GRAPEVINE VIRUSES AND WINEMAKING POTENTIAL

A CASE STUDY ON ITALIAN PINOT GRIGIO

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ABSTRACT

Grapevine viruses represent a critical challenge in viticultural districts, significantly undermining vine productivity and longevity. This study investigated the impact of GPGV, GFLV, GLRaV-1, and GLRaV-3 mixed infections on Pinot gris quality attributes in an alpine vineyard. Molecular analysis (ELISA, RT-PCR) highlighted widespread co-infections, likely originating from infected nursery material and vectors. Comparisons between asymptomatic and infected plants revealed severe discrepancies, including an 80% reduction in average bunch weight. Chemical analyses confirmed a profound metabolic shift, characterized by elevated total acidity and depressed sugar levels. The GPGV/GFLV/GLRaV-3 combination proved most detrimental, whereas the GPGV/GFLV/GLRaV-1 co-infection behaved more similarly to the asymptomatic control. Experimental alcoholic fermentation revealed significant differences in maximum fermentation rates (*Vmax*) and sugar conversion yields under specific viral combinations. Severely affected trials resulted in wines with lower alcohol content and high acidity, confirming that specific co-infections compromise enological suitability. Furthermore, GC-MS/MS analysis verified distinct volatile profiles between infected and asymptomatic samples, driven by alterations in key precursors such as sugars and nitrogenous compounds (YAN). In conclusion, grapevine viruses severely impair vineyard lifespan, productivity, and grape quality, debunking the myth of qualitative improvement via viral infection. While targeted must restoration strategies can mitigate these negative enological effects, strict sanitary control of nursery material remains the primary line of defense.

EXPERIMENTAL PLAN

Four viral associations
Detected in different vines of the vineyard

Vineyard *cv.* Pinot gris. Location: Adige river, Alps, northern Italy. Virus detection performed by ELISA and RT-PCR screening

Harvest

FT-IR and enzymatic analyses were performed on approximately 30 bunches per vine for each viral association.

Experimental alcoholic fermentation

5 liters volume, laboratory conditions. 25°C, ADY, no grape must correction. Monitoring of CO_2 evolution.

Wine characterization

FT-IR and enzymatic analyses for oenological parameters. GC-MS/MS for profile of volatile compounds

RESULTS

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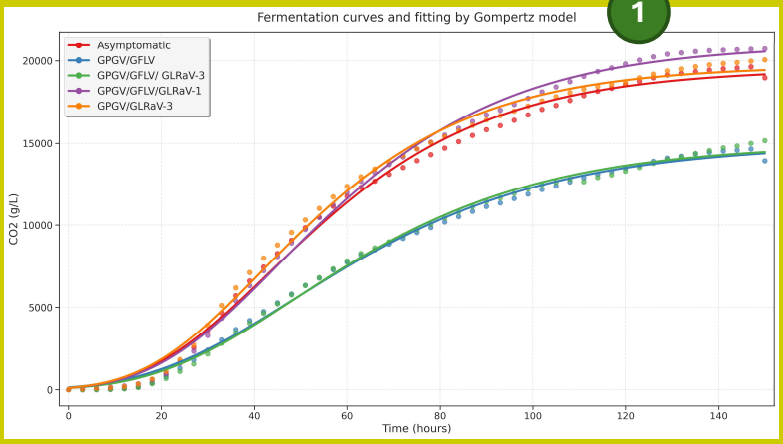

Viral co-infection grape composition	Sugars (Brix degree)	pH	Total acidity (g/L)	Tartaric acid (g/L)	Malic acid (g/L)	YAN (mg/L)	Average bunch weight ± DS (g)
GPGV/GFLV/GLRV-1	22.71^{a}	3.41^{a}	6.40^{b}	6.60^{b}	2.67^{b}	153.50^{a}	25.50 ± 26.55
GPGV/GFLV	17.11^{b}	3.29^{b}	5.85^{b}	6.88^{b}	2.37^{a}	107.50^{b}	36.15 ± 25.20
GPGV/GFLV/GLRaV-3	16.18^{b}	3.26^{b}	5.55^{b}	7.43^{c}	2.80^{b}	114.50^{b}	37.70 ± 21.85
GPGV/GLRaV-3	22.65^{a}	3.49^{a}	6.15^{b}	6.65^{b}	2.75^{b}	133.00^{c}	75.20 ± 25.00
Asymptomatic	21.17^{a}	3.39^{a}	5.10^{a}	6.09^{a}	2.42^{a}	139.00^{c}	198.05 ± 35.95

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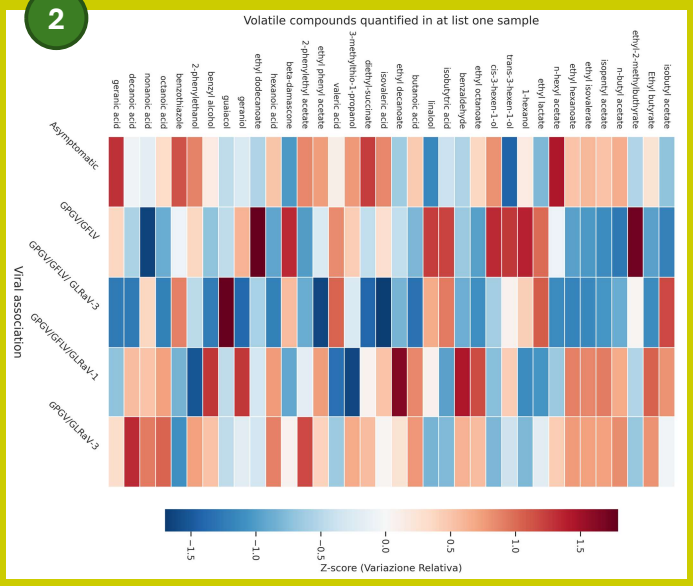

As shown in Figure 1, the co-infections GPGV/GFLV/GLRaV-3 and GPGV/GFLV significantly reduced both the maximum fermentation rate (V_{max}) and total CO_2 production. GPGV/GLRaV-3 and GPGV/GLFV/GLRaV-1 exhibited fermentation performances comparable to those of the asymptomatic control. These kinetic data are highly consistent with the chemical composition of the initial grape musts, particularly regarding sugar accumulation and Yeast Assimilable Nitrogen (YAN) content. Furthermore, the drastic reduction in average bunch weight across all infected plants highlights a severe physiological impairment. This suggests that the observed enological differences are driven by virus-induced metabolic stress and delayed ripening.

The heatmap of volatile aromas (Figure 2) clearly shows that the different combinations of viral infections quantitatively alter the aromatic profile compared to the asymptomatic samples. These variation are linked to the composition of grape musts. Musts characterized by severely depressed sugars and YAN concentrations (e.g., GPGV/GFLV and GPGV/GFLV/GLRaV-3) resulted in weaker fermentative metabolisms, closely correlating with a reduction in fermentative esters. Dominant compounds, such as 2-phenylethanol and hexanoic acid, show strong fluctuations depending on the plant's health status and nitrogen availability.

CONCLUSIONS Viral infections not only compromise plant fitness and longevity but also induce profound alterations in the grape bunches, which can ultimately translate into poor enological suitability. Therefore, appropriate optimization and restoration strategies for must composition will need to be implemented to minimize the severe impact of viral infections on the winemaking process.