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# Vine vigor: a factor associated with the expression of wood disease symptoms

**Marion Claverie**[1], **Maïko Audras**[2], **François Berud**[3], **Didier Richy**[4]

[1] Institut Français de la Vigne et du Vin, Pôle Rhône-Méditerranée, Institut Rhodanien, 2260 Route du Grès, 84100 Orange, France
[2] Chambre d'Agriculture du Gard, 1120 route St-Gilles, CS 38283, 30942 Nîmes Cedex 9, France
[3] Chambre d'Agriculture de Vaucluse, 2260 Route du Grès, 84100 Orange, France
[4] Chambre d'Agriculture des Bouches du Rhône, Maison des Agriculteurs, 22 Avenue Henri Pontier, 13626 Aix en Provence Cedex 01, France

The relationship between vine vigor and the expression of grapevine trunk diseases (esca and Botryosphaeria dieback) is poorly documented in the literature. In this study conducted in the Mediterranean region from 2021 to 2023[1], we have highlighted a link between vine vigor and the expression of grapevine trunk diseases. The results also show the effect of other factors, such as water stress in the previous year, suggesting a broader link to vine physiology. Additional observations to the above-mentioned work are also included in this article.

## Three networks of plots in small geographical areas

To test the effect of vigor on the expression of trunk disease symptoms, we monitored two campaigns (2022 and 2023), three small networks of around thirty plots each, composed of the same grape variety (Grenache N), of similar ages (around 20 years old) and covering small areas located within a radius of 5 to 10 km in the Bouches-du-Rhône, Vaucluse and Gard departments. At this scale, climatic conditions show little variation. These plots were selected from a larger network noted in 2021, in order to represent the entire range of trunk disease incidence, from very low to very high.

Each plot was measured for vigor (using the proxy number of shoots*average shoot cross-sectional area) and described in terms of the main associated variables: water status (apex growth status indicator during the summer and, in 2022, δC13), nitrogen supply (Ntester measurement at veraison), soil maintenance (ground cover rating), estimation of yield per vine and vegetative biomass by visual ratings given at harvest time. Leaf symptoms of grapevine trunk diseases were also noted at harvest, distinguishing between symptoms typical of esca or Botryosphaeria dieback (slow forms with characteristic "tiger-stripes" and severe forms with varying degrees of leaf fall) and apoplexy (sudden and uniform drying out of a vine or half-vine within a few days).

From a viticultural point of view, these networks are typical of AOP viticulture in southeastern France: Grenache N, mainly trained as Royat double cordon on 110R and 140Ru rootstocks, at a density of around 4,000 vines/ha, on clay-limestone soils, more or less sandy or stony and of varying depths. However, there are differences between the networks: the Bouches-du-Rhône network focuses on rosé wines, with half of the selected plots irrigated and fully tilled on rows and inter-rows. The other two networks, in Vaucluse and Gard, are dedicated to red wine production, with little or no irrigation, and the Gard network showing mainly grass-covered inter-rows.

In terms of the vintages monitored, 2022 was a hot and dry year, especially in the spring, while 2021 and 2023 were wetter, particularly in the spring.

## Foliar expression of grapevine trunk diseases: a link to vine vigor

The results show that within each network, vine vigor and several of its associated variables (production, vegetation, nitrogen, etc.) are significantly correlated with the expression of grapevine trunk diseases (Table 1, correlations in green).

The shape of the relationship with vigor is shown in Figure 1. This relationship can be described as follows:

➡Plots showing the lowest vigor show few or no symptoms; for example, the lowest vigor in this study is found on long-established, heavily ground covered plots with little foliage biomass and low production.

➡As vigor increases, symptoms tend to increase; the strongest expressions are generally found in plots with high vigor;

➡However, plots with high vigor may also show few symptoms, reflecting the existence of other factors necessary for expression.

**TABLE 1.** Correlations between the incidence of grapevine trunk diseases (GTD) and the various viticultural indicators monitored in the study.

| | | 2022 | | | | | | | | 2023 | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Pearson correlation coefficient significant at the 10% threshold | | BHestimated | AUC_ICapex | δC13 | Ntest | Ground vegetation cover rating | yield rating | vegetation rating | vigor | BHestimated | AUC_ICapex | Ntester | grass rating | yield rating | vegetation rating | force |
| %GTD incidence in 2022 | Bouches-du-Rhône network | - | - | - | 0.61 | - | - | 0.40 | 0.57 | - | - | - | - | 0.32 | - | 0.37 |
| | Gard network | - | - | - | - | - | - | 0.41 | 0.62 | - | - | - | -0.40 | | - | 0.44 |
| | Vaucluse Network | - | - | - | - | - | 0.43 | 0.34 | - | - | - | - | - | 0.46 | - | 0.53 |
| %GTD incidence in 2023 | Bouches-du-Rhône network | - | - | - | 0.42 | - | - | 0.33 | 0.51 | - | - | - | - | 0.31 | - | 0.35 |
| | Gard network | - | -0.40 | 0.55 | - | - | - | - | - | - | - | - | - | - | - | 0.34 |
| | Vaucluse Network | - | - | - | - | - | 0.44 | - | 0.49 | - | - | - | - | 0.45 | - | 0.58 |

BHestimé=estimated water balance (in mm), AUC_ICapex=area under the curve of the evolution of the apex growth status indicator. Pearson correlations, significance threshold at p = 0.10 ("-"= non-significant correlation). Correlations in green reflect relationships with vigor (and its associated variables). Correlations in red reflect those with water indicators from the previous year.


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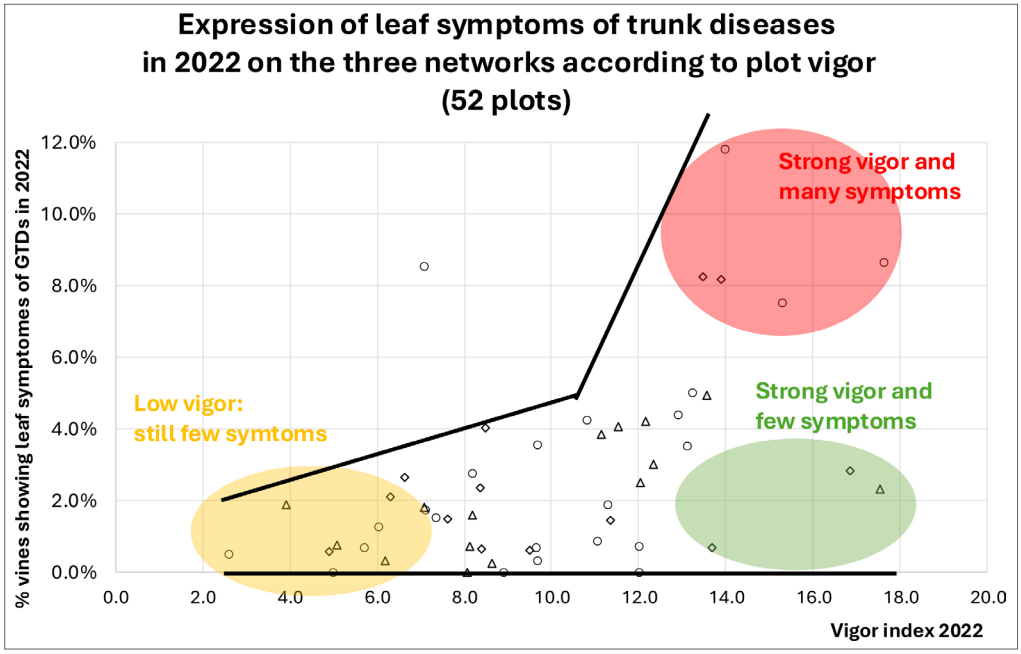



**FIGURE 1.** Relationship between vigor index and expression of wood disease symptoms in 2022.

Vigor index = number of shoots*cross-sectional area of a shoot (mm²) /100- 1 point = 1 plot.

## From vigor to vine physiology

In 5 of the 6 network*vintage situations studied, the vigor index is indeed the indicator that correlates best with the level of trunk disease symptoms. However, in the case of the Gard network in 2023, the best correlation is with the 2022 water supply indicators (area under the ICapex index curve and δC13 index, see Table 1, correlations in red), even though the vigor of the year is also influential. Indicators reflecting water stress in 2022 are associated with more leaf symptoms of grapevine trunk diseases in 2023, with the strongest expressions observed on plots that had both the highest water stress in 2022 and good vigor in 2023, particularly in the spring.

This result, which deserves to be confirmed in more situations, broadens the scope of investigation, suggesting that vigor is probably not the only agronomic variable to be considered. If we add to this the fact that other studies linking esca and vine physiology report correlations with other variables such as soil water availability, for example, or grass cover and nitrogen fertilization[2] [3] [4], it is very tempting to take a broader view of the involvement of vine physiology and to search for the relevant functional variable in the expression of wood disease symptoms.

The Gard network has the most grass cover (permanent natural grass cover) and received significantly less rainfall in 2022 than the other two. The hypothesis that can be made is that the plots that experienced greater water stress in 2022 had less reserve replenishment, which, coupled with good spring vigor, resulted in a carbon deficit in the spring of 2023. This imbalance may have been unfavorable to the synthesis of secondary defense compounds, leading to increased symptoms. **This raises the hypothesis that the vine's carbon and nitrogen balance during the spring and summer period may have played a role.** Confirming these observations on other grape varieties and regions and verifying this hypothesis are the two areas we would now like to focus our research on.

## Interannual fluctuation in expression: predominant water variables

The main objective of this study was to explain the variability in leaf expression of grapevine trunk diseases between plots within the small geographical area of each network, as described in the previous sections of this article. However, observing the expression

**TABLE 2.** Average per network and per year of the various descriptors of grapevine trunk diseases (total incidence of grapevine trunk diseases + apoplexy, proportion of apoplexy in total symptoms and maintenance of symptoms relative to 2021) on the one hand, and the various agronomic indicators monitored on the other. Right-hand column: Kruskal-Wallis test (p=0.05) performed on the years and networks together (6 groups). Values in bold = significantly different groups. Lines with significant differences: automatic coloring of cells according to a red and blue gradient proportional to the distance between the maximum (=red), minimum (=blue) and median (=white) of the group.

| | | Average value per network*year | | | | | | Kruskal-Wallis test between the six groups (year*network) |
|---|---|---|---|---|---|---|---|---|
| | **Network** | **Bouches-du-Rhône network** | | **Gard network** | | **Vaucluse network** | | |
| | **Year** | **2022** | **2023** | **2022** | **2023** | **2022** | **2023** | |
| **Trunk disease variables** | Average incidence | 2.87 | 3.60 | **1.91** | **4.73** | 2.41 | 3.22% | * |
| | %Apop/total | 23 | 24 | **41** | **22** | 32 | 27% | * |
| | Maintained/2021* | -1 | **36** | **-69** | -10 | -32 | -13 | *** |
| **Agronomic variables** | BHestimated (mm) | -240.8 | **-161.2** | **-469.8** | -333.3 | -315.3 | **-164.4** | *** |
| | AUC_ICapex | **22.5** | **29.6** | **16.8** | **35.7** | **20.0** | **29.0** | *** |
| | Ntester | **512** | **531** | **364** | **472** | **470** | **482** | *** |
| | Ground cover rating | **0.73** | **1.06** | **1.91** | **2.02** | **1.24** | **1.53** | *** |
| | Yield rating | 3.28 | 2.95 | 2.65 | 2.96 | 3.03 | 2.98 | ns |
| | Vegetation rating | 3.28 | 3.19 | 2.81 | 3.12 | 3.05 | 3.07 | ns |
| | Vigor indicator | 10.0 | 10.6 | 9.7 | 8.8 | 10.0 | 10.4 | ns |

* Maintenance/2021 = (incidence (2022 or 2023) - incidence 2021) / incidence 2021.

of grapevine trunk diseases between the three years of study and the three networks also led to some interesting additional insights that we would like to share here (results not included in the article by Claverie *et al.*, 2025[1]).

When we now look at the average behavior of the networks (Table 2), the Gard network shows a significantly lower expression of grapevine trunk diseases in 2022 than in 2021 (-69%), which is not the case in the Bouches-du-Rhône network (-1%), and only as a trend (-32%, not significant) in the Vaucluse network. At the same time, the Gard network also shows more apoplexy (41%) in total symptoms. The year 2023 returns to levels close to those of 2021.

However, if we look at what distinguishes the Gard network and the year 2022 in terms of the various indicators monitored (Table 2, "agronomic variables"), we see that the latter, as mentioned above, is the most grassy of the three and received less rainfall in 2022, leading to a deficit of the estimated water balance, in line with the apex growth indicator. This is also reflected in the poorer nitrogen supply levels in this network.

The vigor index, on the other hand, does not differ on average between the three networks or between the two years, suggesting that it is not the vigor of the year that explains the average level of expression in this network in 2022. Water variables seem to be the most relevant.

These elements tend to suggest the involvement of water variables in the decline in expression on the Gard network in 2022. The level of water stress in 2022 on this network may have inhibited the expression of leaf symptoms, based on the same principle as the results of greenhouse experiments conducted by Bortolami *et al.* (2021)[5], which cited lower transpiration as a possible cause of the decline in the expression of leaf symptoms.

Finally, it can be noted that the proportion of apoplexy in total symptoms, which peaked in the Gard network in 2022, follows the decline in symptom expression and limiting water conditions. This is consistent with the literature on the link between apoplexy and drought[6] [7] and the hypothesis of a possible disruption in xylem sap flow under conditions of intense evaporative demand.

## Conclusion

This work has validated the link between vine vigor and the expression of trunk disease symptoms, showing reduced incidence in situations of low vigor and increased risk in situations of high vigor. It also suggests the involvement of water stress in the previous year, which encourages us to broaden the scope of investigation to the physiology of the vine more generally. The involvement of the vine's carbon and nitrogen balance, through source-sink relationships, particularly in the spring, and their impact on the synthesis of defense compounds, is the hypothesis we would now like to test.

From a practical point of view, these results open up interesting avenues for vigorous plots showing a high level of symptoms, and encourage us to initiate vigor management trials using various levers such as vegetation ground cover, but also nitrogen fertilization, while obviously keeping an eye on the context and production plot objectives.

Finally, additional observations to the main result allow us to hypothesize that the annual incidence of esca in a plot could be the result of a two-step process: the determination of a potential level (depending on the vine's C balance) and the actual expression of this potential, which in turn depends on summer weather conditions.

It would be interesting to verify these hypotheses and to repeat this work in other regions, years, and grape varieties in order to confirm these results beyond the Mediterranean region and the Grenache N grape cultivar. ■


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