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Consequences of the 2021 season on yields from vineyards in Wallonia

Louis Delval[1], François Jonard[1,2]
Mathieu Javaux[1,3]

1 Earth and life Institute, UCLouvain, Belgium
2 Earth Observation and Ecosystem Modelling Laboratory, ULiège, Belgium
3 Agrosphere, Forschungszentrum Jülich GmbH, Germany

The vineyard area in Wallonia (Belgium – Figure 1.a) has grown steadily in recent years, from 150 ha (for 36 properties) in 2018 to 300 ha (for 64 properties) by the end of 2021. However, in 2021, Walloon vineyards were severely affected by downy mildew (*Plasmopara viticola*) due to exceptionally wet and cool weather conditions. This study shows that quantitative losses varied between vineyards. This variability is mainly explained by choice of grape variety, viticultural practices and disease management.

Weather conditions in Wallonia were exceptionally wet and cool in 2021

The weather conditions in Wallonia in 2018, 2019 and 2020 favored high yields, rising to more than 10,000 hl (45 hl.ha^{-1}) in 2020. According to the Huglin index[1] (HI), the 2018 growing season was temperate (1800 < HI < 2100) over most of Wallonia, while the 2019 and 2020 seasons were rather cool (1500 < HI < 1800) (Figure 1.b). These same three years saw a negative rainfall anomaly ($\Delta P = P - P_{normal}$) compared with the norm for the whole region, reaching a cumulative deficit of -300 mm between 1 April and 30 September. The 2021 growing season was very cool (HI ≤ 1500) everywhere in Wallonia and exceptionally wet, with a positive ΔP of up to +300 mm (Figure 1.c). As in vineyards in the south of France in 2018, long rainfall sequences allowed the spread of downy mildew. Between 1 April and 30 September 2021 (183 days), it rained on between 70 and 106 days (Figure 1.d), with an average of 3 to 6 consecutive days of precipitation for each rainfall event (Figure 1.e).

Quantitative losses due to downy mildew are variable within the Walloon vineyard

To understand the consequences of downy mildew on yields of Walloon wine in 2021, a survey was conducted among Walloon winegrowers, generating 21 responses, i.e. one-third of producers in the region. In particular, they were asked to provide information regarding quantitative losses due to downy mildew compared with an optimal yield.
10 vineyards lost less than 50% of their optimal yield, while 11 lost more than half (Figure 2). Despite exceptionally wet and cool weather conditions throughout Wallonia, yield losses varied between vineyards.

Several parameters can explain the variability in losses

To understand these differences in terms of quantitative losses, the survey also asked winegrowers for information on six parameters:
. grape varieties (traditional or hybrid),
. rootstocks (*V.riparia* x *V.rupestris*, *V.berlandieri* x *V.riparia* or *V.vinifera* x *V.berlandieri*),
. viticultural methods (conventional, integrated or organic),
. disease management (**proactive** relying only on fungicide sprays in the event of appearance of disease, or **preventive** by applying prophylactic measures in addition to fungicide sprays),
. textural class of the soil (silty soil or other types of soil),
. vine age (more or less than 10 years).

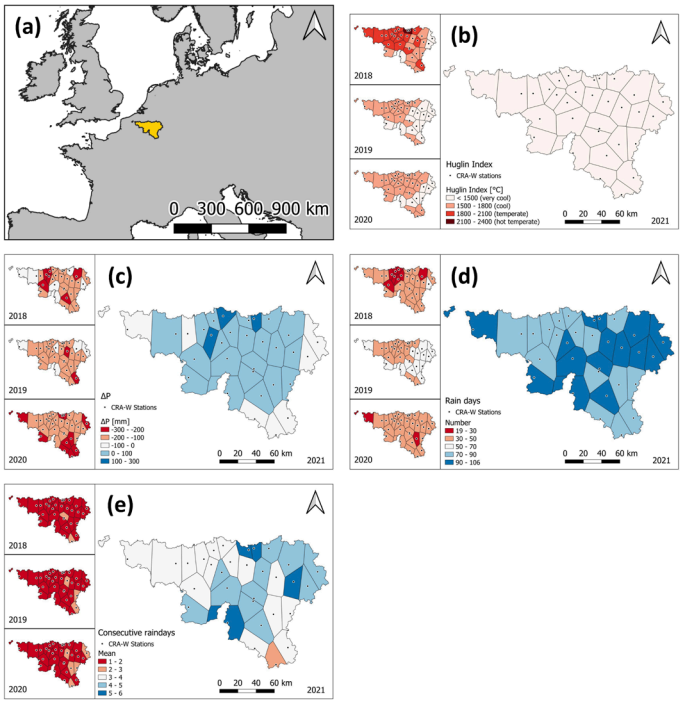

FIGURE 1. (a) Location of Wallonia (in yellow) in Western Europe. (b) Huglin indices, (c) rainfall anomalies, (d) number of rain days and (e) average number of consecutive rain days in Wallonia in 2018, 2019, 2020 and 2021, between 1 April and 30 September (CRA-W/Agromet.be).

Analysis of variance (ANOVA) was first applied to each of the six parameters tested, to find out whether samples of the same parameter followed the same normal distribution. ANOVA returned significant p-values of 0.010, 0.003, and 0.038 for the effects of grape variety, disease management, and viticultural practices, respectively. The effects of rootstock, soil type and vine age, with p-values of 0.473, 0.299 and 0.186 respectively, did not explain the variability of yield losses within Walloon vineyards in 2021 (Table 1). Regarding rootstocks, Boso *et al.* (2007)[2] have already shown that the rootstock type, or whether or not the vine is grafted, has no influence on resistance to infection with downy mildew[2]. The relative uniformity of

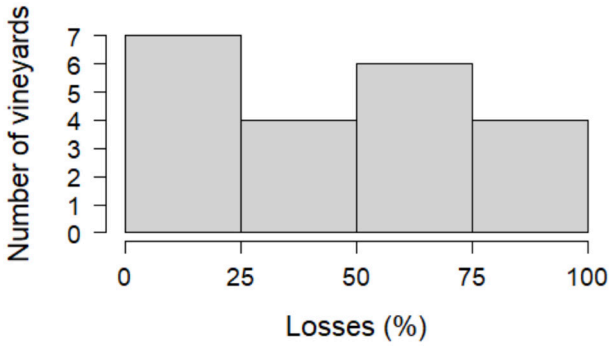

FIGURE 2. Distribution of yield losses for 21 Walloon vineyards in 2021.

soil types in Walloon vineyards (17 silty, 2 sandy-silt, 1 sandy and 1 clay) means that this parameter cannot explain the differences in quantitative losses. Finally, given that downy mildew affects leaves and fruit, i.e. annual organs, the age of the vine has no influence on infection with downy mildew. This effect is distinct from the risk of infection, which decreases as the leaf ages[3].

TABLE 1. P-values for ANOVA applied to 6 parameters tested to understand the differences in yield losses (ns = not significant; * = significant at the 95 % confidence level; ** = significant at the 99 % confidence level).

	Rootstock	Viticultural method	Disease management	Grape varieties	Soil type	Age
P-value (ANOVA)	0.473 ns	0.038 *	0.003 **	0.010 *	0.299 ns	0.186 ns

Vineyards with hybrid grape varieties experienced significantly lower losses than vineyards with traditional varieties, with median losses of 10 % and 66 % respectively (Figure 3.a). This result confirms several studies showing the good potential of hybrid grape varieties for resistance to downy mildew, compared with traditional grape varieties[4, 5].

Winegrowers who took a preventive approach to disease management significantly reduced quantitative losses compared with the others (median losses of 10 % and 68 % respectively) (Figure 3.b). The weather conditions in 2021 required regular application of effective sprays to counter the spread of the disease. However, in many cases, a lack of technical and material resources made it impossible to meet these requirements. Moreover, the length of the rain events (3 to 6 days on average – Figure 1.e) did not allow for timely treatment to prevent the spread and incubation of downy mildew, which under these conditions can take place in 4 days[6]. Proactive winegrowers suffered more damage than those applying a preventive approach who, through their management during the season, were able to limit the need for treatment against the disease. Preventive strategies notably included leaf removal and shoot pruning to promote good aeration and rapid drying of the vine and to limit the spread of downy mildew. By regular mowing between rows, winegrowers could also prevent a significant accumulation of moisture at the foot of the vine, which slows down the growth of the parasite.

The statistical tests on viticultural methods show a significant difference in losses between organic and conventional vineyards (median losses of 68 % and 10 % respectively). However, there is no significant difference between integrated production (median loss of 40 %) and organic production, or between integrated and conventional production (Figure 3.c). In 2013, Bunea *et al.* already showed lower levels of downy mildew attack on 5 grape varieties farmed conventionally compared with the same varieties farmed organically[7].

A combination of parameters explains the variability of losses

Multiple correspondence analysis (MCA) of losses and categories of explanatory parameters (Figure 3.d) shows that the "conventional" and "preventive" categories show the best correlation with MCA dimension 1 (0.81 and 0.72 respectively) and therefore have a similar profile in their response. The "hybrid" category shows the best correlation with MCA dimension 3 (0.37). The analysis also shows that the losses are located in categories that are the opposite of "conventional", "preventive" and "hybrid", indicating that a combination of these three categories helps to explain the limitation of quantitative losses due to downy mildew in Walloon vineyards in 2021.

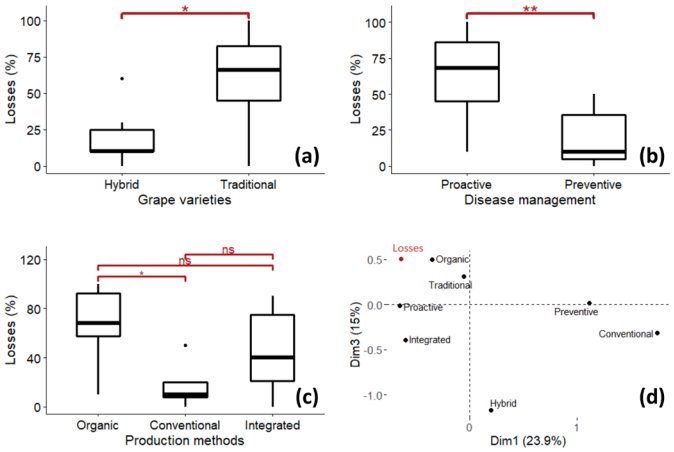

FIGURE 3. Distribution of quantitative losses according to (a) grape variety, (b) disease management and (c) production methods in Walloon vineyards (ns = not significant; * = significant at the 95 % confidence level; ** = significant at the 99 % confidence level). (d) Multiple Correspondence Analysis (MCA) of losses and categories of explanatory parameters.

In conclusion, downy mildew was one of the main causes of crop loss in the Walloon vineyard in 2021, due to exceptionally cool and wet weather conditions. Producers with hybrid grape varieties, using conventional viticulture and preventive disease management, limited the quantitative losses due to downy mildew. Downy mildew requires special attention from winegrowers, who must manage the disease from the choice of grape variety through to risk management in the field. ■

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