severity. As experimental site, a correlation (r2 = 0.58) was observed between the rotundone concentration in experimental wine and PM severity.

**CONCLUSIONS**

Our results found differences in rotundone concentrations in wines made from the four Duras N certified clones. The results also suggested that grapevine defense response to PM could enhance rotundone production in berries. Clonal differences in susceptibility to biotic stress, such as PM, might explain the differences observed in rotundone concentrations between the four studied clones. Our results may assist grape growers to produce wines made from Duras N with a desired aroma attribute. One should consider high levels of rotundone in wines made from this cultivar.

**References**

A SENSORY, CHEMICAL AND CONSUMER STUDY OF THE PEPPERY TYPICALITY OF FRENCH GAMAY N WINES FROM COOL CLIMATE VINEYARDS

In order to study the peppery typicality of Gamay N wines from cool climate vineyard a study was conducted on 21 Gamay N wines from the 2013 vintage and from 4 French viticultural areas (Auvergne, Beaujolais, Loire Valley, and South West). This research work contains a sensory, chemical and consumer part and was inspired by a study conducted by Lund et al. (1) on Sauvignon Blanc.

MATERIAL AND METHODS

- **Wines:** The 21 wines selected for the study were from Auvergne (n = 12), South West (n = 1), Loire Valley (n = 2) and Beaujolais (n = 6). They were selected on the basis of being predominantly from Gamay grapes (>85%) and their retail price varied from 4.50 to 9.00 euros.
- **Sensory Analysis:** 8 trained panelists assessed relevant attributes related to aroma and taste on a 5-point rating scale.
- **Analyses:** Conventional enological parameters and rotundone were determined.
- **Consumer study:** Four wines were chosen to participate in a consumer study (n = 97). Ranking tests were performed and the consumer panelists had to carry out an olfactory assessment based on aroma preferences. Wines were ranked from 1 “their favourite” to 4 “the less appreciated”.
- **Statistical treatment:** Statistical analyses including linear regressions were conducted with Xlstat software (Addinsoft, France). Olfactory data were treated through PCA and AHC. AHC was used to select four wines with distinct sensory profiles for the consumer study.

RESULTS AND DISCUSSION

- **Sensory analysis**
  The PCA plot shows that four attributes explain the main differences observed between the 21 Gamay N wines of the study: intensity, fermentative/lactic, fermentative/amylic and spicy/peppery. The scores discriminated a group of wines from Auvergne with similar sensory characteristics (A-1, A-2, A-3, A-5, A-6, A-7, A-10 and A-12) and heavier peppery notes. S-1, B-4 and B-6 wines had pronounced fermentative/amylic notes, and B-1 and B-5 showed a fermentative/lactic aroma sensory profile. The other wines of the study showed less distinctive aroma profiles.

- **Rotundone in wines**
  Wines from Auvergne show higher rotundone concentrations which is in accordance with the sensory observations. They were produced using traditional winemaking techniques whereas the other wines all contained a percentage of wine produced by semicarbonic [whole berries] maceration or prefermentation heat treatment of grapes. As rotundone is a hydrophobic compound, these higher levels may reflect a real “terroir” effect or arise from specific winemaking techniques. Climatic indices calculated for the wine growing area showed that Auvergne was i) the coolest vineyard over the whole wine-growing season and the ripening period, and ii) the wettest during the veraison-harvest period. Therefore in accordance with previous results (2), its «terroir» is the most likely factor explaining the differences observed between the wines from Auvergne and the other regions of the study. These differences may be further amplified by the winemaking techniques. For the whole data set, a significant correlation was observed between peppery aroma scores and rotundone concentration in wine (r = 0.66).
  There was high variability in rotundone content among the 12 wines from Auvergne. Wine rotundone concentrations were mapped according to the plots from which the grapes were primarily sourced and the rotundone distribution did not appear to be spatially structured. The only parameter that accounted for the variability among the wines was alcohol content and there was a significant positive correlation between this alcohol content and rotundone (r = 0.44).

- **Consumer study**
  Four wines showing distinct sensory profiles were selected for the consumer study. S-1 had higher aromatic intensity and heavy fermentative/amylic and fermentative/lactic notes. B-1 had a more complex profile marked by significantly higher ‘lactic’ notes. A-6 and A-8 were characterized by ‘peppery’ and ‘green’ notes. Regarding the olfactory assessment of the wines, there were no significant differences according to Friedman’s test between the four wines. A lack of consensus was observed for wine S-1 and A-8. The group of consumers who preferred the ‘amylic’ wine frequently rated the ‘peppery’ wine as the least appreciated and vice versa. This led us to think that there is an opposition between the consumers who preferred the ‘amylic’ and the ‘peppery’ wines. Consumers who rated the ‘peppery’ wine as the most appreciated were managers and professionals who are willing to pay more for a bottle.

CONCLUSIONS

These results that scientifically investigated the typicality and originality of Gamay N wines from Auvergne should assist wingrowers in this region in promoting their wines. They allow them to take advantage of the knowledge on rotundone obtained in another wine-growing regions with the aim to produce wines with a desired level of peppery aroma. The consumer study provides the key parameters for developing the Côtes d’Auvergne Gamay N wine range and adapting the products to consumer preferences.

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Recent research works highlighted large variability in rotundone concentration - the main compound responsible for peppery aroma in red wines - within a vineyard block associated with variation in land underlying the vineyard (1) and vine water deficit (2). This study aims at determining practical ways and setting up a methodology to map rotundone spatial variability.

**Material and Methods**

Experimental vineyard: The experiment was carried out on a 0.41 ha Guyot trained Duras vineyard from the South West of France planted in 1999.

Climatic background: The vineyard was located in an area under oceanic climatic influence with normal annual rainfall and mean air temperature of 638 mm and 12.9°C respectively. The 2014 vintage was characterized by an extremely rainy summer (160mm of rain between bunch closure and full veraison).

Sampling optimization protocol: Vineyard sampling was optimized (3). Variability in vine architecture of the plot was assessed through 25 measurements of trunk circumference (TC), a variable reflecting water use and mineral deficits since plantation (4). Data were spatialized through the kriging method. On the basis of the three classes of TC obtained, six smart points of 50 vines were positioned - with A and B corresponding to high, C and D to average and E and F to low TC classes - and monitored independently (see map on the right). The six smart points represented 17.5% of the whole block area.

Nitrogen uptake, water status and vine performances: Nitrogen status was characterized through its petiole analysis on a average sample of 50 basal leaves and 50 measurements (1 per vine) of Duallex®, a fluorescence based sensor which allows the calculation of a chlorophyll ratio named NBI®. For each smart point, stem water potentials (Ψstem) were measured at 4 time points and yields at harvest (kg/vine) were monitored. On each smart point, pruning wood weights (PWW) were measured through manual weighing during winter dormancy.

Fruit composition and rotundone: Conventional biological parameters and δ13C were determined at different time points. Rotundone determinations and sensory analysis on a 5-point rating scale were conducted in wines prepared with minification techniques (60 L tanks).

Statistical treatment: Analytical data were treated through PCA, ANOVA for those with replicated measurements (Ψstem, NBI, yield and PWW).

**Results and Discussion**

**Results overview**

The PCA plot shows that smart points C and D have more similarities with smart points E and F and should be merged with the low TC class when considering selective harvest. Linear regression models (n = 4) indicate that rotundone is correlated with variables related directly or indirectly to water deficit such as Ψstem at bunch closure (r2 = 0.75), at harvest (r2 = 0.87), weight of 200 berries at harvest (r2 = 0.85), malic acid mid-veraison (r2 = 0.76), δ13C at mid-veraison (r2 = 0.93) and at harvest (r2 = 0.82), which is consistent with previous observations (2).

Nitrogen uptake, water status, vine performance, fruit quality, rotundone and sensory analysis

Water deficit and differences between the smart points were weak which is consistent with the hypothesis that low water deficit leads to low spatial contrast (5). Indicators used in routine and well known by winemakers such as yields at harvest, fruit quality, nitrogen uptake through petiole analysis, pruning wood weights did not allow to discriminate the smart points from an agronomical standpoint while better results were obtained with TC, Ψstem and NBI. Ψstem especially at bunch closure, allows a perfect discrimination of the smart point according to TC classes. Variables measured on fruit at harvest were similar between the smart points with the exception of Total Acidity (TA), Yeast Assimilable Nitrogen (YAN) and rotundone. For the pepper aroma compound, average values of 94.5, 60.5 and 61 ng/L were measured in wines from the high, average and low TC area respectively. At tasting, significant differences were noticed between the wines for the peppery score. Our results suggest that it is possible under Atlantic conditions and during vintage with low water deficit, to produce two wines from the same vineyard block, differing only by their rotundone concentration and peppery attribute.

**Conclusions**

The present works allowed to set up a methodology for assessing rotundone spatial distribution through the smart point method. Our results suggest that a link exists between rotundone in wine and plant architecture (TC) and that this cost-effective indicator can be used to approach rotundone spatial distribution. Our study also highlights the sensitivity of rotundone to fine variation of grapevine water status.

**References**

DO DIFFERENT WINEMAKING TECHNIQUES AND PRESSING CONDITIONS IMPACT ROTUNDONE LEVELS IN RED WINE?

Rotundone responsible for ‘black pepper’ aroma in wine (1) has only been detected in the grape berry exocarp (2,3) which suggests that maceration variables are likely to impact its concentration in wine. Two separate experiments were conducted to investigate the impact of i) key fermentation parameters and winemaking techniques at the laboratory scale and ii) pressing conditions at a semi-industrial scale on the extraction of rotundone.

MATERIAL AND METHODS

- **Laboratory scale experiment:** 27 homogenous lots of 800 g destemmed berries were obtained in 2015 from an irrigated Duras vineyard located in the South West of France (PDO Gaillac). Nine treatments were investigated in triplicate in 1L Ehrenimmel - control vinification at 25°C for 8 days (Control), pectolytic enzyme addition at 40 mg/kg [Enzyme], cold soak at 4°C for 72 hours (Cold), thermovinification at 70°C for 2 hours followed by pressuring, clarification and fermentation in liquid phase at 18°C (Thermo), vinification at 30°C (Carbonic), rosé vinification after a 6-hour skin contact at 18°C (Rosé) and fermentation with Saccharomyces uvarum (Uvarum) at 30°C for 14 days (Control). Three repeated trials were carried out to investigate the impact of pressing: free run (Free run), dynamic in the press (De-juicing), pressing at 200mb (200mb), pressing at 400mb (400mb), pressing at 600mb (600mb).

- **Semi-industrial scale experiment:** 2 tons of Syrah grapes from a neighbouring dry-grown vineyard were fermented at 25°C. After 10 days of maceration, grapes were pressed using a pneumatic press. Samples were collected in the tray of the press at different conditions of pressing: free run (Free run), dynamic in the press (De-juicing), pressing at 200mb (200mb), pressing at 400mb (400mb), pressing at 600mb (600mb).

- **Analyses:** Conventional enological parameters and rotundone were determined in wines after one week and one month respectively.

- **Statistical analysis:** Analytical data from the laboratory scale experiment were subjected to a one-way analysis of variance (ANOVA) treatment using Xstat software (Addinssoft, France).

RESULTS AND DISCUSSION

Fermentation parameters and winemaking techniques

In comparison with the control vinification, the Enzyme and Cold treatments had a weak impact on the measured parameters. For Enzyme, the pectin degradation maximized juice yield and surprisingly, Total Phenol Index (TPI) and rotundone were not impacted. Cold soak had no effect on anthocyanins, TPI and rotundone but induced a gain in pH.

The Thermo treatment had a large impact on the enological parameters. In accordance with previous works (4), an increase in tartaric acid, malic acid and total acidity was not accompanied by a consequence of a large extraction of amino and organic acids from the berry exocarp when pressing the grapes at hot temperature. As TPI values were increased by the heat treatment of grapes, a gain in rotundone which also has a hydrophobic behaviour would have been expected. Our results suggest that rotundone is less heat-extractable than proanthocyanidins in aqueous phase.

The impact of maceration parameters (time and temperature of maceration) on TPI and especially on rotundone reflected by the 30°C and 14 days treatments are expected as the literature usually supports the belief that the extension of the time and the increase in the temperature enhance extraction of the skins and seeds (5).

Carbolic wines had significant smallest levels of alcohol due to an increase of the Krebs cycle, anthocyanins and TA leading to a higher pH. Even if the quantity of ethanol produced during the anaerobic phase - typically about 2 to 3 % vol. - remains low at pressing, it allowed a significant extraction of rotundone.

The rotundone in Rosé wines represented on average 13% of the concentration found in the Control which indicates than in most cases, rotundone is not likely to have a large sensory contribution to the aroma of rosé wines. Rotundone, anthocyanins and pH were significantly impacted by the Uvarum treatment which must be the consequence of a lesser extraction or a larger adsorption.

Pressing conditions

Pressing conditions had a limited impact on most of the measured parameters with the exception of glucose and fructose. For rotundone, it remains difficult to draw firm conclusions, as concentrations detected in wines were very low. The 2015 vintage particularly dry and hot in the South West of France, it was not recommended to use such wines for rotundone accumulation.

CONCLUSIONS

None of the studied treatments resulted in enhanced rotundone concentrations in wine compared to Control wine. Semi-carbonic maceration, fermentation with Saccharomyces uvarum or longer skin contact resulted in wine with a significant reduction in rotundone, indicating practical opportunities for reducing pepper aroma in wine. Pre-ferment removal of skins as typically used during thermovinification and in rosé winemaking resulted in the lowest wine rotundone concentrations. Pressing conditions had a limited impact on rotundone in wine.

**Table: Characteristic of the studied wines**

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Control</th>
<th>Enzyme</th>
<th>Cold</th>
<th>Thermol</th>
<th>Carbonic</th>
<th>Rosé</th>
<th>Uvarum</th>
</tr>
</thead>
<tbody>
<tr>
<td>Alcohol (% vol.)</td>
<td>12.70</td>
<td>12.64</td>
<td>12.64</td>
<td>12.64</td>
<td>12.4</td>
<td>12.8</td>
<td>12.6</td>
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<tr>
<td>Tartaric acid (g/L)</td>
<td>4.05</td>
<td>4.00</td>
<td>4.05</td>
<td>4.05</td>
<td>4.08</td>
<td>4.00</td>
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<td>malic acid (g/L)</td>
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<td>5.00</td>
<td>5.50</td>
<td>5.00</td>
<td>5.75</td>
<td>5.00</td>
<td>5.75</td>
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<tr>
<td>Total Phenol Index (TPI)</td>
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<td>164</td>
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<td>164</td>
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<tr>
<td>Total Phenol Index (mg/L)</td>
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<td>8.01</td>
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<tr>
<td>Anthocyanins (mg/L)</td>
<td>700</td>
<td>700</td>
<td>700</td>
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<tr>
<td>Sugar (g/L)</td>
<td>16.0</td>
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<td>Sugar (g/L)</td>
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</table>

Different letters indicate means significantly different according to Fisher’s test at ≤ 0.05.
MODELLING IMPACTS OF VITICULTURAL AND ENVIRONMENTAL FACTORS ON ROTUNDONE IN DURAS WINES

It has been shown that rotundone - the aroma compound responsible for peppery aroma in red wines - was impacted by temperature and water status within a vineyard (1,2). A study was conducted to determine the key environmental and viticultural variables affecting the rotundone concentration in Duras wines grown in the South West of France (IPDO Gaillac) and made from 10 different vineyard blocks in 2013 and in 2014.

MATERIAL AND METHODS

- **Vineyards blocks**: 10 vineyard blocks planted with Duras from the IPDO Gaillac (3400 ha) were used for this study. At each site, a 30-vine panel from 3 consecutive rows was selected for data collection and sampling. No leaf removal was performed.
- **Climatic data**: Antilope data (T°C, rainfalls, evapotranspiration, hygrometry) were provided by MeteoFrance at a kilometer scale. Solar radiation data were obtained from HelioClim-3, a satellite-based surface solar irradiation database.
- **Site, phenology, vine, and crop data**: 43 variables were collected or measured at each experimental site. Stem water potentials were calculated using the WaLIS water balance (3).
- **Rotundone**: Rotundone was quantified in wine (1L Erlenmeyer) made from healthy grapes harvested 44 days after veraison.
- **Statistical treatment**: Partial least squares regression (PLSR) was conducted with Xstat (Addinsoft, Paris, France) to model rotundone.

RESULTS AND DISCUSSION

- **Overview of the 2013 and 2014 vintages**
  The 2013 vintage was characterized by a cold spring, regular and large rainfall events over the vine vegetative cycle which induced a delay of almost 3 weeks at harvest and ripening difficulties. In 2014, winter was rainy and warm; summer was extremely rainy with 160 mm of rain recorded between mid-July and the end of August and conditions during ripening were dry and hot. Severe bunch rot (*Botrytis cinerea*) was recorded on bunches in 2013. Mean air temperatures over the VER-HAR period were lower in 2013 (18.5°C ± 0.6) than in 2014 (19.5 ± 0.4). For the same period, levels of water deficit reflected by measurements of δ¹⁸O were equivalent for the two vintages [-26.4 ± 1.1 in 2013; -26.7 ± 0.6 in 2014].

- **Rotundone concentrations**
  Rotundone concentrations were higher in the cooler and wetter 2013 growing season in accordance with previous results (4). Surprisingly, some high rotundone vineyards in 2013 [i.e. blocks 2, 4 and 8] showed low to moderate levels of concentrations in 2014. In the same way, some blocks having high concentrations in 2014 [i.e. blocks 3, and 5] showed low rotundone in 2013. This led us to think that fixed variables such as year of plantation, altitude, training system, or trunk water potential don’t have a large contribution to the rotundone model.

- **Multistate PLSR models for rotundone in wine**
  During the 2013 vintage with ripening difficulties, precocity of veraison, gluconic acid - a secondary metabolite of *B. cinerea* - and cumulative rainfalls over the VER-HAR period had negative regression coefficients. *B. cinerea* has the ability to withstand the toxic effects of plant such as sesquiterpenes by its laccase through oxidation and detoxification (5). Therefore, our results suggest that the fungi can induce the degradation of rotundone. For the 2014 and 2013-2014 models, rotundone was best predicted by cumulative rainfalls over the 1st of April-30th of September and by stem water potentials 15 days before veraison in 2014, which is in agreement with previous results (6,2).

CONCLUSIONS

Important variables identified for modelling rotundone in wine were those associated with cumulative rainfalls and *B. cinerea* damages. Our results suggest that mesoclimate is the key factor to explain the differences in rotundone observed among the sites.

(4) Geffroy, O. et al. (2014). Onset of VER (Julian day) and PM severity
FOLIAR NITROGEN AND SULFUR
SPRAYING ALLOW TO PRODUCE WINES WITH ENHANCED CONCENTRATION IN VARIETAL THIOLS

Varietal thiols, especially 3-mercaptohexanol (3MH) and 3-mercaptohexylacetate (3MHA), are desirable aroma compounds identified in white, rosé and red wines made from several cultivars. These fruity compounds are linked to the plant nitrogen (N) uptake (1) and sulfur (S) metabolism by its S-cysteine and S-glutathione conjugates described as aroma precursor (2). Between 2005 and 2011, several experiments were conducted to assess the impact of foliar applications of nitrogen (formulated forms of urea, organic fertilizers) combined or not with sulfur on several cultivars.

CONDITIONS OF SPRAYING
- To allow sufficient dilution of the fertilizer and to avoid toxicity, foliar sprayings were carried out at 400L/ha and divided into two applications (onset of veraison and full veraison).
- A formulated form of urea (Folur, Tradecorp, Belgium) was applied through foliar spray at the rate of 10, 15 and 20 kg N/ha. These applications were combined or not with elemental soluble sulfur (Microthiol, Ceroxagri, France) at reduced doses (from 5 to 10 kg S/ha). Sprayings were tested on Colombard B, Gros Manseng B, Négrette N, Sauvignon B, Melon B and Sauvignon B between 2005 and 2008.
- 3 commercial products obtained from enzymatic digestion of animal (Aminovital, Bioa, Germany), vegetal (Diaglutin, Bioa, Germany) and marin (Liquoplant B336, Plantin, France) proteins were tested at 10kg N/ha in 2010 on Sauvignon B grown in the South West of France.
- A formulated form of urea (Azofol SR, Agronutrition, France) was applied in 2011 at 20 kg N/ha without sulfur due to the risk of developing reductive off-flavours, on Fer N and Carignan N.

WINEMAKING AND ANALYSES
- For all the experiments, wines were elaborated at pilot scale (30L). Grapes were processed under a strict non-oxidative protocol for white and rosé wines. For red wines, fermentation and maceration took place at 25°C for 8 days. Nitrogen in must was determined as the percentage of N as NO3 and NO2, and presented higher scores for grapefruit and tropical fruit attributes. No undesirable sulfur/reductive notes were perceived at tasting.

RESULTS AND DISCUSSION

A large impact on the nitrogen content of the must and the aroma composition of white and rosé wines
The gain in nitrogen induced by the foliar application was linear: 50% and 100% increases were noticed for 10 and 20kg N/ha applications respectively. In comparison with controls, nitrogen and sulfur sprayings induced a three to four-fold gain in varietal thiols. This increase was observed even for control wines with high concentrations in thiols (from 10 to 40 nM/L). When performing sensory analysis, wines from the N and S treatment were judged more intense and presented higher scores for grapefruit and tropical fruit attributes. No undesirable sulfur/reductive notes were perceived at tasting.

<table>
<thead>
<tr>
<th>Treatment</th>
<th>Nitrogen in must Content (mg/L)</th>
<th>Gain in comparison with the control (%)</th>
<th>3MH (nM/L)</th>
<th>3MHA (nM/L)</th>
<th>Molar sum 3MH +3MHA (mg/L)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Control</td>
<td>115</td>
<td>-</td>
<td>439</td>
<td>44</td>
<td>3.53</td>
</tr>
<tr>
<td>Liquoplant B336</td>
<td>136</td>
<td>18%</td>
<td>128</td>
<td>11</td>
<td>1.02</td>
</tr>
<tr>
<td>Diaglutin</td>
<td>153</td>
<td>33%</td>
<td>174</td>
<td>37</td>
<td>1.30</td>
</tr>
<tr>
<td>Aminovital</td>
<td>170</td>
<td>48%</td>
<td>128</td>
<td>15</td>
<td>1.04</td>
</tr>
</tbody>
</table>

Can the technique be adapted to organic viticulture?
Our results showed that organic fertilizers can be assimilated by grapevine through foliar way. The gain obtained for Aminovital reaching 48%, was equivalent to the increase expected for a urea-based application (50%). Concentrations in varietal thiols measured in wines were very weak and foliar sprayings had a depreciable impact on the quantity of molecules. No differences were found between the four wines at tasting. Severe burn damages, particularly marked for the Liquoplant B336 and Diaglutin treatments, were noticed on the foliage at harvest. This phytotoxicity can be mainly explained by the concentration in nitrogen of the organic fertilizers which doesn’t allow sufficient dilution. The cost of this product also poses a serious threat to the development of the technique.

Is the technique also suitable for the production of red wines?
Red wines from the foliar treatment had lower Total Phenol Index (TPI) which is not completely unexpected as it has been shown that biosynthesis pathways of proanthocyanidins were down-regulated by an excessive nitrogen uptake [3]. Surprisingly, despite average gains of 25% and 30% in glutathione and cysteine precursors of 3MH respectively, concentrations in 3MH were not impacted in finished wines. Red winemaking conditions (higher temperature and turbidity) are less favourable to the release of 3MH (4) and the absence of nitrogen/sulfur combination in this experiment might also have played a role [5]. From a sensory point of view, wines from the nitrogen treatment had marked reductive off-favours which can be explained by the higher concentration in hydrogen sulphide found in wines.

CONCLUSIONS
The application of sulfur and nitrogen through foliar way at veraison is a powerful viticultural technique to over-express the varietal character of white and rosé wines. The technique cannot be yet adapted to organic viticulture and its interest is limited when making red wines.
WINETWORK is a European collaborative project for the exchange and transfer of innovative knowledge between European wine-growing regions to increase the productivity and sustainability of the sector. For 3 years, 11 partners of 7 European countries will exchange knowledge on two important diseases in vineyard: Grapevine Trunk Diseases and Flavescence dorée. These diseases are well-known in many vineyards and have been extending for several years in different European countries, and having big economic importance for the European wine industry. As many winegrowers are testing innovative and sustainable approaches to fight against these diseases, it is very beneficial to capture these ideas and to share them between European countries.

Project WINETWORK is developing the innovation-driven methodology, which promotes the exchange of knowledge between science and practice. This network is implemented in ten winegrowing regions, within seven European countries. The methodology is built on a network of winegrowers and regional experts gathered in regional Technical Working Groups, Scientific Working Groups (one for each disease), and ten regional Facilitator Agents that stimulate their interaction.

Bottom-up approach applied in WINETWORK includes surveys, conducted and synthesized by Facilitator Agents, to identify winegrower’s innovative practices, while scientists revise scientific data and adapt it to dissemination and practical use.

This participatory approach will allow transferring results from science and practical knowledge to materials adapted to end-users. This network will promote interactions between scientists and practitioners to gather and share experiences and knowledge of different actors from the main wine producing European regions.

Collected knowledge will be gathered in the knowledge reservoir, and will serve as a basis for Facilitator Agents in collaboration with Technical Working Groups and Scientific Working Groups to co-create original material adapted to innovation support services and to winegrowers. The knowledge reservoir is a participative tool having the ambition to host all existing knowledge on the topics, both developed by research or derived from practical experience. Those stakeholders—such as scientists, advisors or winegrowers—who would like to share their documented knowledge can contribute to this webarchive by uploading videos, images and documents. All the created material will be available for the European wine sector and will allow, for example, winegrowers to recognize diseases symptoms and to better understand their management.

Flavescence Dorée is a quarantine disease caused by a phytoplasma affecting grapevine. This pathology is transmitted from a vine to another by an insect vector, Scaphoideus titanus. Once affected grapevine can express symptoms as an absence of lignification of green shoots which become rubbery and dangling, additionally a yellow or red discoloration and rolling down of leaves is observed, berry setting and withering of clusters are also reduced.

Grapevine Trunk Diseases gather three main diseases: Esca, Botryosphaeria dieback and Eutypa dieback. These diseases are widely spread and cause large damages in European vineyards. Depending on grape variety, symptoms are expressed with variable intensity. Foliar symptoms and internal symptoms are typical of grapevine trunk diseases.

For Flavescence Dorée, control strategies are based on vector monitoring, insecticide application and removal of infected vines, and secondary hosts. Hot water treatment (HWT) is a technique applied in nursery to suppress potential phytoplasma from planting material. In field, insecticides treatments are used by winegrowers to limit *Scaphoideus titanus* population. Alternatives in organic viticulture are existing as based natural pyrethrin product and spraying of chaolinite or orange oil/extract on foliage to reduce plant attractiveness.

Control strategies for Grapevine Trunk diseases are based on preventive techniques which minimize news infections. Scientific Working Group identified the most efficient chemicals and bio-control agents regarding one or two diseases. Then, they provided recommendations for nursery and vineyard management. In field, most European winegrowers are using pruning techniques and protection of pruning wounds to limit pathogens infection (Guyot Poussard, Simonit and Sirch, bio-control agent spraying), trunk cleaning and a combination of practices insuring a good vineyard health status.