15TH INTERNATIONAL TERROIR CONGRESS

MENDOZA, ARGENTINA

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CATENA INSTITUTE of Wine

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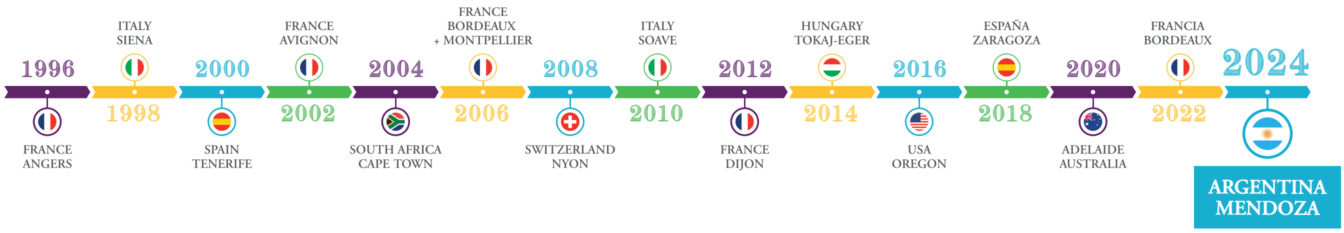

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Soil

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Managing soil health to support the resilience and future success of the wine industry: lessons learned in California

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ABSTRACT

The importance of soil health is increasingly understood by winegrape producers, not only because of its role of producing high-quality grapes, but also because of its importance in the mitigation and adaptation to climate change. Nonetheless, there are still uncertainties on what management practices better support soil health and industry competitiveness under increasing incidence of extreme temperature and precipitation events. We present the results of several projects that have evaluated the efficacy of practices like cover cropping, no-till, compost application and sheep grazing on soil C sequestration, greenhouse gas emissions, soil physical properties and water cycling. We looked closely at the potential trade-offs of the practices through changes in grape yield and quality or economic outcomes. This was accomplished by the following: (I) controlled experiments that evaluated the practices in the short-term (<3 years) and (II) surveys of commercial vineyards to evaluate long-term effects (>3 years). Findings reveal the general feasibility of using soil health building practices to produce high quality grapes in California, although the effects are variable depending on the time since adoption, stacking of practices, and inherent soil properties. No-till, sheep grazing or compost, result in short-term changes in C cycling that may lead to future increases in soil C stocks, particularly in soils with higher clay content. These practices combined with minimal greenhouse gas emissions, shows potential for climate change mitigation, although this

may be significantly constrained by soil properties and the stacking of different management practices. Co-benefits include improvemed soil structural stability, increased porosity, and reduced erosion, which enhance climate change adaptation. Economic analysis shows that initial costs of managing soil health can be offset by long-term benefits, including reductions in operational expenses, enhanced soil health, and additional revenue streams from sheep grazing, if grape yields and price premiums can be maintained.

Introduction:

The wine industry is facing the challenge of adapting to climate change while meeting the sustainability and quality standards of the consumers worldwide. In California, the frequency of potentially damaging extreme heat events (temperature above 35°C) has increased significantly over the last decade (OEHHA, 2022). Climate models project a continued increase in extreme heat days for the region that will change grape phenology with more rapid development for winegrape, including earlier budburst, flowering, veraison, and maturation across the main red and white varieties and viticultural regions in California (Parker et al., 2024). Climate change drives changes in precipitation patterns, which have become more extreme, alternating between prolonged droughts and floods (Swain et al., 2018). Heat and water stress have strong negative consequences for crop yield and quality (Parker et al., 2020). As it becomes clear that a paradigm shift is needed for agricultural production, many growers are adopting nature-based strategies to mitigate and adapt to climate change.

As essential components of the water and carbon cycles, soils play a key role in climate change adaptation and mitigation. Globally, soils store more carbon than the atmosphere and the biosphere combined through the capture of atmospheric CO_2 into plant biomass and the subsequent recycling of this by soil organisms. A portion of the biomass C may be retained in the soil, with a permanence time period that can be more than 100 years. This leads to reduced CO_2 emissions, offering a pathway for climate change mitigation (Paustian et al., 2016). Soil structure, which determines the balance between macro and micropores, regulates water infiltration, percolation and retention. The concept of soil health, which emphasizes the capacity of soils to support these and other essential life supporting functions, has generated great enthusiasm among stakeholders, including agricultural producers, consumers, and policymakers. This enthusiasm has led to legislative initiatives worldwide to support soil health. Grape growers in California consider soil health as essential for vineyard resilience, an appreciation that stems from the recognition of the importance of soils as essential components of the terroir (Gonzalez-Maldonado et al., 2024; Lazcano et al., 2020). Nevertheless, while the concept of terroir is focused on inherent soil properties such as texture, depth and mineralogy, the concept of soil health has a strong focus on more dynamic soil properties that can be changed through management such as soil organic matter or biodiversity (Burns et al., 2016). In recent interviews, grape growers in Napa (California, USA) expressed that the lack of practical information on environmental, agronomic and economic outcomes of soil health practices for wine grape production systems are the main barriers for adoption of healthy soil management practices (Gonzalez-Maldonado et al., 2024). Because soil organic matter contains approximately 60% carbon, healthy soil practices usually focus on increasing and stabilizing soil organic matter (SOM) content. To achieve this, soil health practices 1) maintain plant cover, 2) sustain organic matter inputs,

3) decrease soil physical disturbances and 4) diversify cropping systems. These principles hinge on the soil microbial communities involved in the breakdown and stabilization of carbon inputs (Nunes et al., 2020). The use of cover crops meets most of the principles of healthy soil management, and it is therefore increasingly adopted by grape growers. Nonetheless the benefits of cover crops depend largely on how they are managed, whether they are terminated through tillage, mowing or animal grazing, and whether they are fertilized with compost. Here we present an overview of different studies carried out in California, where we investigated the effects of healthy soil practices, either alone or stacked, on soil health and the capacity to mitigate and adapt to climate change. Furthermore, we addressed important knowledge gaps such as the impacts of these practices on grape quality and vineyard economic performance.

Materials and methods:
To evaluate the efficacy of soil health management practices (cover cropping, organic amendments, no till and sheep grazing) to support the future success of the winegrape industry, we followed a double pronged approach: (I) controlled and replicated experiments at commercial vineyards where we applied the soil health management practices for 3 years (Lazcano et al. 2022a; Lazcano et al. 2022b); and (II) landscape surveys where we sampled commercial vineyards that have been using the soil health management practices for more than 3 years (Moonilall et al. in preparation; Decock et al., in preparation; Gonzalez Maldonado et al. in preparation).

Controlled experiment: The experiment was conducted in a *Vitis vinifera* L. cv. Syrah biodynamic commercial vineyard located at Tablas Creek Winery (California, USA) for 3 years (2018-2020). The area has a Mediterranean climate with annual average temperature of 15.3°C and average annual rainfall of 364 mm, distributed mostly between November and March. The soil is classified as Fine-loamy, mixed, thermic Calcic Pachic Haploxeroll, with 30% clay. Since vine establishment in 1992, soil management included cover cropping consisting of 15% *Avena sativa,* 30% *Vicia faba,* 20% *Vicia americana,* 10% *Vicia sativa,* and 25% *Pisium sativum* subsp. dundale. We assessed the effects of grazing with or without tillage on soil C, N and greenhouse gas emissions. The experimental design consisted of alternating till and no-till blocks (blocks included four rows of vines and three tractor rows), overlaid with grazing enclosures, resulting in 7.3 m x 9.7 m plots. The combination of tillage and grazing resulted in a total of four treatments: (I) Grazed + tilled, (II) Grazed + non-tilled, (III) non-grazed + tilled, and (IV) non-grazed + non-tilled. Each treatment was replicated four times, and plots were arranged in the field following a split-plot design with tillage as the main blocks, and grazing as the factors within the blocks, resulting in a total of 16 experimental plots. Within each plot, two different functional locations, receiving different soil management, were considered: (1) the soil under the vine canopy (vine row), which receives water and is not tilled, and (2) the soil in the tractor rows (tractor row), which does not receive water through irrigation and is tilled, depending on the plot. We collected soil samples at the two functional locations within the central vine and tractor rows of each plot and at 0-15 and 15-30 cm depth. Soils were stored in plastic bags at 4°C and transported to the lab prior to analysis. Grape yields were determined in mid-September 2019 and 2020, when berries reached approximately 23 Brix. To determine yields we randomly selected 10 vines from the central rows of each plot and measured the total number and fresh weight of all grape clusters for each vine. A subsample of 200 berries was collected in each plot for further chemical analysis. For grape phenolic analysis, berries were homogenized to measure berry anthocyanins and total phenolics following a previously published protocol (Iland, 2013). We measured the fluxes of GHG (N_2O, CO_2 and CH_4) from the experimental plots before and after each of the main management events including grazing, mowing, tillage, irrigation and harvest as well as after the first precipitation in fall, to measure baseline and event-related fluxes. Fluxes were sampled using static chambers and gases were analyzed using a gas chromatograph.

Landscape survey: This study was carried out in Napa Valley (California USA). Between 2022 and 2023, we recruited growers that have been using healthy soil management practices (cover cropping, organic amendments, no till and sheep grazing) for at least three years. Once these growers were identified, we looked for neighboring vineyard plots with the same soil type but without any healthy soil management practices (controls). A total of three pairs (six vineyards) were identified. In summer 2023 and 2024 we collected samples from the tractor rows at 5 random locations within each vineyard at 0-10, 10-20, 20-30, and 30-40 cm depths. Furthermore, we performed measurements of water infiltration in the field using mini disk infiltrometers. Soil samples were transported to the lab and stored at 4°C prior to analysis of soil physical properties and water holding capacity.

Analysis of soil samples: Total C and N were determined in dried and ground soil and plant samples via dry combustion using a Vario Max CNS elemental analyzer (Elementar, Langenselbold, Hesse, Germany). Active C, also known as permanganate oxidizable carbon (POXC), was determined in air-dried soil samples following (Weil et al., 2003). Particle size analysis was measured using the hydrometer method to quantify the fractional composition of sand, silt, and clay with each sample (Gee & Or, 2018). A textural classification was assigned using the percentages from each soil separate and the USDA soil textural triangle. Soil bulk density ($Mg\ m^{-3}$) was assessed using the intact core method (Grossman and Reinsch, 2002). Water stable aggregates (WSA; %) were determined using the wet sieving method outlined in Nimmo and Perkins (2002). Erodibility potential (K-Factor from the Universal Soil Loss Equation) was assessed across the surface 0-10 cm depth from each of the five tractor rows per vineyard block using the K-factor from the Universal Soil Loss Equation (Wischmeier and Smith, 1978).

Cost-benefit analysis: We used four experimental vineyards established in Sonoma (California, USA) under three different varieties: Pinot noir, Chardonnay and Cabernet Sauvignon (Herrera et al. 2024 under review). We collected data on the average cost of inputs needed for establishing and operating vineyards under soil health management (with cover crops, compost and sheep grazing) as compared to conventional management (only cover crops). The data set contained more than 50 variables including trellis cost and maintenance, large equipment, inputs of agrochemicals, labor, insurance and other indirect cost. Furthermore, we estimated the potential revenue under conventional and regenerative scenarios. The economic viability of the management practices was assessed over a 30-year vineyard lifespan, reflecting the typical period of consistent productivity before decline. We conducted a sensitivity analysis to evaluate the stability of our model's results to assumptions on yield and price.

Results and discussion:
Effects of soil health management on soil C sequestration and GHG emissions

Results of the controlled experiment showed that after 3 years of implementation, no-till increased stratification in the distribution of active soil C (POXC), further accentuating the already existing difference between top and subsoil. Nonetheless, no-till did not increase total soil C stocks. No-till also slightly reduced the daily efflux of CO_2 from the soil during the rainy season, showing that these plots were less prone to lose C than tilled plots and may show higher soil C stocks in the future if the practices are maintained. Sheep grazing of the cover crop did not produce an increase in available soil N and C but resulted in sporadic and localized peaks in daily N_2O, CH_4 and CO_2 emissions. Nevertheless, emissions were not significantly larger than non-grazed soils when extrapolated to the cumulative emissions of the whole season. The combination of tillage and grazing increased N_2O emissions from the soil under the vine potentially due to increased nitrification rates.

Effects of soil health management on crop yield and quality

In the controlled field experiment, we did not observe any significant differences in yields between vines grown in soils subjected to grazing or tillage in the three years of practice implementation. We did not observe any differences in the number of clusters produced per vine either between years, tillage or grazing treatments. Grape chemical composition changed between years with higher anthocyanin and phenolic content in 2020 as compared to 2019. Nevertheless, grazing and tillage did not have any effects on these two parameters of grape chemical composition.

Effects of soil health management on soil structure and water cycling

Results of the landscape survey with the three paired sites, showed that the use of soil health management practices (cover crops, no till, compost and sheep grazing) for more than three years significantly influenced soil physical properties and water cycling as compared to conventional management (tillage, no compost and no sheep grazing). Soil health practices reduced soil bulk density, especially in the subsoil, and increased the proportion of stable aggregates. Specifically, soil health management increased the proportion of large macroaggregates, suggesting an increase in soil porosity. Water infiltration rates measured in situ were higher in the conventional than in the vineyards under soil health management. This is likely due to the short-term increase in soil porosity and surface roughness by recent tillage in conventionally managed soils (Novara et al., 2011). Nonetheless, soils that were tilled, also had a larger erodibility and higher proportion of disaggregated particles of sand, silt, and clay that suggest a higher likelihood of soil erosion during intense rainstorms (Belmonte et al., 2018). Total soil C was significantly higher in soils under healthy soil practices although this depended on the site and soil depth analyzed. We further evaluated the role of soil texture on soil C, and we observed a significant effect of clay content on soil C. Generally, soils with higher clay content and with soil health practices accumulated more soil C than soils with lower clay and higher sand content.

Effects of soil health management on costs and benefits of winegrape production

Our findings revealed that, while soil health management practices (cover crops, no till, compost and sheep grazing) entail higher initial costs, they offer meaningful long-term benefits, including reductions in operational expenses, enhanced soil health, and additional revenue streams from sheep grazing integration. However, financial success after adopting soil health practices largely depends on maintaining grape yields and securing price premiums. Given the variability in yield impacts across different grape varieties and vineyard conditions, site-specific assessments are crucial during the transition to soil health management practices.

Conclusion:

Through controlled experiments and landscape surveys we observed that the use of no-till, compost and sheep grazing of cover crops are valid strategies for supporting vineyard soil health. These practices lead to short term changes in C and N cycling without increasing greenhouse gas emissions or negative effects for winegrape quality and yield. The benefits of the practices become more obvious when they are maintained in the long term, with changes in soil structural stability and porosity that can increase the capacity of the vineyards to adapt to climate extremes. While an initial investment is needed for growers that want to adopt soil health practices, reductions in operational expenses (synthetic fertilizer, tractor passes), enhanced soil health, and additional revenue streams from sheep grazing integration may bring long-term economic benefits. This highlights the need for continued commitment to managing soil health.

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NOV 18, 2024 | 11 AM | SCIENTIFIC SESSION: **SOIL I - SCIENTIFIC ORAL**

Cover crops under the vines promote the biological soil health: a case of study in Navarra

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Keywords: **functional diversity, microbial diversity, soil health, Tempranillo, *Trifolium fragiferum,* water content.**

ABSTRACT

Soil management through cover crops at the interrow is a common practice in viticulture, since it improves the characteristics of the soil and grapevines. It has been shown that the cover crops can influence the cycle of nutrients, promote infiltration, decrease erosion, and enhance the soil microbiota biodiversity improving the grapevine fitness. However, the area under the vines tends to be left bare by applying herbicides or tillage to avoid competition with the crop, particularly in warm regions. The use of cover crops under the vines might be a plausible alternative to the use of herbicides or cultivation, improving grapevine quality and soil characteristics. Within this context, the aim of this research was to study how various soil management practices beneath vineyards (such as herbicide use, tillage, or employing a cover crop like *Trifolium fragiferum*) affect grapevine growth and the microbial communities thriving below the ground.

According to our results, the use of *T. fragiferum* as the cover crop under the vine had a little impact on grapevine agronomy and physiology. In spite of the enhanced vegetative development of *T. fragiferum,* results did not show differences in grapevine water status and berry quality parameters. Rather on the contrary, the use of the cover crop under the vine modified soil microbial communities enhancing their diversity and their activity, also changing the rates of native mycorrhization of grapevine roots. The lack of effect on cover crops under the vines on the grapevine performance might indicate a minimum competition between the grapevine and the studied cover crops. Overall, the cur-

rent study showed that, under-vine cover crops, particularly *Trifolium fragiferum*, offer a sustainable alternative to herbicides, positively impacting soil health without affecting grapevine performance.

Introduction:

Vineyards are currently cultivated on every continent accounting globally for >7.4 million hectares, 107.5 million tons of berry production and 262 million hectoliters of wine in 2020. Given the unquestionable economic importance of this crop and the current environmental conditions, there is an increasing interest in studying the soil-plant continuum interactions in order to achieve resilient viticulture production systems. In this sense, the traditional concept of 'terroir', used to refer to different factors such as the cultivated variety, the location of the vineyard (climate and soil), and the vineyard management link the agricultural product (quality, taste, style) to its origin (Van Leeuwen and Seguin, 2006), it is being replaced by the term 'microbial terroir'; given that vineyard microbiomes shaped by vineyard geography and management strongly affect grape and wine quality (Torres et al., 2021, Zarraonaindia et al., 2015).

On the other hand, the vineyard soil has been kept for decades absolutely free of adventitious vegetation, in order to avoid competition between the crop and weeds for water and nutritional resources given the location of vineyards on poor and dry lands. This elimination of weeds was initially carried out by mechanical tillage of the soil, although since the appearance of herbicides, chemical control has become increasingly important, with the combined use of mechanical and chemical tillage remaining as the most common management strategy. However, these soil management practices, when applied recurrently, have a detrimental impact on the environment and on the crop.

In the last years, a large body of research highlights the benefits that cover crops provide to both soil characteristics and biodiversity and grapevine agronomic performance (Abad et al. 2021a, 2021b). Thus, the use of cover crops increases soil organic carbon (SOC), improves water infiltration and aggregate stability, and reduces erosion and greenhouse gases emission to the atmosphere. Furthermore, there is an increase in biodiversity, both in soil and the vineyard (Abad et al., 2021a). Regarding the cover crops effects on grapevine physiology, water use, yield and berry size and composition, previous studies have highlighted their strong dependence on the soil and climate characteristics, the period of the year in which the covers are active, the type of covers, and the characteristics of the grapevine rootstocks, and need therefore to be analysed site-specifically. Contrarily, the research on the impact of cover crops on vineyard performance has been frequently limited to the use of cover crops in the vineyard lanes, keeping the soil beneath the vines free of vegetation through the use of herbicide or mechanical tillage, barely exploring the great agronomic potential and environmental benefits this could convey. Thus, vineyard soil management through cover crops may favour the presence of beneficial microbial communities in vineyards. Within beneficial microbial species, arbuscular mycorrhizal fungi (AMF) stand out given that they may establish symbiosis with grapevine roots and provide several ecosystemic benefits (Trouvelot et al., 2015; Torres et al., 2018).

The use of cover crops under the vines might be a plausible alternative to the use of herbicides or cultivation, improving grapevine quality and soil characteristics, including beneficial microbial spectra. Furthermore, Capó-Bauçà et al. (2019) reported that after 7 years of using a permanent cover crop, an increment of the

AMF spores was observed. This was translated into a higher microbial activity and functional diversity (Capó-Bauçà et al., 2019). Therefore, the aim of this research was to study the implications of different strategies of soil management under the vines (herbicide, cultivation or cover crop) on grapevine growth, water status, yield and berry composition and belowground microbial communities.

Materials and methods:

Experimental design and plant material

Experiment was conducted in a commercial vineyard belonging to Otazu Winery (Otazu, Navarra, Spain) planted with Tempranillo variety grafted onto 110 Richter. Vines were irrigated three times during the season to fit maximal evapotranspiration. Experimental design consisted in 3 treatments, a cover crop (*Trifolium fragiferum* L.) sown under the vines, herbicide (glyphosate at 36%) and mechanical tillage that acted as an untreated control. Experiment was set in January of 2023 and monitored during that season.

Plant measurements and berry quality

Grapevine vegetative growth was estimated by the total cross-sectional area after measuring the shoot areas with a digital caliper (CD67-S15PP, Mitutoyo Corp., Japan). Water status was monitored during the season by measuring the stem water potential (Ψ_S) of a fully expanded leaf exposed to sun and without signs of disease and/or damage per treatment-replicate. Leaves were then covered before measurements with a reflective foil-lined zip-top plastic bag to suppress transpiration. The Ψ_S was measured with a Scholander pressure chamber (P3000, Soil Moisture Corp., Santa Barbara, CA, USA).

Berry ripening and quality parameters were monitored during both seasons by collecting berries from 10 vines within each treatment-replicate. Berry technical quality was measured on a 100 berry sample. Total Soluble Solid content (TSS, °Brix) was measured using a high precision temperature compensating refractometer, pH was determined by a digital pHmeter, Total acidity (TA, g tartaric acid·L^{-1}) was determined by titration and malic acid (g malic acid L^{-1}) by enzymatic analysis. Another 200 berry sample was used to monitor the phenolic maturity following the Cromoenos™ method.

Soil microbial communities

After the first season, soil microbial diversity and physiological profiles were measured using the Biolog Ecoplates™ and FF-Microplates™ from soil samples collected at 25 cm close to grapevine roots. The presence of AMF in grapevines roots was monitored after collecting grapevine fine roots, staining and observation under the microscope following the methodology described in Torres et al. (2016).

Statistical analysis

Statistical analyses were conducted with R studio version 3.6.1 (RStudio Team, 2020). Grapevine growth, water status and microbial diversity parameters were analysed by using the one-way analysis of variance (ANOVA) after assessing the normality of the data. Means ± standard errors (SE) were calculated and, when the F ratio was significant ($P \leq 0.05$), a Duncan posthoc test was executed using "agricolae" 1.2–8 R package.

Results and discussion:

Under-vine cover crop impact on grapevine performance

A little effect of the use of cover crop was observed on the vegetative growth of grapevines during the first growing season. Previous researchers have shown that grapevine vegetative growth is impaired by cover crops compared to conventional tillage (Wolff et al., 2018). However, in accordance with recent studies, cover crops might have no effect on it (Abad et al., 2020; Zumkeller et al., 2022). Water potential analyses (data not shown) carried out in grapevines did not detect differences on leaf water status associated to the different soil management strategies. Accordingly, several studies have reported no effect of cover crops on grapevines water status given that these effects are largely driven by the climatic conditions and irrigation regime at a given site (Zumkeller et al., 2023).

Regarding yield and berry quality, our results showed an increased cluster mass in the vines with *T. fragiferum* as cover crop (Table 1). However, this did not lead to changes on berry quality (data not shown). Similarly, Abad et al. (2020) found no effect on berry quality after three seasons with *T. fragiferum* used as a cover crop.

Soil management with cover crops affected microbes associated with grapevine roots and vineyard soil

Heterotrophic microorganisms in vineyard soils were increased after using herbicide (Figure 1a). In this sense, there is a growing body of research that demonstrates that glyphosate (the herbicide used in this study and initially considered safe) has profound effects on ecosystem functions via altered microbial communities (Ruuskanen et al., 2023). Regarding soil fungal communities, different soil management did not affect filamentous fungi (Figure 1b). However, AMF associated with grapevine roots strongly responded to soil managements as shows in Figure 2. Thus, grapevines grown with *T. fragiferum* showed higher rates of native mycorrhizal colonization, in agreement with previous studies that showed that the establishment of cover crops promotes the proliferation of natural mycorrhizal communities (Nogales et al., 2021; Capó-Bauçà et al., 2019).

Conclusion:

Although current research presents data from a single-year experiment, and should therefore be treated with due caution, our results are promising, demonstrating that the use of cover crops for soil management under the vines seems to have benefits compared to the conventional soil management with herbicide and tilling to control the growth of adventitious vegetation. In this sense, this study remark that using *Trifolium fragiferum* as an under-vine cover crop had minimal impact on grapevine growth and quality but significantly improved soil health by enhancing microbial diversity and activity. This suggests under-vine cover crops could offer a sustainable alternative to herbicides without compromising grapevine performance, indicating potential for coexistence in vineyard ecosystems.

Table 1. Yield components of Tempranillo/110R vines subjected to different soil management (T. fragiferum as cover crop, herbicide and mechanical control) in the harvest of 2023.

	Cluster #	Yield (Kg)	Cluster mass (g)
Mechanical tillage	9.66	1.18	125.15 ab
Herbicide	8.72	1.02	118.12 b
T. fragiferum	8.56	1.15	134.34 a

Values are means ± SE. Within each column different letters represent significant difference according to the Duncan posthoc test.

Figure 1. Average well colour development (AWCD) for heterotrophic microorganisms (a) and filamentous fungi (b), measured with Ecoplates™ and FF-Microplates™ from Biologs, respectively.

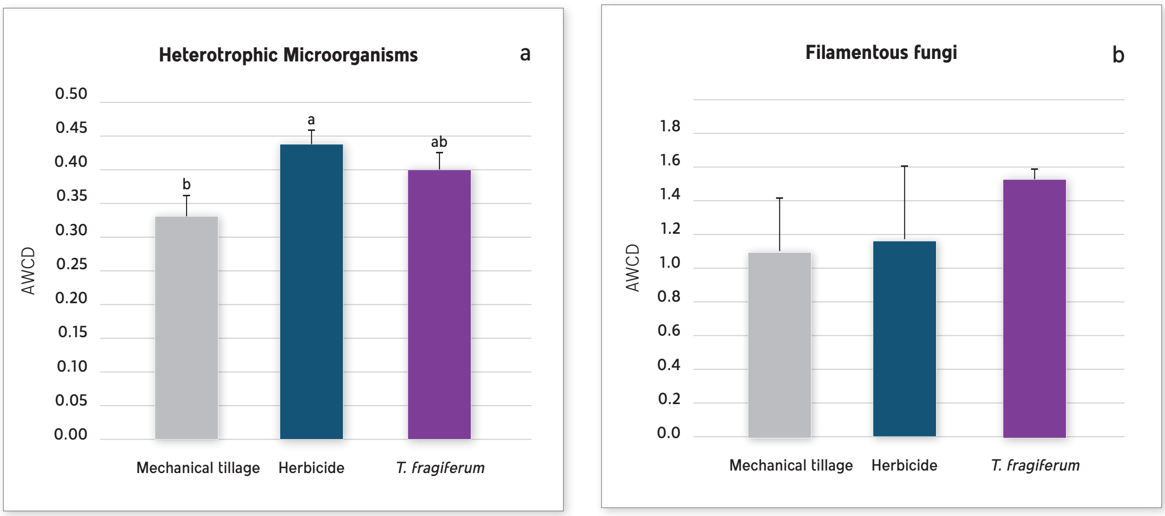
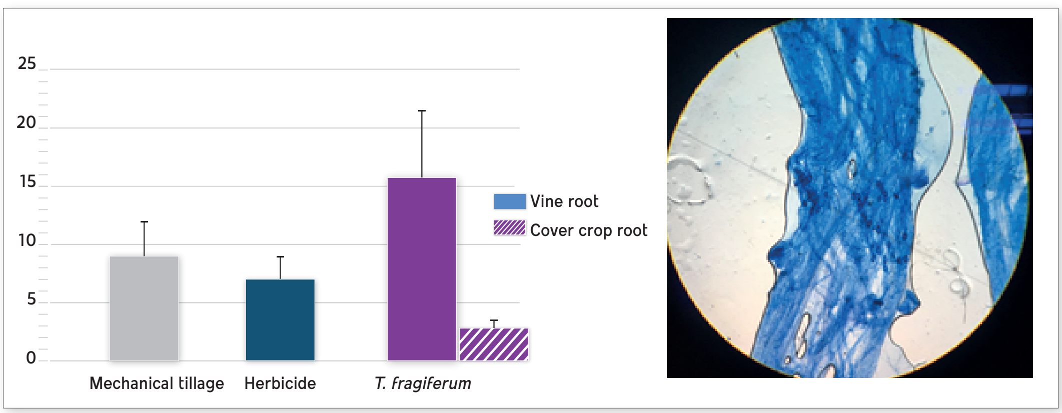


Figure 2. Arbuscular mycorrhizal colonization rates of grapevine and cover crop roots (a) and mycorrhizal fungal structures observed under the microscope (40X, b).



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NOV 18, 2024 | 11.15 AM | SCIENTIFIC SESSION: **SOIL I - FLASH ORAL**

Soil microbiome composition in a Malbec biodynamic vineyard

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Keywords: **microbiome, mycorrhiza, soil sodicity, soil nutrition.**

ABSTRACT

The composition of soil microbiota is crucial for the optimal functioning of biogeochemical cycles, which enhances soil organic matter and benefits crop nutrition in the long term. Based on this premise, we explored the microbiome through a metabarcoding strategy and the physicochemical characterisation of soil in a biodynamically (B) managed vineyard. The aim was to understand its microbiome composition, especially in comparison to a nearby conventionally (C) managed vineyard. Both vineyards were located proximate in Ugarteche region from Luján de Cuyo, Mendoza (Argentina). Amplicon sequence variants (ASVs) were generated as proxies for taxa through the use of Dada2. The structure of the bacterial community in the B vineyard revealed that the most abundant bacterial phyla were Proteobacteria (30%), Actinobacteria (21%), Acidobacteriota (19%), and Gemmatimonadota (5.6%), with all remaining phyla comprising less than 5% of the community. In terms of mycobiota composition, the dominant fungal phyla were Basidiomycota (42%), Mortierellomycota (23%), Ascomycota (20%), and Glomeromycota (8.9%). Comparing B to C, the primary distinguishing factor was a higher Fungal-to-Bacteria Ratio (calculated as the number of fungal ASVs to bacterial ASVs), mainly driven by greater fungal diversity in B. In contrast, the biodynamic soil showed a greater abundance of mycorrhizal fungi (Glomus and Septoglomus) and a lower representation of plant pathogens, distinguishing it from the conventional soil management. Based on the extensive literature on the importance of mycorrhizae in grapevine nutrition and wine quality, the results suggests that biodynamic management could enhance vineyard resilience which seems promising in future climate challenging scenarios for the wine production.

NOV 18, 2024 | 11.20 AM | SCIENTIFIC SESSION: **SOIL I - FLASH ORAL**

Soil health biological indicators of Argentinean vineyards

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Keywords: **enzyme activity, phosphatases, β-glucosidase, β-glucose-amidase, spontaneous vegetation.**

ABSTRACT

Sustainable Viticulture pursue keeping alive and healthy soils. Soil health is understood as the capacity of a soil to sustain the productivity, diversity and environmental services of terrestrial ecosystems. There are different types of indicators to assess soil health which are grouped into three main categories: chemical, physical and biological. Meanwhile chemical and physical indicators have been worldwide studied in many wine regions, biological indicators have emerged in the last decade as important cues to understand the vineyard soil health.

Micro-organisms diversity contribute to the definition of a terroir, as well as their activity which is essential to achieve healthy soils. Cover crops are used in organic management given the multiple ecosystem services they provided. Micro-organism's enzymes activity is sensitive to environmental changes and to soil management practices such us cover crops. To our knowledge, reports of soil enzymatic activity of Argentinean vineyard and even less under different soil management are still missing. The objective of this study was to characterise the soil enzymatic activity of different biogeochemical nutrient cycles (C, P y N) by means of measuring β-glucosidase, alkaline and acid phosphatases and β-glucose-amidase in three wine regions of Argentina. We measured the activity of above-mentioned soil enzymes before flowering (peak grapevine root growth) in two vineyards of the main (Valle de Uco y Agrelo, Mendoza) and the most southern (Sarmiento, Chubut) wine regions of Argentina. At least five soil samples were taken on each location inside the vineyards (cultivated) and surrounded (not cultivated). In Agrelo, we additionally sampled (cultivated) soil with different soil management (spontaneous, seeded vs. bare soil).

The enzymatic activity of the four soil enzymes varied between locations. However, some of them showed differences between different cover crops management. These biological indicators contributed to shed light into the characterization of the soil health and Argentinean terroirs.

NOV 18, 2024 | 11.25 AM | SCIENTIFIC SESSION: **SOIL I - FLASH ORAL**

Exploring the fungal diversity of vineyards soils and its local variability in Argentina

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Keywords: **eDNA, ecology, climate, mycorrhizae, practices.**

ABSTRACT

In a context of climate change, searching for sustainable practices becomes a priority for viticulturists. Favouring soil diversity and functionality could increase vineyard resilience, but also questions the observation of the response of this below ground biodiversity. Interestingly, the development of soil metabarcoding from environmental DNA has revolutionised the access to soil biodiversity, and the discovery of microbial terroirs has opened the use of such techniques to wineries. We explored the soil fungal diversity in Uco Valley and Luján de Cuyo regions from 2021 to 2023, in 15 vineyard plots engaged in transition to organic practices from 7 vineyards of Terrazas de los Andes and Chandon Argentina. Soil environmental DNA was extracted and the fungal ITS1 was sequenced using MiSeq, analyzed using OBITOOLs. Soil physico-chemical analyses were produced each year from the same soil samples. We hypothesised an increase in fungal diversity linked with the regenerative organic transition and aimed at detecting the soil core microbiome stable over years, and possibly indicating terroir associated fungi. Our results reveal 2008 Operational Taxonomic Unit (OTU) of fungi detected over the two first years, and the high prevalence of mycorrhizal fungi, representing 70% of sequences. The local diversity did increase between the two first years of sampling, following our hypothesis, and communities changed significantly between years, suggesting that only few fungi could contribute to a stable terroir effect over year. Indeed, only one to 21 fungal OTUs could be considered as associated to a given vineyard. Soil fungal communities changes were mainly correlated with the C/N ratio and its increase over the two first years, as well as by the local climatic and elevation gradient. We illustrate the interest of exploring the local soil biodiversity, its potential functions and interactions with practices and the local environmental context.

NOV 18, 2024 | 11.30 AM | SCIENTIFIC SESSION: SOIL I - FLASH ORAL

Cover crops management in high-altitude regenerative vineyards under arid conditions

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Keywords: **regenerative agriculture, cover crops, plant water status, plant nutrition, soil health.**

ABSTRACT

Vegetal cover, minimal soil disturbance and the non-use of synthetic agrochemicals promote soil health and are the main premises of soil management practices in regenerative agriculture. Cover crops have numerous advantages, but their management in high altitude irrigated vineyards in arid areas is challenging, and even more so in the context of climate change.

We evaluated three cover crops managements strategies in a drip-irrigated Malbec vineyard placed in Gualtallary (1650 m asl) Mendoza, Argentina. The treatments were: spontaneous vegetation (S, inter-row and under-row), mowing (M, inter-row and under-row) and cover crops (CC, inter-row mowed and under-row seeded with mixture of winter annual species of *Trifolium alexadrinum* and *Brassica rubra*). In CC the spontaneous vegetation under the vine was mechanically removed before sowing.

CC showed a better plant water and nutrient status than S and M, as the SPAD index and stem water potential were higher throughout the growing season. Pruning weight of CC was greater than in M and S. The CC and M treatments had similar but higher yield per plant than S. However, M reduced cluster weight and number of berries per cluster compared to CC. On the other hand, S reduced cluster and berry weight and number of berries per cluster compared to M and CC. The grape composition, measured by anthocyanin and total polyphenol concentration, total soluble solids, titratable acidity and pH, was similar between treatments.

From these results it can be concluded that S and M were not the most suitable cover crop treatments. However, CC under vines improve plant water and nutrient status and yield in drip-irrigated vineyards under arid conditions, at least after the first year of evaluation. These results may be explained by the atmospheric N fixation made by the clover and the lower summer water consumption of the sown winter annual species.

NOV 18, 2024 | 13.30 PM | SCIENTIFIC SESSION: **SOIL II - CONFERENCE**

Defining the identity of argentinian wine regions: a comprehensive characterization study

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Keywords: **characterization, wine regions, soil, climate, landscape.**

ABSTRACT

The characterization of Argentinian wine regions highlights the unique attributes of production and contributes to a better understanding by leveraging their differentiation, strengthening their singular identity, and supporting the commercial message to consumers. These attributes are also emphasized by arguing, strengthening and improving the position of Argentinian wines in the markets, increasing world wine sales.

Since 2020, the Argentinian Wine Corporation (COVIAR) signed an agreement with the Inter-American Development Bank (IDB). This agreement financed the first stage of environmental characterization studies in the provinces of Mendoza, San Juan, and the Calchaquí Valleys. In 2022, additional contributions were made by the Federal Investment Council (CFI) and the governments of La Rioja, Jujuy, Catamarca, Córdoba, Entre Ríos, La Pampa, Buenos Aires, Río Negro, Neuquén, and Chubut.

Soil, geology, geomorphology, climate and landscape of 59 valleys and wine-growing oases in Argentina were studied. The characterization of the different wine valleys and oases of the country was carried out simultaneously using the same methodology. The aim of this work was to characterize the Argentinian wine regions to identify their differentiating attributes. Thereby contributing to capitalizing on their uniqueness, strengthening the identity of the products, supporting the commercial messaging to consumers, and enhancing the position of Argentinian wines in international markets. Moreover, the characterization of regions is a relevant input for managers in the formulation of wine policies and implement recovery efforts in areas with production limitations.

Introduction:

Location-based differentiation strategies are crucial for competitiveness in viticulture, especially in 'Old World' countries. For instance, these countries have traditionally focused their marketing on territorial and geographical origin. Furthermore, in recent years, this trend has also expanded to new wine-producing regions.

The consensus on value generated in situ, along with territorial and cultural diversity, was highlighted during regional workshops across different productive oases. These workshops contributed to the collective development of the Strategic Vitivinicultural Plan 2030. According to its vision, "Argentine viticulture will be a sustainable and diverse activity, enabling the growth of its stakeholders, adapting to consumer trends, and creating new market opportunities." Its mission further states that "Argentine viticulture delivers competitive products, valued for their consistent quality, recognized for their origin, territorial and cultural diversity, and broad socio-productive framework.

Thus, the soil, geology, geomorphology, climate and landscape of 59 valleys and wine-growing oases in Argentina were studied. Since 2020, the Argentinian Wine Corporation (COVIAR) has signed an agreement with the Inter-American Development Bank (IDB), which financed the first stage of the environmental characterization studies in the provinces of Mendoza, San Juan and the Calchaquí Valleys. Since 2022, contributions from the Federal Investment Council (CFI), and the governments of La Rioja, Jujuy, Catamarca, Córdoba, Entre Ríos, La Pampa, Buenos Aires, Río Negro, Neuquén and Chubut have been added.

Characterizing the country's wine valleys, using a consistent methodology, is a valuable tool for defining the identity of wines based on where the grapes are grown. It helps producers and wineries communicate their products more effectively, supported by scientific and technological data. This is a key strategy for differentiating our products from major global competitors. At the regional level, this characterization offers important insights for policymakers. It helps structure the sector and guide recovery efforts in areas with production challenges.

Therefore, the aim of this study was to characterize the Argentinian wine regions in order to identify their differentiating attributes. This characterization helps to capitalize the uniqueness of these regions and strengthens the identity of the products. Additionally, it supports the commercial messaging directed towards consumers, while enhancing the market positioning of Argentinian wines. Moreover, the characterization of regions is a relevant input for managers in the formulation of wine policies and implement recovery efforts in areas with production limitations.

Materials and methods:

To characterize wine regions, we studied the physical and environmental characteristics of key valleys where grapevines are grown.

In the climate study, both single-criteria variables, such as temperature and precipitation, and bioclimatic indices -including the Huglin heliothermal index, Winkler effective thermal integral, night coolness index, thermal regime during the vine ripening period, and the frequency of extreme absolute temperatures exceeding 35°C and falling below 0°C- were considered. Thus, the climate of each wine region was examined through the analysis of existing data from the National Meteorological Service.

A geological and geomorphological study for each wine region was also carried out. The study encompasses a description of the geological framework. It also features a chronostratigraphic and lithostratigraphic table, as well as a geological map. Additionally, a geomorphological assessment is provided, detailing the identification of geoforms and the analysis of the terrain characteristics to elucidate the topography of the region.

The soil analysis was conducted in accordance with the scale recommended by the International Organisation of Vine and Wine (OIV) as outlined in Resolution OIV-VITI 423-2012. At the locations determined by the sampling methodology, test pits were excavated to facilitate the morphological characterization of the soil profiles. Soil samples were collected from each horizon or layer and sent to laboratories for physicochemical analysis (Bouyoucos, pH, electrical conductivity, cations, CIC, RAS, carbonates, gypsum N and organic matter). In addition, a photographic record of the modal profiles and associated landscapes was made. Through digital soil mapping, thematic maps of soil variables were created. Furthermore, through spatial analysis and the use of statistical techniques, Homogeneous Edaphoclimatic Zones (HZ) were defined.

Finally, an evaluation of the potential of landscapes was conducted. The methodology was based on the "Landscape Character Assessment: Guidance for England and Scotland," developed by the Countryside Commission and Scottish Natural Heritage (Swanwick, 2002).

A digital platform was developed to host the generated information. It is accessible via the website of the Argentinian Vitivinicultural Observatory (https://observatoriova.com/) and the Strategic Vitivinicultural Plan 2030 (https://pevi2030.com.ar/).

Results and Conclusion:

This study produced two thousand layers of maps detailing the soils, climate, and landscapes of the studied regions. To achieve this, the same methodology was used to standardize and systematize the information.

Argentine currently has soil, climate, geological, geomorphological, and landscape data for 59 wine-producing valleys. This data is now hosted in a public digital repository (https://observatoriova.com/), accessible to producers, entrepreneurs, managers, and the general public. In addition, technical reports can be accessed.

This study allows Argentina to stand out, thus placing the country at the forefront in this field.

NOV 18, 2024 | 14 PM | SCIENTIFIC SESSION: **SOIL II - SCIENTIFIC ORAL**

A methodological protocol for delimitation of viticultural zones to terroir description

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Keywords: **spatial clustering, edaphoclimatic zones, variable importance, argentinian vineyards.**

ABSTRACT

Understanding soil and climatic spatial variation within a viticultural region is essential to describe wine terroir, which requires the delineation of homogeneous edaphoclimatic zones. Climate, landscape, and soil are usually measured at multiple sites within a region. This paper presents an approach to promoting the integration of different statistical tools for identifying edaphoclimatic homogeneous. The methodological proposal involves re-scaling of spatial data, as well as multivariate analysis (spatial climatic clustering and nested soil clustering) as well as the identification of main zoning drivers to describe terroirs. The data analyses are applied in a logical sequence (protocol). Statistical topics for further improvement are noted. The protocol has been illustrated using climatic, geomorphometric, and soil data layers from the oasis of Mendoza river, Argentine. However, it may be applied to other viticultural regions using georeferenced data. The R scripts to run the protocol are available upon request.

Introduction:
Viticulture is one of the most widespread horticultural crops globally (Mukherjee and Mishra, 2021). In Argentina, vines are situated in several mesoclimatic, landscapes y soils areas. Currently, sustainable viticulture requires mainly the use of large volumes of soil and climatic data to improve management. Recently, a study, coordinated by the Argentine Viticultural Corporation (COVIAR), has provided foundational information on the soils and climate of the wine Argentinian regions, promoting a better understanding of spatial differences. Even though terroir is a concept used in viticulture to explain variations in wine quality and wine style, it refers to an area and thus possesses a geographical dimension (Van Leeuwen et al., 2010) that makes sense to spatial classification. In this work, we propose a methodological approach for the zoning of a viticultural region to delimitate edaphoclimatic areas.

Input data are in different spatial scales, but after properly rescaling they are used to obtain synthetic variables that reflect the joint variability of the data layers. The methodology uses such synthetic variables (principal components) for clustering sites within a region to identify homogeneous zones in a multivariate sense (edaphoclimatic zones). The data to create the principal components are obtained from soil and geomorphological maps derived from digital elevation models (DEM), as well as bioclimatic digital maps. Because of soil data show greater spatial variability than DEM and climatic data, we proposed a hierarchical spatial clustering handling first geomorphological and climatic data for a first zoning and then a nested soil-based zoning. The k-means or fuzzy k-means clustering methods (Fridgen et al., 2004), are usually employed to perform clustering analysis of data points at several scales (Moral et al., 2016). However, these cluster algorithms do not take into account the georeference of the data. They were not developed for spatial data. A high zone fragmentation was observed when the clustering techniques ignore the spatial nature of the data (Frogbrook & Oliver, 2007; Ping & Dobermann, 2003). Cordoba et al. (2013) developed a method (KM-sPC) based on the use of spatial principal component analysis (sPCA) and the posterior application of the fuzzy k-means algorithm using the spatial principal components as input to avoid fragmentation. The KM-sPC algorithm was used for site classification at a fine scale in precision agriculture. Later such algorithm was successfully applied at the regional scale (Giannini Kurina et al., 2018). More contiguous classes and reduced fragmentation of the delimited homogeneous zones were obtained by incorporating spatial information.

The interpretation of variable coefficients at each spatial principal component provides insight into the spatial correlation among input properties, but they are not enough to identify variables leading the posterior zoning. Consequently, it is essential to identify the main drivers of zoning. However, for high dimensional data (many variables or features associated with each data point), feature selection explaining classification is another computational task demanding efficient algorithms. The proposed protocol includes machine learning to identify important variables causing the edaphoclimatic zoning. Finally, the appropriateness of delineated zones needs to be evaluated. Evaluation requires determining if there are differences among the zones in terms of eco-physiological traits (Van Leeuwen et al., 2010) or other variables selected as validation traits. We use spatially correlated Mixed Linear Models (MLM) (West et al, 2022) for zone mean comparison. The objective of this work is to develop a protocol (logical sequence of analytic algorithms) to delimitate homogeneous zones in a viticultural region using climatic, geomorphometric, and soil spatial data.

Materials and methods:

Data

The limits of the study area (the northern oasis of the Mendoza River, Argentina) were delineated (Fig. 1), incorporating digital maps depicting geomorphometric variables (see Table 1) and soil variables (obtained from test pits conducted in vineyards (Vallone et al, 2023); also listed in Table 1), as well as maps of bioclimatic indices, also listed in Table 1. A processing of the SRTM elevation model was performed using SAGA software to define the morphometry of the study area. The aim was to calculate the geomorphometric indices. Data from the Soil Utility Map for the Mendoza River Basin (Vallone et al., 2007) and the geomorphometric study conducted by COVIAR were compiled. A total of 153 soil samples were collected for physicochemical characterization. Thematic maps of soil variables of interest were developed from digital soil mapping. Horizon harmonization was performed using the mass-preserving spline function (Malone et al., 2009) fitted to each individual soil profile, which requires more than one layer per profile. This generated two synthetic horizons: 0-50 cm and 50-100 cm. From these horizons, machine learning models were applied to predict soil properties using environmental covariates linked to soil-forming factors as predictor variables (FAO, 2022). This resulted in the generation of continuous maps of soil variables for the surveyed profiles.

The bioclimatic digital maps were obtained from a previous study characterizing the climatic conditions of wine regions in Argentina (Cavagnaro, 2023). Daily weather data from meteorological stations of the National Meteorological Service, homologated by the World Meteorological Organization, were used as official and reference stations. The datasets used covered a temporal extent of 41 years (1980 – 2020). Additionally, data from stations belonging to provincial meteorological networks and private companies were utilized. Maps were generated using geostatistical interpolation for bioclimatic variables. All available data layers were integrated into a grid format with a pixel size of 4 hectares (200 m × 200 m).

Analytical Protocol

Step 1. Delimitation of bioclimatic subzones: Spatial Principal Component Analysis of six bioclimatic variables and one morphometric variable (Digital Elevation Model, DEM) is used to generate synthetic variables summarizing information for each grid cell. Using components explaining 80% or more of total variability as input for fuzzy K-means cluster analysis, climatic subzones are delineated within the study area. The determination of the optimum number of climatic subzones followed the methodology proposed by Córdoba et al. (2013).

Step 2. Soil zoning within each climatic subzone: The KM-sPC algorithm was applied with soil and morphometric variables from pixels corresponding to each climatic subzone. This algorithm identified clusters of pixels with high multivariate similarity regarding soil. Because we are using Fuzzy K-means, each pixel is assigned to a specific cluster based on the maximum probability of belonging to a cluster. Additionally, spatial filters were used to identify sites comprising each homogeneous zone as proposed by Córdoba et al. (2013).

Step 3. Characterization of delimited homogeneous zones using two methods: A graphical approach (star plot where each ray represents a measured soil or bioclimate variable) and calculation of the importance of each variable for classifying a pixel into each edaphoclimatic zone. The importance of each variable is measured as the reduction in the classification capacity of a zone versus the rest of the zones. This classification was performed using the Random Forest machine learning algorithm (Breiman, 2001).

Step 4. Identification of typifying values for each zone: Base information for drafting "zone notes," i.e., text based on keywords characterizing a zone.

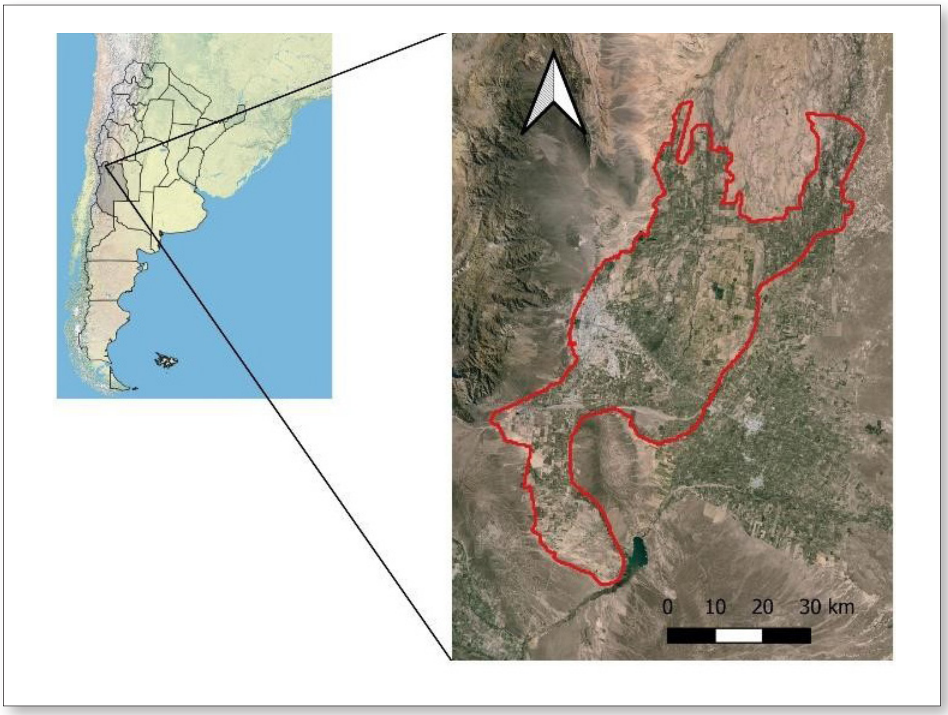

Figure 1. Study area, the northern oasis of the Mendoza River, Argentina.

Results and discussion:

In Fig. 2 we illustrate the multivariate zoning of the northern oasis of the Mendoza River and the symbolic objects (star plots) that characterize each of the zones. Subsequently, Table 1 presents the edaphoclimatic characterization of subzones 1_1, soil zone nested within bioclimate and geomorphology (DEM) zone 1. The climate zoning identifies two subzones: one on the left bank of the Mendoza River, between 600 to 900 meters above sea level (m.s.l.), encompassing the so-called transition and low zones of the river basin, including the peri-urban areas of the Capital, Godoy Cruz, and the departments of Guaymallén, part of Maipú, Las Heras, and Lavalle (Subzone 1). This subzone experiences the highest temperatures and lowest precipitation levels in the oasis. The other subzone comprises the river basin and right bank thereof, between 900 and 1100 m.s.l. (Subzone 2), characterized by cooler temperatures and higher rainfall. Topography plays a significant role in the variation of mesoclimate and edaphic characteristics within the Northern oasis. The edaphoclimatic zoning delineated 5 homogeneous zones (HZ) for this oasis.

In Table 1, it is observed that the characterization of zone 1_1 is primarily based on bioclimatic indices, placing it as a very warm viticultural climate zone with mild nights. Precipitation is the lowest in the oasis (140 mm annually). The duration of the active period exceeds 260 days. Morphometric indicators reveal gentle slopes throughout most of the zone; the terrain orientation, or aspect, generally faces northeast and towards the north in the final stretch of the river in the Lavalle sector. Factors indicative of the topography's effect on water erosion (convergence, surface flow accumulation, and slope length) suggest that the erosion risk decreases in this subzone of alluvial plains compared to the lower zone of the Mendoza River where no defined channels are observed. Signs of gully erosion are observed in the courses associated with the Mendoza River system, Leyes Stream, and Tulumaya Stream. The effective rooting depth of the soil is high on average, with texture ranging from loamy to sandy loam. Lower permeability values and more restricted natural drainage are observed. Soil salinity profiles reach the highest values in the oasis. There are greater accumulations of limestone and gypsum both superficially and in depth. The comparison of means for the variables with high importance according to the random forest algorithm indicated statistically significant differences between zone 1_1 and the rest of the zones.

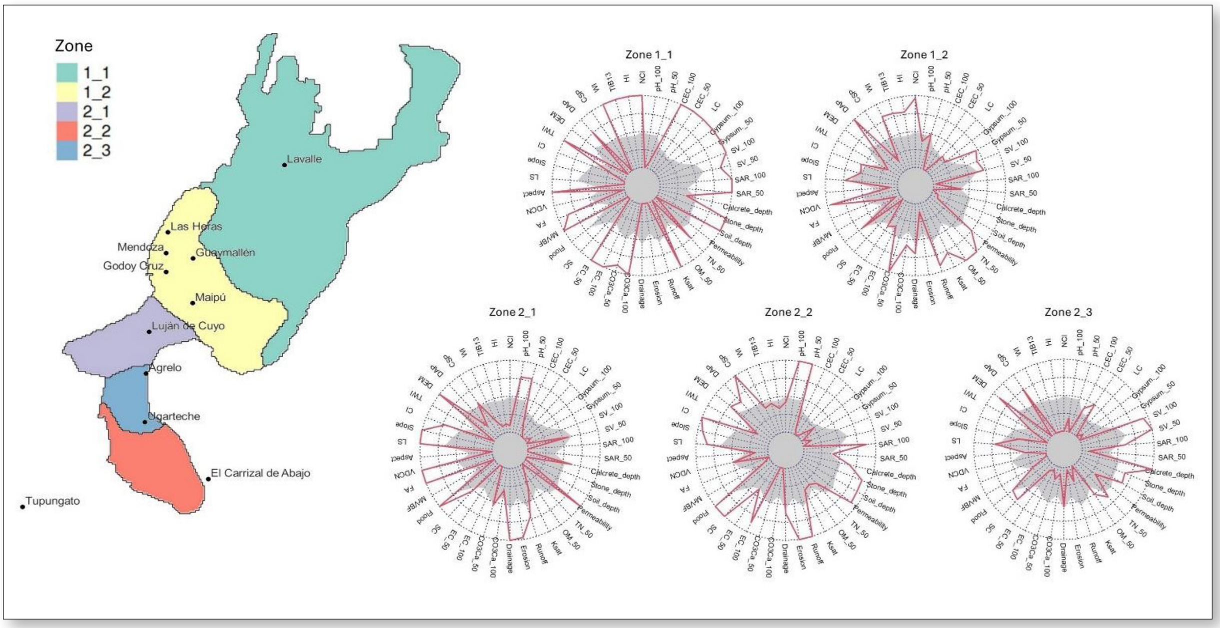

Figure 2. Edaphoclimatic zoning of the northern oasis of the Mendoza River, Argentina.

The variables listed clockwise from 12 o'clock are as follows: Cool Night Index (CNI), Soil pH (0-50 cm and 50-100 cm), Cation Exchange Capacity (CEC) (0-50 cm), Gypsum (0-50 cm and 50-100 cm), Sedimentation Volume (SV) (0-50 cm and 50-100 cm), Sodium Adsorption Ratio (SAR) (0-50 cm and 50-100 cm), Calcrete depth, Stone depth, Soil depth, Permeability, Total Nitrogen (TN) (0-50 cm), Organic Matter (OM) (0-50 cm), Saturated Hydraulic Conductivity (Ksat), Runoff, Erosion, Drainage, Calcium Carbonate (CO3Ca) (0-50 cm and 50-100 cm), Electrical Conductivity (EC) (0-50 cm and 50-100 cm), Storage Capacity (SC), Flooding, Multi-resolution Valley Bottom Flatness (MrVBF), Flow Accumulation (FA), Vertical Distance to Drainage Network (VDCN), Aspect, Longitudinal Slope (LS), Slope, Convergence Index (CI), Topographic Wetness Index, Digital Elevation Model, Growing Degree Days, Cumulative Seasonal Precipitation, Winkler Index, Thermal Integral with Base 13 ºC, Huglin Index.

Table 1. Summary measures for climate, geomorphological, and soil variables characterizing zone 1_1 of the edaphoclimatic zoning of the northern oasis of the Mendoza River.

Class	Variable	Mean
Bioclimatic	Cool Night Index	14.2 (CI+1)
	Huglin Index	3182.7 (HI+3)
	Thermal Integral with Base 13 ºC	1796.1 (Suitable LC)
	Winkler Index	2430.7 (V)
	Cumulative Seasonal Precipitation	143.2
	Growing Degree Days	268.9
Geomorphometric	Digital Elevation Model	614.7
	Topographic Wetness Index	11.3
	Longitudinal Curvature	4.0E-06
	Slope	2.5
	Longitudinal Slope	0.1
	Convergence Index	-3.9E-02
	Aspect	197.5
	Vertical Distance to Chanel Network	2.0
	Flow Accumulation ($FAx10^5$)	2.9
	Multi-resolution Valley Bottom Flatness	6.2
Soil	Flood	4.4
	Storage Capacity	123.0
	Electrical Conductivity (0-50 cm)	9.2
	Electrical Conductivity (50-100 cm)	7.9
	Cation Exchange Capacity (0-50 cm)	17.4
	Cation Exchange Capacity (50-100 cm)	18.1
	Calcium Carbonate (0-50 cm)	5.2
	Calcium Carbonate (50-100 cm)	5.8
	Drainage	3.0
	Erosion	0
	Runoff	2.1
	Saturated Hydraulic Conductivity	42.1
	Organic Matter (0-50 cm)	0.8
	Total Nitrogen (0-50 cm)	589.1
	Calcrete depth	192.6
	Stone depth	198.4
	Soil depth	196.6
	Permeability	4.0
	Soil pH (0-50 cm)	7.8
	Soil pH (50-100 cm)	7.8
	Sodium Adsorption Ratio (0-50 cm)	4.2
	Sodium Adsorption Ratio (50-100 cm)	4.0
	Sedimentation Volume (0-50 cm)	99.2
	Sedimentation Volume (50-100 cm)	98.1
	Gypsum (0-50 cm)	2.4
	Gypsum (50-100 cm)	2.1

Conclusion:

Multiple causative agents of vineyard variability should be considered in the terroir description. However, the delimitation of homogeneous edaphoclimatic zones serves as a first step for establishing the typicality of vineyard environments in wine-producing regions The proposed protocol produced an homogeneous zone map closely linked to the soil and climatic variability and suggest at least five different terroirs in the Mendoza river, Argentine.

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NOV 18, 2024 | 14.15 PM | SCIENTIFIC SESSION: **SOIL II - SCIENTIFIC ORAL**

Terroir and the new quality figures in the denominations of origin of Spain. The cases of Bierzo, Priorat, Rioja, Rueda and Cava

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Keywords: **premium wines, terroir, quality viticulture, Spain.**

ABSTRACT

The development of new premium wine projects in Spain is being facilitated by the creation of new quality labels in some denominations of origin. To this end, their regulatory councils have carried out zoning work to identify their particular areas and take advantage of their terroir effect.

The new quality figures are associated with a classification of the vineyard into smaller geographical units and allow wineries to increase their differentiation, as well as to produce wines that express the uniqueness, notoriety, and authenticity of the territory from which the grapes come. This chapter examines the cases of the Bierzo, Priorat, Rioja, Rueda and Cava appellations, as they are representative of those in Spain.

Introduction: Denominations of Origin, Terroir and Zoning

In the process of the expansion of viticulture, man has observed and selected certain environments for their suitability to produce great wines. Some of these areas have achieved world renown and their fame has been passed on to their products. To protect their authenticity and uniqueness, spatial delimitations have been established whose administrative protection affects both the territory and the types of wine produced there.

Resolution OIV/ECO 656-2021 defines a Denomination of Origin (DO) as "the name of a geographical area, which serves to designate a wine as originating in that area when the quality or characteristics of that wine are due exclusively or essentially to the geographical environment, including natural and human factors. The protection of the Denomination of Origin is conditional upon the grapes being harvested and processed into wine in the defined region or area".

In many cases, the area included in a DO is very large and the natural conditions determine the presence of particular areas which, managed differently by man, allow the production of wines of high qualitative value, providing a notoriety and differentiated typicity, circumstances that are directly linked to the terroir effect.

According to Resolution OIV/VITI 333/2010, the viticultural terroir refers to a delimited space in which the interactions between an identifiable physical and biological environment and the viticultural practices applied confer distinctive characteristics to the products originating from this area.

The definition stresses the importance of the human factor and their level of knowledge of the environment-plant relationships, and the possibility of characterisation (identification) of the terroir area. The winegrower can alter terroir expression –in any prestigious winegrowing area, we can observe that not all the wines produced reach the same level, even if the natural conditions are similar–. In this regard, it is interesting to recall what Vauban, a French politician and scholar of the 17th century said: "the best terroir does not differ in anything from the bad if it is not cultivated with a view to producing the most pleasant wine" (Branas,1993).

The DO cannot be defined with a homogeneous result and can include many terroirs, so it is important to delimit them and know their properties in detail. This is the objective of zoning, which is the investigation of the territory to distribute it in relatively homogeneous areas of the environment (UHM), with similar potentialities and limitations for the development of the vine and perfectly characterised, not only in terms of their properties and factors, but also in terms of their geographical distribution and cartography. Zoning allows us to define the terroir of each wine region both to determine and manage the established areas and to identify and differentiate other emerging areas (Fregoni, 1998).

Zoning is complex, as it requires a multidisciplinary methodology, including experts in viticulture, oenology, soil science, climatology, geology, cartography, statistics, computer science and markets. The work requires a lot of data, so the cost of studies can be very high if you need to go into great detail.

Zoning is carried out on different scales: (a) with little detail or macrozoning (scale less than 1:50,000), where the environment is defined by rock type, macroclimate and soil; and (b) with great detail or microzoning (scale greater than 1:25,000), where environmental parameters can relate to product quality (Gómez-Miguel V., & Sotés V., 2001).

The Natural Environment of Vineyards in Spain

In Spain there are many privileged places to produce different wines with high typicity and good quality due to the wide range of climates, soils, vegetation and landscape, native varieties –or varieties that have been established for years and are adapted to different areas–. There are also personal and collective initiatives to improve the image and prestige of Spanish products in domestic and foreign markets (Compés et al, 2024). At present (2024), there are 109 wine appellations of origin.

In this chapter we will analyse the cases of several Spanish DO that have carried out actions aimed at protecting and developing the image, quality, and prestige of certain high-end wines in their respective territories, namely Bierzo, Priorat, Rioja, Rueda and Cava. They differ significantly in both the size of the registered vineyards and the number of winegrowers, the largest being Rioja. The interesting thing is that they have all been pioneers or advantaged in the need for zoning and the creation of quality figures adapted to smaller production units.

Table 1. General data on areas and number of wineries in each DO

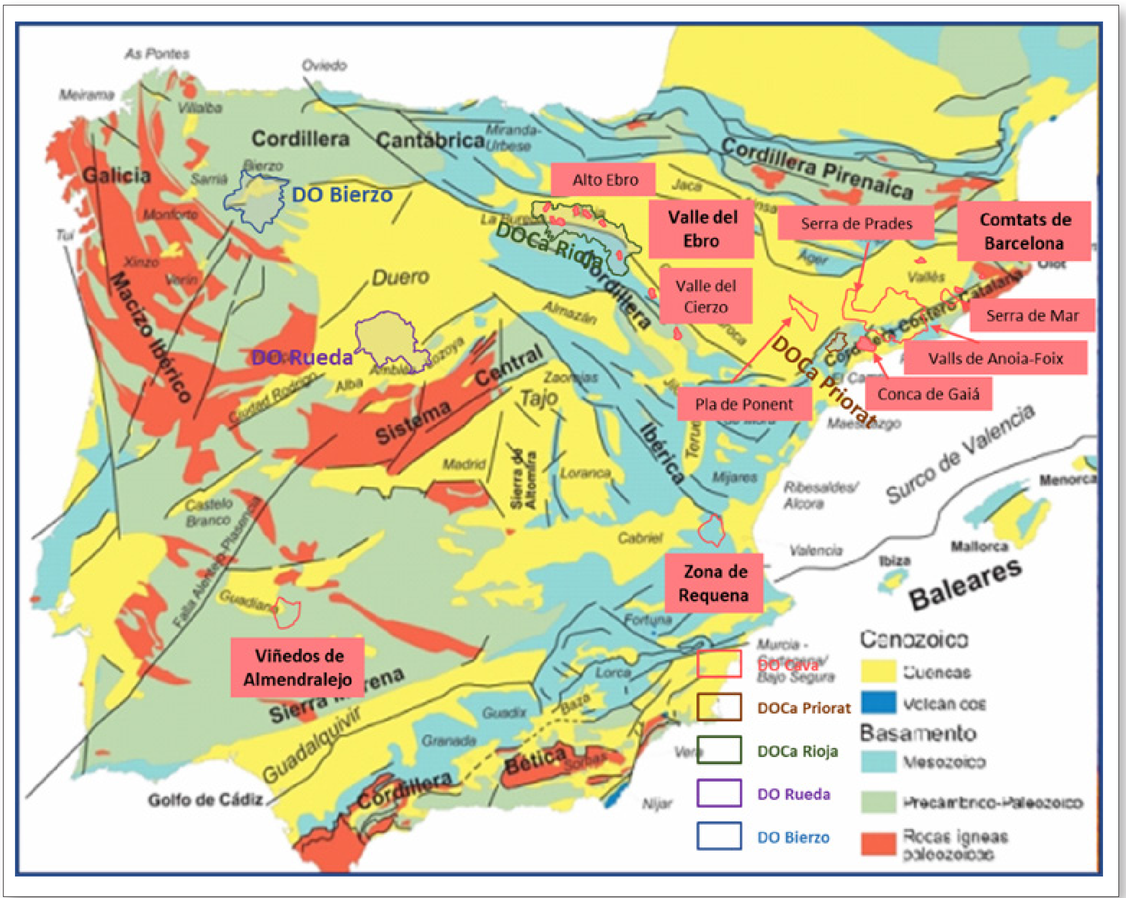
PDO	Vineyard (ha)	Winemakers	Ha/Winemaker	Total, area delimited (ha)
Bierzo	2.420	1.109	2,18	232.213
Cava	38.152	6.391	5,97	
Priorat	2.164	516	4,2	17.629
Rioja	66.653	14.384	4,63	342.526
Rueda	20.611	1.655	12,4	282.154

Source: MAPA Campaign 2020/2021

Maps 1, 2 and 3 show the variability of situations in the areas under consideration. The amplitude of reliefs and altitudes, combined with the great variability of orientations, slopes and exposures of vineyards, geology, soils, and climates, offers a wide range of differentiations.

Map 1. Relief configuration of the Iberian Peninsula (Source IGN, 2008)

Map 2. Geological scheme of the Iberian Peninsula. Source: IGN (2008).



Map 3. Climates of Spain according to Köppen classification.
Source: state meteorological agency (1981-2010).

New quality figures
Denomination of Origin Bierzo: New Quality Figures by Geographical Units

a) DO Bierzo (DO Bierzo Wine). This is the current geographical delimitation of the DO Bierzo.

b) Vino de villa (village wine). Followed by the geographical name of a municipality or locality of those included in the defined geographical area. 100 % of the grapes used must come from plots belonging to the municipality or district concerned. The grape yield (kg/ha) shall be 20 % less than the maximum set by the DO Bierzo. A total of 29 municipalities and 210 villages are recognised for labelling under this figure.

c) Vino de paraje (wine from a single site). Followed by the geographical name of one of the sites identified in the geographical area of the DO Bierzo, provided that the protected wine has been made with 100 % of grapes from plots located in that site. Exceptionally, a site may have part of its territory in several neighbouring municipalities or districts. The grape yield (kg/ha) shall be 25 % lower than the maximum laid down by the Bierzo DO. The delimitation of each site is identified by the cadastral references of the plots within.

d) Viñedo clasificado (classified vineyard). 100 % of the grapes used must come from the same plot or adjoining plots in the same site, with a name recognised in the specifications of the DO Bierzo and which have been classified as wines from that site for at least five years and whose quality has been recognised by the control board's Committee of Experts. The grape yield (kg/ha) shall be 30 % lower than the maximum laid down by the Bierzo DO.

e) Gran viñedo clasificado (great classified vineyard). Similar case to the previous one, but classified for at least five years as wines from classified vineyards and whose quality has been recognised by the regulatory board's Committee of Experts. The grape yield (kg/ha) shall be 35 % lower than the maximum laid down by the Bierzo DO.

Rioja Qualified Denomination of Origin: New Certified Geographical Indications for DOCa Rioja Wines

a) Vino amparado por la DOCa Rioja (Qualified Denomination of Origin Rioja wine). This corresponds to the geographical delimitation of the DOCa Rioja.

b) Vino de municipio (wine of the municipality). Grapes exclusively from the municipality; exceptionally, up to a maximum of 15 % from neighbouring municipalities may be used, provided that: 'this 15 % has been available for at least 10 years without interruption. Production, ageing and bottling in the municipality. Exclusive brand. Traceability and back label with specific coding'. In the 2021 campaign, 36 holders marketed 1,163,394 litres.

c) Vino de zona (zone wine). Grapes coming exclusively from the municipality; exceptionally, up to a maximum of 15 % from neighbouring municipalities may be used, provided that: 'this 15 % has been available for at least 10 years without interruption. Production, ageing and bottling in the municipality. Exclusive brand. Traceability and back label with specific coding'. In the 2021 campaign, 36 holders marketed 1,163,394 litres.

d) Vino de viñedo singular (wine from a singular vineyard). Grapes exclusively from the plot or plots that make up the 'singular vineyard'. Production, ageing, storage and bottling in the same winery. Minimum age of the vineyard of 35 years. Limited vigour. To be credited to –by any legally valid legal title– Exclusive use of the production resulting from the single vineyard for a minimum period of 10 years without interruption. Maximum production of 5,000 kg/ha for red varieties and 6,922 kg/ha for white varieties. Manual harvesting. Maximum processing yield of 65 %. Specific winegrower's card. For the characterisation of the singular vineyard, account is taken of the background and justification for the use of the proposed name, the cartographic delimitation of the area concerned, the climatological, topoclimatic, agrogeological and viticultural characteristics, the uniformity of the vineyard and its differentiation. In addition, it establishes a traceability system, specific labelling and reinforced control, specific qualification and requires assessment as excellent, prior to marketing, recognition by the Ministry of Agriculture and the need for a specific brand. In 2022, 133 singular vineyards are recognised, with a total surface area of 222.22 ha.

e) Vino espumoso de calidad (quality sparkling wine). 'Rioja sparkling wine', white or rosé obtained using the traditional method. Harvested by hand. Maximum processing yield 62 %. Minimum ageing period of 15 months for the Crianza category, 24 months for the Reserva and 36 months for the Gran Añada. Specific labelling.

Priorat Qualified Denomination of Origin: New Wine Categories

The wine must be made, aged and bottled by natural or legal persons who have ownership or title to the vineyard, or a lease of the registered plots of land of 10 years or more. The wine must have been made and aged in a fully identifiable and independent manner within the winery.

a) Vino de la DOCa Priorat (Qualifed Denomination of Origin). A reflection of the general winemaking personality and typicity of the Priorat DOCa.

b) Vino de villa (village wine). Grapes come exclusively from the delimited area. Maximum yield 5,000 kg/ha for red varieties and 7,000 kg/ha for white varieties. Minimum of 60 % of cariñena and/or garnacha. 90 % of the vines must be at least 5 years old.

c) Vino de paraje (wine from a single site). Grapes exclusively from vines located in a single site (or cadastral parcel). Maximum yield of 4,000 kg/ha for reds and 6,000 kg/ha for whites. Minimum of 60 % of cariñena and/or garnacha. 90 % of the vines must be at least 10 years old. The wine must be produced in wineries within the village where the grapes are grown; the Regulatory Board may authorise production outside the village where the grapes are grown if the owner or holder of the plots is the same as the person who makes the wine in the winery.

d) Vino de viña clasificada DOCa (QDO wine from a classified vineyard). Grapes come exclusively from a single classified vineyard. Maximum yield of 4,000 kg/ha for reds and 6,000 kg/ha for whites. Minimum of 60 % of cariñena and/or garnacha. 80 % of the vines must be at least 15 years old; the remaining 20 % must be more than 5 years old. The wines must have a proven traceability of at least 10 years.

e) Vino de gran viña clasificada DOCa (QDO wine from a great classified vineyard). Grapes come exclusively from a single vineyard classified as traditionally grown. Maximum yield of 3,000 kg/ha for reds and 4,000 kg/ha for whites. Minimum of 90 % of cariñena and/or garnacha. 80 % of the vines must be at least 25 years old; the remaining 20 % must be more than 10 years old. The wines must have a proven traceability of at least 10 years.

There are two indications to be noted on wine labels:
+ Velles vinyes (old vines): Grapes from vines that must have been planted before 1945 or more than 75 years ago.

+ Viticultor - Bodega (winegrower - winemaker): A natural or legal person who, while cultivating vines, exclusively processes the production of the identified vines into a wine.

Rueda Denomination of Origin.
New Quality Figures and Mentions
a) Gran vino de Rueda (great Rueda wine). Wines that meet all of the following requirements: (i) obtained from grapes from registered vineyards more than 30 years old; (ii) vineyard yield not exceeding 6,500 kg/ha; and (iii) extraction yield not exceeding 65 %. In the 2021 wine year the authorised area was 273.02 ha and the quantity of wine marketed was 569,379 litres (99.79 % white).

b) Vino de pueblo (village wine). The name of a smaller geographical unit may be used, together with the words "Vino de" next to the name of the municipality, when the protected wine has been made from 85 % of grapes from plots located in that municipality.

c) Vino espumoso de gran añada (great vintage sparkling wine). When the production process, from tirage to disgorgement, exceeds 30 months. It must be accompanied by the year of harvest.

Cava Denomination of Origin.
Quality Figures in Cava (from 2020)
a) Cava de Guarda (Guarda cava wine): Cava aged for more than 9 months. It is the youngest of the entire range of cavas. Produced using the traditional method, from a base wine and then aged for a minimum of 9 months in the bottle.

b) Cava de Guarda Superior (Guarda Superior cava wine): Cava made with grapes from vineyards registered in a specific Register of Superior Guarda Superior of the Consejo Regulador and which has high requirements such as long ageing (18 months minimum). The vineyard must be at least 10 years old, with a limited qualitative production (10,000 kg/ha), sustainability and tendency towards organic production –the production of Superior 'Guarda Superior' Cavas will be 100 % organic in 2025 (5 years transitional period)–. Separate production is also required (traceability from the vineyard to the bottle separately), production from January onwards, and the vintage must be stated on Vintage labelling (mention of the year of harvest is compulsory). The 2022 vintage is the first in which the grapes of the Superior Guarda Cavas are differentiated.

c) Cava Reserva (Reserva cava wine): Cava aged for more than 18 months.

d) Cava Gran Reserva (Gran Reserva cava wine): Cava aged for more than 30 months.

e) Cava de Paraje Calificado (Qualified wine from a single site): Cava aged for 36 months. Qualified site defined by the identification of the plots in the site, with its own edaphic, climatic and cultivation characteristics that differentiate it from its surroundings.

Optional labelling is created, which includes the region of origin (zone and sub-zone), the Integral Producer Stamp, the mention of Cava de Guarda or Cava de Guarda Superior, depending on ageing, and a quality guarantee code, issued by the Regulatory Board. The recognition of the 'Integral Producer' implies that the winery has carried out the entire cava production process, from growing the grapes to bottling, on its own estate.

Conclusions

The knowledge and development of areas –the terroir effect– within the denominations of origin has been the subject of much zoning work in the main winegrowing areas, contrasting empirical methods with traditional observations. The geographical delimitation of optimal areas, as well as traceability, stricter control of the grapes, the wines produced and recognition by consumers, support the interest of this process.

Sustainability is a common approach, with responsible cultivation by limiting grape yields (kg/ha) and promoting more respectful and higher quality viticulture, as well as better management of the production and marketing process. The cultural and socio-economic factors for the uniqueness of the products are essential.

The cases analysed serve as a reference for other denominations. The process is complex and costly, but it is essential to create and gain a foothold in the premium wine market.

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NOV 18, 2024 | 14.30 PM | SCIENTIFIC SESSION: **SOIL II - SCIENTIFIC ORAL**

Historical transformations of the territorial units in the French wine terroirs. A comparative analysis of Bourgogne, Champagne, Bordeaux and Saint-Émilion

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Keywords: **terroir, history of wine production area, units, soil management, St. Emilion.**

ABSTRACT

The historical analysis of terroir in viticulture poses a complex challenge due to the multiplicity of the territorial units involved. This research examines the long-term historical evolution of territorial units in terroir analysis, shedding light on the intricate interplay between territorial units and natural and human factors. Scholars recognise four territorial units in terroir analysis, from vineyards to global markets. However, a divide persists between studies that focus on natural terroir and those that emphasize social aspects, hindering a holistic understanding of human intervention, and historical changes. To bridge this gap, a group of historians in Japan undertook a comprehensive investigation spanning architectural, economic, and political history in key wine-producing regions of France. Through historical sources and fieldwork, the study revealed the transformative dynamics of territorial units within production areas in the Medieval to early modern times emphasizing integration, segmentation, and dissolution of the units over time. In Burgundy, the study traced the evolution of terroir units through *climats*, showing how human interventions such as soil replenishments at the medieval stage shaped vineyard units. Similarly, in Champagne, the integration of territorial units was analysed. The study clarified the influence of *caves* and *maisons* on terroir expressions. The research culminated in an analysis of Bordeaux and St. Emilion, illustrating the segmentation of territorial units and the cultivation of terroir expressions within a château. Through archival investigations and field surveys, the study uncovered the historical processes that shaped vineyard's territorial units and practices and the relationship between human activity and geological diversity.

Introduction:

One of the prominent challenges in historical terroir analysis stems from the dynamic and diverse nature of territorial units across different scales. Particularly since the increased recognition of human factors in terroir definitions by institutions such as INAO (2002, 2006) and UN (1999), scholars have widely acknowledged the presence of multi-layered units in terroir analysis. (Cassabianca et al, 2006). These include the four evolutionary territorial levels delineated by Vélasco-Graciet (2007): (1)Vineyard unit: Often not the minimum terroir unit, but encompassing multiple terroir zones within it; (2) Wine producing area unit: Comprising numerous vineyards, serving as both production sites and hubs for knowledge and skill transmission; (3) AOC region unit: Forming a cohesive territorial entity with shared regulations on production and evaluation, ensuring wine quality across multiple wine-producing areas; (4) Market unit: Involving varying degrees of participation from wine producers, now expanding globally in scale. This fluidity and multiplicity of territorial units underscore the complexity inherent in terroir analysis, necessitating a comprehensive approach that considers the interplay between natural and human factors across diverse scales.

However, a notable issue arises due to a division among researchers: those focusing on the natural/physical aspects of terroir *(terroir physique)* primarily concentrate on units at (1) level or at most, (2), while studies emphasizing the social aspects *(terroir social/humaine)* incorporate broader units of (3) and (4). Moreover, this division impacts the delineation of natural and human factors within terroir analysis. While both factors are expected to manifest across all unit levels (1) to (4), it cannot be denied that historical, geographical, sociological, or anthropological terroir studies have occasionally succumbed to disconnecting their scopes from natural factors. This occurs as they emphasize the inclusion of layers (3) and (4) alongside human factors, which are increasingly analysed from socio-economic perspectives. This situation has led to a disconnect between historical viticultural analysis and natural factors. Soil scientists advocate for inclusion of human factors and history to better comprehend soil dynamics. Van Leeuwen and Seguin (2006) emphasized that terroir expression involves (at a minimum a history of wine growing in a given place' but also human intervention to optimise it. In addition, soil scientist have proven that high quality wines have been produces in various soil types, and that often within a single vineyard unit where diverse soils and grapevine varieties have been carefully managed. (van Leeuwen, de Rességuier et al 2018) Enhanced historical insights into the transformations of territorial units at the vineyard and production area levels would undoubtedly enrich our understanding of soil diversities and terroir expressions. Such clarifications would illuminate the role of human factors and interventions, such as land use and soil management, associated with these terrains.

Materials and methods:

With this challenge in focus, the Terroir Study Group was established in Japan since 2015[1]. Comprised of eleven experts in history and geography spanning various disciplines, periods, and regions, the group specializes in the architectural, economic, and political histories of France, Italy, and Japan, covering the 12th to 20th centuries. The group's research encompasses the territorial scale units of French and Italian wines, as well as Japanese green tea, which has recently embraced the terroir framework. Special emphasis is placed on identifying human factors associated with territorial units of scale, The term territorial here is aligned with defi-

[1] In 2017-2022, the group secured a significant national grant under the theme 'Charting a New Territorial History of Land and Culture through Terroir Analysis'. The members are Kazue Akamatsu, Osamu Nakagawa, Takeshi Ito, Gen Kato, Yasuko Kishi, Miwa Kojima, Tomoaki Nakajima, Keisuke Nomura, Shoichi Ota, Masanori Sakano, Miki Sugiura, Kazuo Uesugi.

nitions in architectural history, including geographical, geological, political and socio-cultural layers.

Drawing upon a spectrum of historical sources encompassing cadastral records, legal documents, and archives from wine producers' families, our research endeavours to delineate the historical evolution of territorial units of scale in three key French wine terroir regions: Burgundy, Champagne, Bordeaux, and St. Emilion. Multiple field expeditions were conducted in these regions (Burgundy, 2017; Champagne, 2017, 2018, 2019; Bordeaux, 2018; St. Emilion, 2019) to bridge historical narratives of territorial units with actual topographical features, scrutinizing land utilization, soil management, and other viticultural practices. The culmination of these efforts was synthesized into a comprehensive volume published in 2023 (Nakagawa and Akamatsu, 2023).

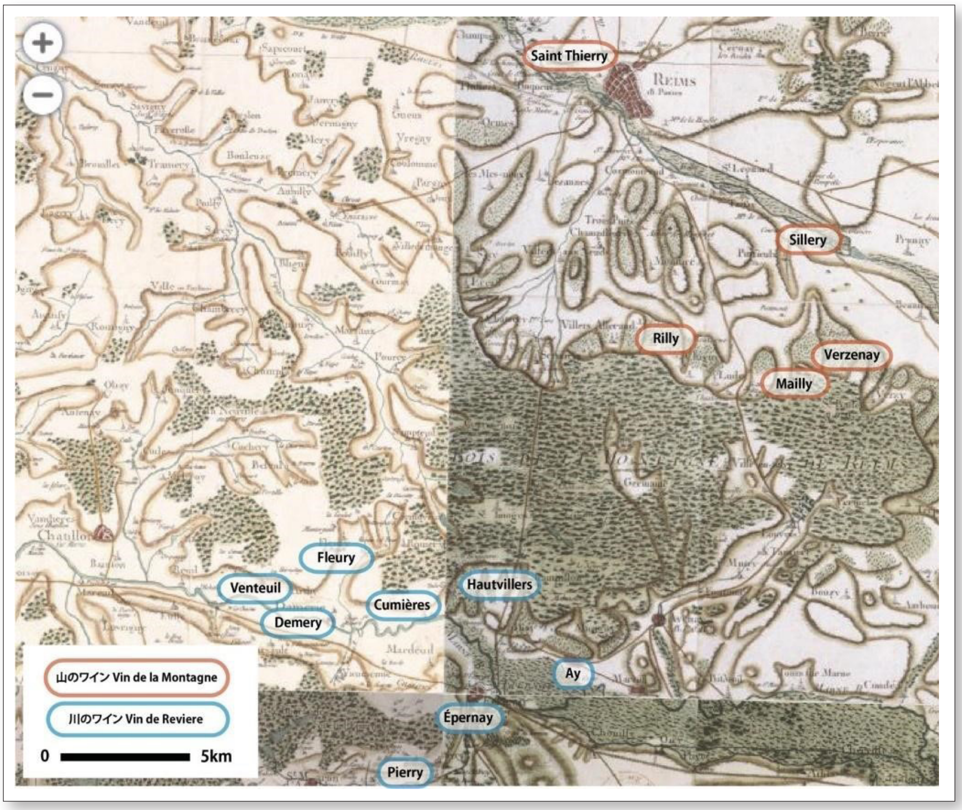
Our approach posits that historical territorial units of scale in each region were initially diverse and underwent distinct transformations over time. Contrary to a linear progression from smaller to larger units or from vineyards to higher tiers such as production areas, AOC regions, and markets, our analysis underscores the non-linear nature of these changes. Emphasizing a novel perspective, we highlight transformative dynamics at the vineyard and production area levels, encompassing processes of integration, segmentation, and dissolution. Through this lens, we identify human factors driving these transformations and sustaining territorial units.

Results and discussion:

For Burgundy, the long-term evolution of the territorial units could be analysed by taking the *climats*, a terroir unit that was created in the 16th century, as the orbit. (Garcia 2011;2016) The human factors required to maintain such units are also evident in this case. The path for *climats* started with the establishment of wine on the less fertile hills *(côtes)* in the early Middle Ages, which led to the distinction between wines from the hills and wines from the plains. In the process of expanding wines from the hills, they ensured that the location, exposure, soil properties, grape varieties and cultivation methods were compatible with each other to achieve quality and diversity. The terms 'terroir and boundary' *(terrouers et fins)* were used in 1486 in a decree by Charles VIII concerning keeping grapevine sorts. The territorial units affected by this decree were determined and analysed. (Kato, 2023) Soil management was inextricably linked to the creation and maintenance of such units. Constant soil replacement and replenishment was necessary to maintain vine-growing on hillsides and was closely linked both to the process of land fragmentation and to the selection of vineyards suitable for Pinot Noir.

In Champagne, we find a process of the integration of territorial units dating back to the Medieval to early modern Ages. In the 13-14th centuries, the production area units of river and mountain wines were established, reflecting also differences in soils. (Figure 1) The process of integration of the two wines and the dissolution of several underlaying units, was analysed in the early modern period on the basis historical documents and maps relating the construction of roads in the 1676 and 1735. Moreover, further integration of territorial units, that led to the establishment of Champagne, were promoted alongside the transition of the wines from non-fizzy to fizzy. *Caves and maisons* were essential here in understanding human factors associated to creation of territorial units as well as soil management. The caves and maisons of Champagne were secondary artificial environments and units created for processing, storage and marketing. However, it was found through our investigation that they were influenced by the nature of the soil in terms of underground space and land use. (Akamatsu, 2023).

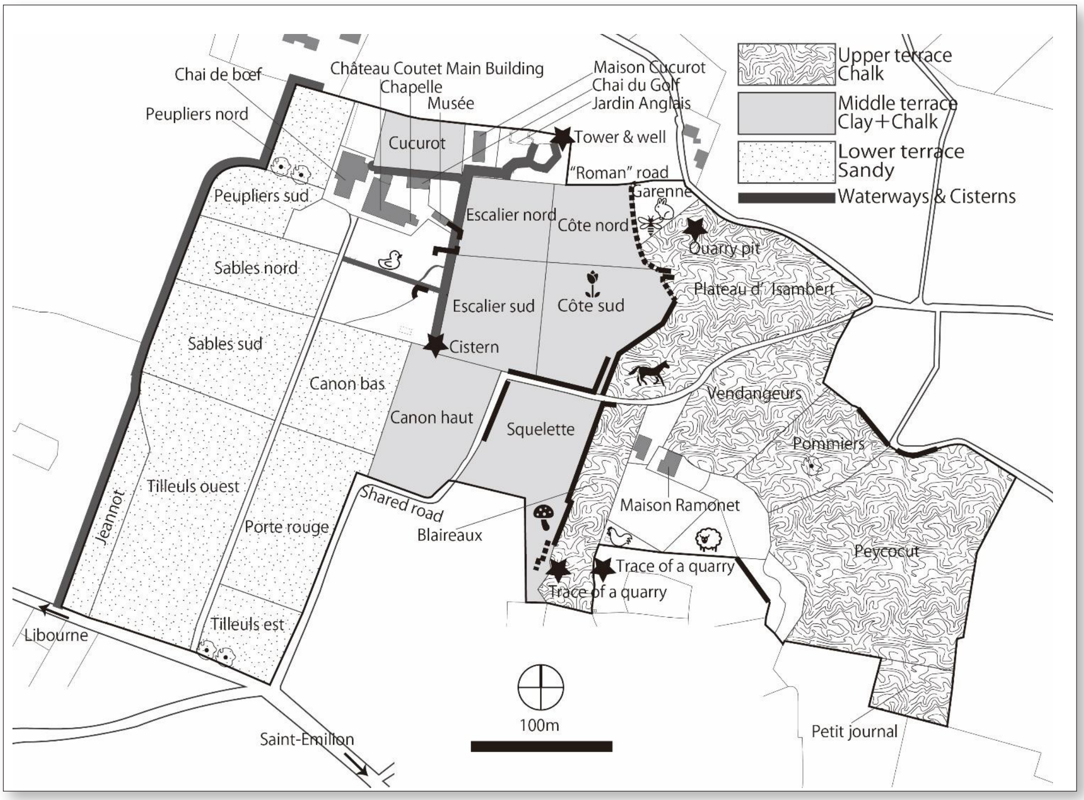
Figure 1. Vins de rivière (River wine) and vins de montagne (mountain wine) locations on the map by Cassini 1717



Source: Created by Akamatsu from Geoportal, https://www.geoportail.gouv.fr.

The most extensive research has been carried out for Bordeaux and St Emilion. The regions demonstrate the long-term process of segmentation of territorial units, from the integrated 'artificial wine' of the early modern period, based on the blending of wines from different vineyards. (Nomura 2023a, Sugiura 2022) In order to determine how the terroir expression based on different geological classifications came to be cultivated within a château, fieldwork at Châteaux Coutet and Cru de Cadet, now part of St Emillion, and the exploration of the family archives of the owner family David-Beaulieu *(Archives privées des David-Beaulieu)* confirmed that the three terraces within the château correspond to three different geological classifications, as shown in Figure 2. The David-Beaulieu family did not vary the grape varieties grown according to geological composition, nor did they plant specific varieties in particular vineyards, but rather experimented with different grape varieties using these diverse geological compositions to see how terroir expressions vary, and gradually varied the varieties they planted. (Kojima 2023). By analysing account registers, administrative documents and the changing political status of the family in the 18th to 19th century from the family archives, the introduction phase of these practices and the human factors involved in establishing such a practice were determined. (Nomura 2023b).

Figure 2. Three Terrases for Land Use and Soil Characters at Chateau Coutet, investigated in 2019



Source: Made by Miwa Kojima based on the investigation of 2019, using Geoportal, https://www.geoportail.gouv.fr.

Conclusion:

In conclusion, this study provides historical insights into the challenges and opportunities in terroir analysis, emphasizing the need for a holistic approach that integrates natural and human factors across multiple territorial scales. By elucidating the historical trajectories of territorial units of segmentation, integration and dissolution, this research enhances our understanding of terroir dynamics and underscores the importance of interdisciplinary collaboration in unraveling the complexities of viticultural heritage.

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NOV 18, 2024 | 14.45 PM | SCIENTIFIC SESSION: **SOIL II - SCIENTIFIC ORAL**

Determination of geological origin of wine through strontium isotope ($^{87}Sr/^{86}Sr$) analysis

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Keywords: **traceability, wine, geology, strontium, isotope.**

ABSTRACT

The concept of "terroir" integrates the interaction of the physical environment (climate, topography, geology, and pedology), the biological material (e.g., rootstock, variety, and soil biodiversity), and the cultural factor (tradition), and how these affect the typicity of wine. Soil characteristics and the processes involved in soil-plant and atmosphere interactions (e.g., soil water balance, nutrient cycles, etc.) are crucial for vine responses and, consequently, wine quality.

Determining stable isotope ratios in certain elements represents an important quality control and fraud prevention tool for many products. It is one of the most modern traceability methods in the wine industry. Earth's geochemical systems can generate different isotopic quantities for certain chemical elements, leading to variations from one location to another on the Earth. Therefore, isotopic ratios of specific elements can characterise a specific soil and, thus, terroir, allowing the determination of the product's origin.

In this study, we aim to identify the elements that enable the traceability of wine from the vineyard to the final consumer. To achieve this, stable isotopes of strontium ($^{87}Sr/^{86}Sr$) were determined using mass spectrometry techniques from three different areas of Castilla-La Mancha (Spain), analysing a total of 30 samples: 10 soil samples (5 from limestone origin, 3 from granitic origin, and 2 from volcanic origin), 10 samples of leaf, and 10 wine samples. It was observed that the isotopic ratio remains stable in the soil, leaves, and wine. Furthermore, the relationships obtained from different soils are consistent with the data presented in the scientific literature for various geological origins.

SCIENTIFIC SESSION: **SOIL - POSTER**

Regenerative agricultural approaches to improve ecosystem services in Mediterranean vineyards

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Keywords: **regenerative agriculture, vineyards, soil microbial biodiversity, biofertilizers.**

ABSTRACT

REVINE is a 3 year European projected funded by PRIMA programme which proposes the adoption of regenerative agriculture practices with an innovative and original perspective, in order to improve the resilience of vineyards to climate change in the Mediterranean area. The potential for innovation lies in developing and combining new approaches that make agriculture more environmentally sustainable and enable a circular economy capable of improving farmers' incomes. Primarily REVINE aims to improve soil health and biodiversity by promoting the multiplication of soil saprophytic microorganisms and the presence of useful microorganisms linked to the life cycle of the plant, such as rhizobacteria (PGPR) and fungi (PGPF) that promote plant growth which, in addition to increasing plant performance, increase tolerance to biotic and abiotic stresses.

The project has the main goals to improve the biodiversity in vineyard and the fertility and water availability of soil.

Regenerative agriculture ameliorates soil structure and microbial biodiversity that, in turn, leads to crop resilience against biotic and abiotic stressful factors. Moreover, enrichment of beneficial microbes in the rhizosphere, such as PGPR and PGPF, are known to trigger the plant immunity inducing the priming state. REVINE intends to improve the biodiversity in the vineyards by using multiple approaches, including: I) screening of tolerant grapevine genotypes; II) consociation of the grapevine with profitable cover crops; iii) the use of cultivation practices able to enhance soil biodiversity and the beneficial rhizosphere microorganisms.

REVINE, by means of Regenerative Agriculture, intends to rebuild soil organic matter and restore degraded soil biodiversity, resulting in both carbon drawdown and water cycle improvement, by using biofertilizers and amendments (fermented manure, compost and biochar.

Biofertilizers and amendments will be produced from crop residues. In this way, REVINE intends to valorise agricultural waste and to increase farmers income, promoting the circular economy.

SCIENTIFIC SESSION: **SOIL - POSTER**

Are organic mulches an alternative to conventional management of the soil under the vines?

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Keywords: **circular economy, grapevine quality, microbial diversity, Tempranillo, water status.**

ABSTRACT

Climate emergency is going to affect the agricultural sustainability, wine grapes being probably one of the crops more sensitive to environmental constraints. In this context, mitigation strategies such as the revalorization of agricultural wastes are paramount to cope with the current challenges. The use of organic mulches has been reported to reduce soil water evaporation and improve vine water status, reduce soil erosion, and increase soil organic matter with little impact on berry quality. However, less is known about their effects on the microbiote in vineyard soils. The aims of this work were to study the effect of mulches of different nature on grapevine water status, yield and berry quality and, and to assess their impact on heterotrophic bacterial communities. The experiment was carried out in a commercial vineyard in Olite/Erriberri (Navarra, Spain) with cv. Tempranillo. Five different mulches (grapevine pruning waste, almond shell, pine bark, wood waste, and straw) were applied in the summer of 2022, and compared to a control (bare soil) and monitored during two seasons.

Results show that grapevine pruning waste and almond shell mulches tended to improve grapevine water status during berry ripening. However, whereas the former increased yield, the latter decreased it. Treatments did not impact on monitored berry quality parameters. In regard to bacterial diversity, all the considered mulches promoted it comparatively to bare soil. To sum up, mulches might be a sustainable alternative to improve soil characteristics by means of increasing bacterial diversity, with the subsequent improvement of grapevine performance.

SCIENTIFIC SESSION: **SOIL - POSTER**

Plant diversity and carbon storage in relation to two contrasting vineyards situations of Mendoza, Argentina

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Keywords: **regenerative agriculture, vineyards, soil microbial biodiversity, biofertilizers.**

ABSTRACT

In the current context of climate change, viticulture faces the challenge of implementing sustainable practices that conserve plant diversity and optimize carbon storage. The objective of this work was to characterize avineyard - associated plant diversity and carbon storage in vineyards managed mainly with spontaneous vegetation coverage and located at two contrasting situations in Mendoza: a traditional vineyard from Las Compuertas, at 1070 m a.s.l in Luján de Cuyo (LC), planted in 1929 and surrounded by urban areas; and a more recent plantation from 2008 at Gualtallary, at 1650 m a.s.l. in Tupungato (GY), which neighbors native vegetation areas. Analyses of floristic and partitioning of assimilates (aerial and root) of spontaneous vegetation from the row and the inter-rows spaces were carried out. The total accumulated carbon (TacC) was calculated taking into account the mulch contribution, and transformed into CO2 equivalent per ha (CO2 eqv/ha). Results of plant richness and coverage were different between vineyards: 23 species were identified for LC, with Chenopodium album, Cirsium vulgare and Dysphania pumilio being the most abundant, while GY showed 41 species, with major presence of Chenopodium album, Salsola kali, Cenchrus spinifex, Hirschfeldia incana and Thinopyrum ponticum. The greatest amount of carbon occurred in the above-ground biomass (ag) compared to the below-ground (bg). Overall, the TacC content was 0.38 t/ha for LC, and 1.86 t/ha for GY vineyards; that mean 3.10 t CO2 eqv/ha and 6.86 t CO2 eqv/ha stored, respectively. These results support the advantages that employing less intensive soil management practices can provide in vineyards. Besides, this knowledge paves the way for further studies regarding the benefits of keeping native areas close to productive plots. Thus, biodiversity can be preserved at new plantations, and contribute to the sustainability of the viticultural systems.

SCIENTIFIC SESSION: **SOIL - POSTER**

Comparison of management of accompanying vegetation in the row of viticultural agroecosystems of the Uco Valley in terms of soils and plant community

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Keywords: **agroecosystems; vineyards; vegetal community; soil management.**

ABSTRACT

The literature distinguishes between practices that control competition for resources and/or facilitate tillage and practices that optimize agro-ecosystem function to ensure stable yields. The management of the accompanying vegetation of the vineyard contributes to sustainability as it can improve production and the conservation of the ecosystem.

We asked ourselves about the condition of the soil and the plant community according to the type of technical management. Three methods of accompanying vegetation management were compared in 81 plots located in vineyard agroecosystems in Gualtallary (Mendoza). One method controls spontaneous vegetation with systemic herbicide (MH), another with inter-tillage (MI) and the last method combines both methods (MC). The community resulting from MC shows intermediate values of vegetation cover, while richness and diversity are high. In contrast, in the MH the vegetation cover is low and the richness and diversity are intermediate to low. Finally, in the IM, vegetation cover is high but richness and diversity are low to intermediate. Organic matter values in the MC are high, while total fungal and bacterial activity is intermediate. In the IM the organic matter and total fungi are low, but it has a lot of bacterial activity. And in the MH, organic matter is intermediate, total fungi are abundant and total bacteria are scarce. In conclusion, the MH was effective in controlling competition and achieved intermediate levels of organic matter but with higher total fungal counts. The CM is suitable for productive optimisation if ecosystem functions and soil characteristics are taken into account. Finally, MI expresses a plant community and soil condition that is far from ideal for both approaches, but stands out for its high total bacterial content.

SCIENTIFIC SESSION: **SOIL - POSTER**

Compositional analysis of the vegetal community in the grapevine row according to the soil management

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Keywords: **agroecosystems; vineyards; vegetal comunity; soil management.**

ABSTRACT

The sustainability of viticultural agroecosystems is a matter of preoccupation for science, decision-makers and producers themselves. It requires knowledge about the integral functioning of the agroecosystem, but there are few studies related to the response and functionality of the vegetal community resulting from the application of different viticultural technical management. In this work, phytosociological methods are used to analyse the plant composition in the vineyard row according to different soil managements in five vineyard agroecosystems located in Gualtallary (Tupungato, Mendoza) with similar environmental, socioeconomic and technical characteristics. In two agroecosystems, weed control in the row is carried out with systemic herbicide (MH), in two others with inter-strain (grating) (MI) and the last one with a combination of systemic herbicide and inter-strain (grating) (MC). The temporal and cluster analysis indicated that after 4 years of implementation of the above-mentioned management, the plant communities are different and relatively stable. The management practices share the same most abundant families: *Asteraceae, Poaceae, Brassicaceae, Fabaceae* and *Amarantaceae*, but are different in indicator and abundant species, as well as in richness and family equitability. MI is richer than MH and MC. Equitability is expressed in the opposite direction. It should be noted that the abundant and indicator species in the MI are competitive species and not very desirable in the crops. On the other hand, native and less competitive species are present in the MH and in the MC without a clear typicity. These results raise questions about quantitative aspects and the ecosystem functions of the plant communities that accompany the vineyards.

SCIENTIFIC SESSION: **SOIL - POSTER**

Native vegetation communities as a proxy of parcel selection for new vineyards considering an approach of biodiversity conservation

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Keywords: **viticulture of conservation, terroir, site selection, vineyard design, biodiversity.**

ABSTRACT

The current concept of the terroir definition includes the care of the viticultural ecosystem. For this work, an evaluation of native vegetation communities was included as a new aspect for site selection in pristine areas located in Gualtallary, Mendoza. In addition, a quali-quantitative analysis of the native plant community was carried out before and after planting with the aim of quantifying and monitoring its changes. Topographic maps and NDVI indexes were used to delimitate homogeneous areas of vegetation that were characterised through a phytosociological method. With that study and maps of soil type, hydrology and microclimate, 56 plots in 15 hectares were selected for planting vines. The planting was carried out with a conservative approach: no mechanization was used, soil disturbance and native herbaceous cleaning were minimum, only holes for each vine were manually performed up to 80 cm depth to ensure root exploration and no vines were planted on shrub positions. Furthermore, all the soil material was temporarily placed over a fabric and then returned to the original hole after the vines were planted, so that no native vegetation was removed by these pre-planting procedures. The irrigation system was designed for direct vine root zone irrigation, applying water at a depth of 30cm. To analyse the changes in vegetation, 14 plots were compared before and after implantation in summer of 2022 and 2023, respectively, in terms of vegetation cover, richness, diversity and plant layer. The results showed that all clusters of phytosociological communities detected were preserved after plantation. Overall, although vegetation cover decreased, species richness was maintained, and diversity increased. As expected, the shrub layer decreased in cover and height because of the maintenance work aimed at allowing vines to co-exist with native vegetation. This pre-planting approach shows promising results that will be monitored and represents an innovative way to consider conservation viticulture for future projects.

SCIENTIFIC SESSION: **SOIL - POSTER**

Effect of elicitors on soil microbiome, physical and chemical soil properties, vine growth and grape composition of Cabernet sauvignon cultivated in Maipo Valley

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Keywords: **microbiome, humic acids, carboxylic acid, sea weed, organic amendment, soil ripper, *Bacillus* sp, *Pseudomonas* sp,**

ABSTRACT

Among all the factors that contribute to *terroir* definition, soil microorganisms play a major role from nutrient recycling to an influence on plant growth and protection, wine production and quality. Overall, understanding and managing soil microbiome elicitors can be a powerful tool in optimizing grape quality and wine characteristics, and improving soil health and biodiversity.

This trial aimed to study the effects of different elicitors applied through irrigation system during two consecutive years compared with ripped soil between row and bare soil under vines as control, on soil microbiome, soil properties, vine growth and grape composition of Cabernet sauvignon in 2024 season.

Microbiological consortium and humic acids treatments improved physical soils properties at 30 cm depth showing less soil bulk density. However, despite that there were not significant differences in soil nutrients, humic acids reached high exchangeable cations and organic matter decreased in ripped soil.

Stem water potential measured on vines treated by organic amendment and microbiological consortium showed less water stress than control from pre *veraison* to harvest. Pruning weights registered in organic amendment and ripped soil were lower than control in winter 2024.

Berry composition, assessed at harvest, showed high levels of soluble solids and phenolic maturity parameters in organic amendment, where potential and extractable anthocyanins (g/L), TPI, and skin phenols were greater than control. According to yield components, humic and carboxylic acids obtained higher cluster and single vine weight than ripped soil and organic amendment. However, there was not differences in the number of clusters per vines.
Preliminarily, the addition of *Bacillus, Pseudomonas* and *Tricoderma* increased the level of fungal and bacterial biomass, and the number of beneficial protozoa in soil, despite those fungi: bacteria ratio was low. However, detrimental *Oomycetes* were identified in the control site, while anaerobic protozoa and root-feeding nematodes were not detected.

SCIENTIFIC SESSION: **SOIL - POSTER**

Edaphological topographic and climatic characterization of the main wine-growing regions of the province of Catamarca in Argentina

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Keywords: **Catamarca, Argentina, soil characterization, wine-growing regions, random forest.**

ABSTRACT

Argentina is the fifth wine-world producing country with 207.047 cultivated has which are mainly spread in Mendoza 71,2 %, San Juan 19,9 %, La Rioja 3,6 %, Salta 1,8 % and Catamarca 1,3 %. The main wine regions in the province of Catamarca are located at the foot of the Andes Mountain range, in high-altitude valleys (1,500m above sea level). The characterization of the soil and climate of wine-growing regions is a key stone for sustainable vineyard management. Here, we are reporting for the first time a comprehensive characterization of the main wine-growing regions of Catamarca (Tinogasta-Fiambalá (Abaucán Valley), Hualfín and Andalgalá-Siján) that include the factors of soil, topography and climatic characteristics. For soil characterization, sampling sites were defined using census data from the National Institute of Viticulture (INV) and satellite images. Soils were described by opening 25 trial pits and 15 auger holes in different wine-growing establishments, following the Soil Recognition Standards of Etchevehere (1976). Physical-chemical analyses were performed on the extracted samples according to the protocols of the IRAM-SAMLA Standards. Using the Digital Elevation Models of the National Geographic Institute (IGN), morphometric and bioclimatic indices were calculated. The analytical data and environmental covariates were processed using the R software. Finally, using Machine Learning techniques (Random Forest), a series of predictive models of the behavior of soil variables for the areas of interest were generated. As a result, five maps of edaphic units and more than 60 spatial distribution maps of soil variables were defined. In the Abaucán valley, well-drained, non-saline sandy loam soils predominate, with a low total limestone content (1.9 %). Hualfín presented a similar texture composition but with a limited effective soil depth, a slight saline risk and low limestone (0.8%). Andalgalá valley has well-drained soils with a loam to sandy loam texture with 1.4% organic carbon and almost no total limestone. This information is available in a digital repository to advance the characterization of the argentinean terroirs.

SCIENTIFIC SESSION: **SOIL - POSTER**

Geomorphological studies in terroirs characterization of the Abaucán Valley, Catamarca province, Argentina

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Keywords: **terroir zonation, soil studies, geomorphological environments, Quaternary.**

ABSTRACT

A terroir concept is strongly related to the geomorphological environment, which significantly influences pedogenetic processes and soil formation. Moreover, the soil parameters such as texture, lithological composition, organic matter content, water saturation, lateral changes, among others, mainly depend on the intrinsic soil nature. Nevertheless, geomorphological studies are seldom considered in research on Argentinean terroirs, which are predominantly based on physiographic settings and geographic/political boundaries. Consequently, there is a pressing need to incorporate knowledge about this aspect gap of terroir into existing research. Geomorphological studies were conducted in three areas along the Abaucán River, Catamarca. This valley runs parallel to the western Planchadas Range (Famatina System) and eastern Famatina Range (Sierras Pampeanas Noroccidentales System) associated both with metamorphic outcrops. Our results reveal that this extended valley, known as well as Grande Valley, exposing fluvial deposits (alluvial plains, fluvial terraces, streambeds, saline playa-lake) is laterally confined by different aggradational pediment levels (I, II and III) and covered by dunes fields in some sectors. These variable sedimentological deposits generated diverse types of soils with different degrees of development. Silt and sand material deposits of the Abaucán River alluvial plain predominate in the Medanitos area containing pumicites gravels due to regional volcanic activity, while in alluvial fan deposits and aeolian layers mask alluvial plain deposits in the Famatina region. Gravel to sand material of alluvial fans prograding into the Abaucan valley predominate in Tinogasta region. Variations in lithological composition were also found along the valley studied, highlighting the importance of detailed geomorphological studies in the terroir.

SCIENTIFIC SESSION: **SOIL - POSTER**

Digital soil mapping as a tool for the study of spatial variability of soils in viticultural terroirs

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Keywords: **digital soil mapping, soils, terroir, viticulture, zoning.**

ABSTRACT

Digital Soil Mapping (DSM) is a discipline that links field observations, laboratory results and quantitative pedology methods to infer spatial patterns of soils at different spatial and temporal scales. Considering the great spatial heterogeneity of viticultural soils in Argentina, associated with multiple pedogenetic processes and variations due to transport and sedimentation, the availability of tools that facilitate the analysis of the spatial distribution of soil properties is of great relevance. The objective of this work is the development of a workflow for the application of Digital Soil Mapping techniques to predict the edaphic properties (e.g. pH, texture, etc) and to analyze the spatial variability of soils in different Argentine viticultural terroirs. Based on environmental and geomorphometric variables related to soil-forming processes, a soil sampling design using the Conditioned Latin Hypercube method was defined for each winegrowing area studied. The data collected were harmonized with previously available datasets, synthesizing two soil horizons at 0-50 and 50-100 cm for several physical and chemical soil profile characteristics. According to the characteristics of the study variables, Random Forest was used as a predictive tool for categorical variables (characteristics of the associated external landscape) and Quantile Random Forest for numerical properties (mainly physical-chemical variables). For this purpose, multiple geomorphometric, climatic and biological layers were considered as predictor variables, allowing linking these covariates with the soil properties analyzed. This methodology was applied to 30 Argentine viticultural valleys, using 2,111 study sites and covering 197,168 ha of vineyards. The present work illustrates the results obtained for the Mendoza River Oasis, which were used as input for the subsequently carried out soil-climate zoning.

SCIENTIFIC SESSION: **SOIL - POSTER**

Service crops in Mendoza vineyards: study of cover-crops in different wine-regions of Mendoza

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Keywords: **cover-crops, service-crops, vineyard, vines, regenerative-agriculture, Mendoza.**

ABSTRACT

Wine producers from Mendoza grouped in CREA, and the Facultad de Ciencias Agrarias of the Universidad Nacional de Cuyo, studied the potential of different plant species as service providers in *Vitis vinifera* L. cv. Malbec vineyards in Mendoza. The most demanded ecosystem services were identified among growers participating in the trial (weed control, improvement in soil physical properties and fertility), winter cover crop species were selected considering the following criteria: behavior, availability, regional and global background, among others. Eight treatments were contrasted: four pure sowings (rye, mustard, vetch, melilotus), two associated (rye / vetch and rye / vetch / mustard / melilotus), spontaneous vegetation and bare soil. The experience was repeated during the 2021/22, 2022 /23 and 2023/24 agricultural cycles. The trial was performed in ten vineyards in Mendoza's northern central oases. The sowing was carried out between March and April in the three cycles. Cover crops were not incorporated into the soil. In each treatment, height, width, dry matter production and weed control of the cover crop were evaluated. In the vineyard pruning weight and grape yield were measured. On the soil: physical properties (sedimentation volume, pH, electrical conductivity), chemical (N, P, K, Ca, Mg, Na, SAR, Organic Matter) and biological characteristics (total microbiological activity and microbiological composition). Rye and both associated seedlings produced more biomass and exerted greater control over weeds in Winter. In the last cycle also summer weed control was important in these treatments. We did not detect any influence on the vigour of the plants (pruning weight) or the grape yield. We did not detect statistical differences on the physicochemical or microbiological properties of the soil. In conclusion, service crops that include Rye are useful to control winter and summer weeds when these treatments are maintained in time. Longer periods may be needed to obtain a significant impact on soil's physical and chemical properties.

SCIENTIFIC SESSION: **SOIL - POSTER**

A new irrigation device implemented at a high-altitude slope commercial vineyard: a case of study from Mendoza, Argentina

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Keywords: **climate change adaptation, irrigation efficiency, viticulture of conservation, sub-surface irrigation, terroir.**

ABSTRACT

Climate change and related extreme events such as heat waves, hailstorms and rainfall are becoming more intense and frequent in viticultural regions worldwide. Moving vineyards to high-altitude areas is a strategy to deal with higher temperatures in the desertic region of Mendoza, Argentina, where irrigation management is challenging and a fundamental aspect of vineyard sustainability. The care of native biodiversity is another axis when thinking about conserving the natural ecosystems in the terroir concept. The aim of this contribution is to show the results of the introduction of a new irrigation device (i.e. diffuser tube) into the drip system from emitters to dispose water at 30 cm depth in the root zone, aimed at increasing irrigation efficiency, diminishing competition with native flora cover and providing slope stability, in a 15 ha vineyard located at 20-60% slopes in Gualtallary, between 1400-1500 m asl. Thirty parcels from a commercial vineyard - out of 56 - have been already planted in 5ha based on soil type, topography, native vegetation, hydrology and microclimate environmental homogeneity. The pressure of the irrigation system is generated by natural slope, thus optimizing energy consumption and giving flexibility to operate valves independently for each predefined site, optimizing water balance. Challenges and nature-based solutions for the sustainability of these growing areas are presented.

Climate

SCIENTIFIC SESSION

NOV 18, 2024 | 15.30 PM | SCIENTIFIC SESSION: **CLIMATE I - SCIENTIFIC ORAL**

Climate typing of wine regions characteristics and changes

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Keywords: **climate classification, Köppen-Geiger, climate types, climate change, wine regions.**

ABSTRACT

A useful resource for understanding and describing worldwide climatic patterns is the Köppen-Geiger (KG) climate classification system. The classification of climates suited for viticulture has been important in comparing regions, finding suitable climates for specific varieties, and how the industry, journalists, and public talk about wine regions. Over time wine production has come to be associated with Mediterranean climates due to the combination of the KG climate classification system and the geographic location of Europe's old-world wine areas. While these climate types can also be found in other mid-latitude regions around the world, today wine is produced across many different climate types.

This study examines the KG classification system's application to the most recent Coupled Model Intercomparison Project (CMIP6) experiments. Using an ensemble of 14 global climate models and the WorldClim dataset, a baseline for the historical period 1970–2000 was established. Climatic changes in winemaking regions are assessed using future estimates of climate from 2041 to 2060, based on several scenarios of human radiative forcing (SSP2-4.5, SSP5-8.5). The findings represent the most thorough record of past climate classifications for most wine regions globally, as well as prospective future changes to these categories.

The results indicate that wine regions in the recent past have been largely located in temperate oceanic (~30%), Mediterranean (~20%), cold dry semi-arid (~17%), and humid subtropical (~13%) KG climate types. Overall, this research points to general shifts with tropical and arid climates likely expanding into the midlatitudes, while continental hot summer and humid climates will likely increase in area, and high-latitude subarctic and polar climates are likely to shrink in area. For wine regions the results indicate that significant shifts from warm summer climates to hotter and drier summer climates are likely in the temperate zones where many wine regions are located.

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Assessment of Albariño grapevine *(Vitis vinifera sp.)* plasticity in the eastern coastal terroir of Uruguay

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Keywords: **Adaptability, Atlantic Ocean, Climate Variability, Albariño, South America.**

ABSTRACT

For a viticulture production system under the same management practices, studying the plasticity of a specific cultivar under different environmental conditions could help to determine adequate vineyard techniques and a better understanding of the grape typicity and hence wine style of a region. This work aims to assess the performance of Albariño vines grown in different mesoclimates in the eastern wine region of Uruguay. The study was developed in a commercial vineyard in an emerging wine region on the Atlantic side of southeastern Uruguay (Garzón, located in the Maldonado Department). Four temperature sensors were installed in plots of Albariño in two contrasting topographic situations, classified as high and low coastal influence (Tachini et al., 2023). Climatic and agronomic measurements were taken to assess the performance of Albariño in the local climates. Differences were observed in berry composition when harvested from plots at different ocean facing slopes, potentially influencing wine flavour attributes from temperature spatial variability within the same region.

Introduction:

Phenotypic plasticity is the ability of an individual organism to alter its physiology/morphology in response to changes in environmental conditions (Schliching, 1986). Phenotypic plasticity and local adaptation are complementary mechanisms that allow plants to adjust to environmental heterogeneity (Liu et al., 2016). Grapevine responses to different environmental conditions (spatial and seasonal climates and type of soils) are well reported (Sadras et al., 2009; Gladstone, 2015).

Understanding the plasticity of a cultivar could, therefore, help in adapting vineyard management practices to get the best terroir expression in wine typicity and styles. This work focuses on the Albariño vine's plasticity grown under a specific management practice in the eastern wine region of Uruguay yet experiencing different environmental conditions.

Materials and methods:
The study was developed in a commercial vineyard in an emerging wine region on the Atlantic side of southeastern Uruguay (Garzón, located in the Maldonado Department). Four temperature sensors (Tinytag data loggers, Gemini, UK) were installed in plots of Albariño in contrasted topographical situations, which were classified into two classes as high and low coastal influence based on spatial differences in climate (Table 1 in Tacchini et al., 2023). This study shows results over five consecutive growing seasons (2019, 2020, 2021, 2022 and 2023).

Climate assessment: Regional seasonal temperature and precipitation variability were evaluated from daily data from the Rocha agro-climatic station from the Meteorology National Institute (INUMET) network of the World Meteorological Organization (WMO). In the vineyards, hourly temperature data measured by temperature sensors (Tinytag dataloggers, Gemini, UK) was used to assess spatial and seasonal variability for each plot through bioclimatic indices (listed in the heading of Table 1). During heat waves, we considered the sea breeze influence using the frequency of the number of hours with a decrease in temperature at different intensities (0.5º and 1.0º) at the time of maximum temperature (between 11 LH to 16 LH; Fourment et al., 2014).

Albariño performance assessment: Four plots of high-quality white wine Albariño were planted in 2009 (13 years old), to a vertically shoot positioned (VSP) training system, double guyot pruned, and the canopy was managed. Yield components were evaluated from each plot (number of clusters, yield per vine, berry weight, pruning weight and Ravaz Index). During ripening period, berry samples were collected weekly as outlined in Carbonneau et al. (1991). Grape berry composition measures undertaken were sugar concentration (g/l) by refractometry, titratable acidity (g H_2SO_4/l) by titration, pH by potentiometry, according to the O.I.V. protocol (1990). To analyze phenolic potential (Phenolic richness of grapes), Glories and Agustin (1993) protocol was followed with a Shimadzu UV-1240 Mini (Shimadzu, Japan) spectrophotometer.

Plasticity assessment: Univariate statistical analysis (ANOVA) was evaluated for every climate and agronomic variable to determine the year's influence and High and Low exposure to the Atlantic Ocean's influence at different confidence levels. Multivariate statistical analysis was performed to elucidate correlations between climate and agronomic data. Principal components analysis (PCA) was done to analyse the dataset of different nature to discriminate the plot's location and year effect. We performed the statistical analysis on Infostat® and OriginLab® programs.

Results and discussion:
Temporal and spatial climate variability during 5 growing seasons: The region's climate variability was strongly associated with precipitation patterns and temperature high extremes. The 2023 growing season was the hottest and driest of the series (Fourment and Piccardo, 2023), during which the greatest differences between plot locations were found (spatial variability). For example, under the warmest seasonal conditions of the study period, the impact of sea breeze was greater on plots exposed to the Atlantic Ocean, recording 6.5 hours more than others with a temperature drop at midday (Table 1). Other bioclimatic indices were influenced by Ocean exposition: Minimum temperatures, such as the Cool Night Index, Minimum Temperature during the growing season, January Minimum Temperature, and November Minimum Temperature (Table 1).

Yield and berry composition: Yields were on average 1.7 kg per vine, with similar berry weight between years (1.3 g) and similar cluster number (19.2 clusters per vine on average). Differences in 2022 were due to *Botrytis cinerea* rot incidence observed on grapes, resulting in yield losses, which can be an issue under the Uruguayan humid summer conditions (Table 2).

Low temperatures during flowering (November in Uruguay) could impact fruit set and thus final yield in the season (Keller et al., 2010) and cluster number of the next season (May, 1961). That could be the case of the Spring 2021, which showed the lowest values in November Minimum temperature (0.9 and 1.1ºC lower compared with the five-year average, in H and L plots, respectively), which impacted the significance of the plot's final yield in season (specifically, in L plots, 0.72 kg per plant lower than H plots). The lower Maximum Temperatures during spring 2021 could explain the limited cluster number of the 2022 season for both plot locations, reaching a statistical difference of 7.6 clusters per vine between H and L plots.

Table 1. Climatic indicators during 2019, 2020, 2021, 2022 and 2023 growing seasons with the statistical significance between High (H) and Low (L) Coastal Influence, and the year effect.

Climatic variables		2019	2020	2021	2022	2023	Average
GDD	H	1654.6 b	1717.5	1660.8 b	1744.7	1760.5	1708.0 b
	L	1628.4 a	1725.5	1572.6 a	1722.0	1694.0	1673.4 a
	Year						***
	Plot site	***	ns	**	ns	ns	***
THA	H	11.51	12.61 a	11.28	10.34	11.38	11.42 a
	L	12.35	14.64 b	12.73	11.80	13.06	12.81 b
	Year						***
	Plot site	ns	**	ns	ns	ns	***
CNI	H	16.34	16.41 b	17.20 b	16.67	17.61	16.85 b
	L	15.55	15.35 a	15.96 a	15.72	16.86	15.85 a
	Year						***
	Plot site	ns	*	*	ns	**	***
TN	H	16.26	13.37	13.22 b	14.42	14.33 b	14.32 b
	L	15.61	13.38	11.73 a	13.37	13.00 a	13.41 a
	Year						***
	Plot site	ns	ns	*	ns	***	***
TX	H	27.49	25.69	24.77	24.66 a	24.85	25.49 a
	L	27.62	25.75	25.22	25.43 b	25.48	25.86 b
	Year						***
	Plot site	ns	ns	ns	**	ns	***
ND30	H	22.9	55.0	35.0	36.0 a	45.0	40.0 a
	L	28.5	58.5	39.5	42.00 b	52.5	44.2 b
	Year						***
	Plot site	ns	ns	ns	**	ns	**

Climatic variables		2019	2020	2021	2022	2023	Average
ND35	H	6.5	5	1.5	4.5 a	3.5	4.2
	L	3.5	4	1.0	7.3 b	4.5	4.36
	Year						***
	Plot site	ns	ns	ns	*	ns	ns
TXJan	H	28.36	29.75	29.47	29.65	30.04	29.45
	L	28.44	29.17	29.53	30.15	30.52	29.61
	Year						***
	Plot site	ns	ns	ns	ns	ns	ns
TNJan	H	17.59 b	15.59	16.94 b	17.68	18.12 b	17.31 b
	L	17.01 a	15.7	15.61 a	18.30	16.72 a	16.55 a
	Year						***
	Plot site	**	ns	***	ns	**	***
TXNov	H		25.62	23.66	23.09 b	24.08	24.11
	L		26.27	24.40	23.83 a	24.84	24.83
	Year						***
	Plot site		ns	ns	0.02	ns	ns
TNNov	H		14.49 b	12.60 b	12.99 b	13.78 b	13.47 a
	L		13.56 a	10.65 a	10.68 a	12.29 a	11.80 b
	Year						***
	Plot site		***	**	*	***	**
Freq.H-0.5	H	50,5	46	49,5	50,5	101,5 a	59,6
	L	42,5	42	52,5	48	82 b	37,2
	Year						***
	Plot site	ns	ns	ns	ns	*	ns
Freq.H-1	H	28	29.5	35	32	61.5 a	53.4
	L	25.5	30	31.5	33.5	55 b	35.1
	Year						***
	Plot site	ns	ns	ns	ns	**	ns

*P 0.01 **P 0.005 ***P 0.001. Abbreviations mean GGD=Growing Degree Days; THA=Thermal amplitude in summer; CNI=Cool night index; TN=Season minimum temperature; TX=Season Maximum temperature; ND30=Number of days with temperatures above 3ºC; ND35=Number of days with temperatures above 35ºC; TXJan=Maximum temperature in January; TNJan=Minimum temperature in January; TXNov=Maximum temperature in November; TNNov=Minimum temperature in November; Freq.H-0.5=Frequency in the number of hours with a temperature drop of 0.5ºC; Freq.H-1= Frequency in the number of hours with a temperature drop of 1ºC.

Table 2. Yield components (Yield kg/vine), Berry weight (g), Number of clusters per vine, Yield without rot as diseased fruit (kg/vine), Pruning weight (g/vine) and Ravaz Index (RI) for 2019, 2020, 2021, 2022 and 2023 with the statistical significance between High (H) and Low (L) Coastal Influence, and the year effect.

		2019	2020	2021	2022	2023	Treatment mean
Yield	H	1.47	2.39	2.28 b	1.06	1.69	1.79
	L	1.79	1.71	1.56 a	1.28	1.95	1.71
	Year						***
	Plot site	ns	ns	*	ns	ns	
Berry weight	H	1.15	1.28	1.61	1.25	1.37	1.3
	L	1.19	1.27	1.58	1.26	1.33	1.3
	Year						***
	Plot site	ns	ns	ns	ns	ns	
Cluster number	H	17.5	22.2	18.67	13.1 a	17.1	18.7
	L	21.2	20.7	24.25	20.7 b	19.0	19.7
	Year						*
	Plot site	ns	ns	ns	***	ns	
Yield without rot	H	1.47	2.39	2.28 b	0.91	1.69	1.76
	L	1.78	1.71	1.56 a	1.12	1.95	1.70
	Year						***
	Plot site	ns	ns	*	ns	ns	
Pruning weight	H	570.0	720.7 b	424.3	563.5	735.1 b	681.6
	L	433.3	496.3 a	533.8	747.8	530.2 a	495.8
	Year						ns
	Plot site	ns	*	ns	ns	***	
RI	H	4.13	3.6	4.96	1.59 a	2.58 a	3.17
	L	6.28	3.94	4.44	2.91 b	4.39 b	4.3
	Year						***
	Plot site	ns	ns	ns	**	***	

*P 0.01 **P 0.005 ***P 0.001

Albariño plasticity: when Albariño performance was analyzed between plots of High or Lower Atlantic Ocean exposition, differences in berry composition were observed (Figure 1). Higher ºBrix levels in berries resulting from the L plots were associated with greater Thermal amplitude during the ripening period ($R=0.62$; $p=0.003$), and higher acidity levels of berries from the same plots were associated with higher January Minimum Temperature.

PCA analysis showed that when plots, location and years were analyzed through Albariño performances, berry composition variables were more significant than yield components (70.6 % and 63.4% of the total variability, respectively). In that sense, a clear discrimination between berry acidity and sugar content was determined between plots with different expositions to the Atlantic Ocean (Figure 2C), where higher ºBrix were reached in L plots. Also, we found discrimination between the berry's final composition and years (Figure 2D), showing an interesting finding through the five studied years, where climate conditions were contrasted.

Figure 1. Plasticity assessment between Albariño plots at different oceanic exposition (High; and L)

(A) Grapes' ºBrix at harvest and Thermal Amplitude during summer (R pearson 0.62; p value 0.003), (B) Grapes' pH at harvest and Maximum Temperature in the Growing Season (R pearson 0.75; p value 0.0001), (C) Grapes' Total Acidity at harvest and January Minimum Temperature (R pearson 0.83; p value 0.0001), (D) Berry weight at harvest and Number of days above 30ºC (R pearson -0.67; p value 0.01).

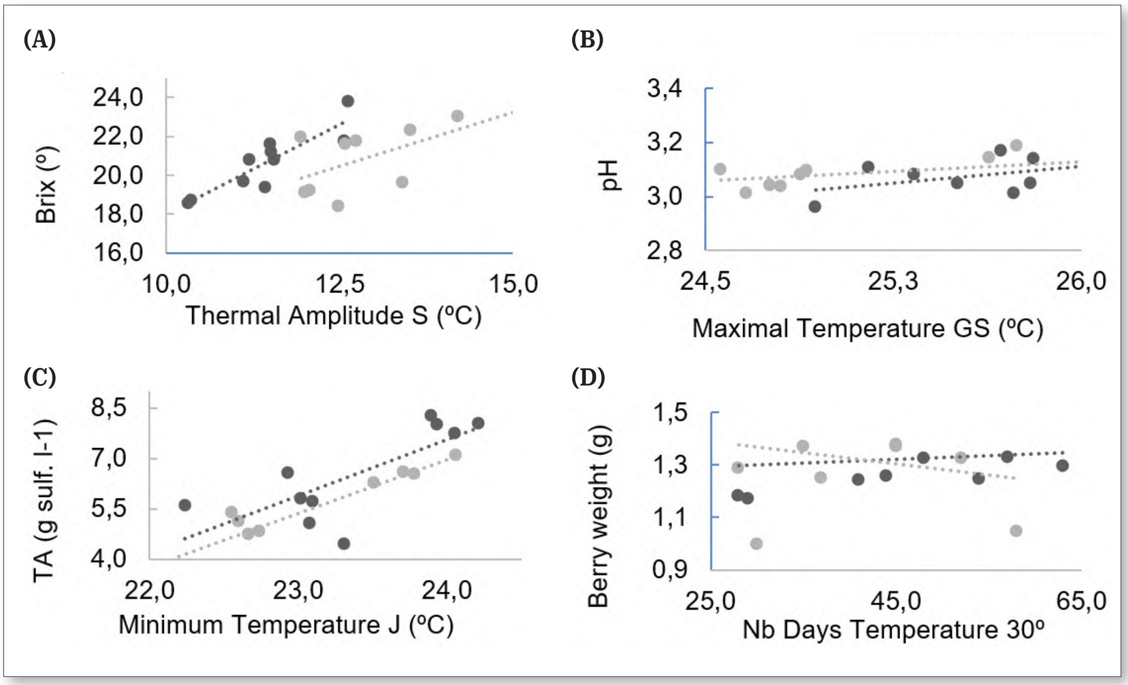
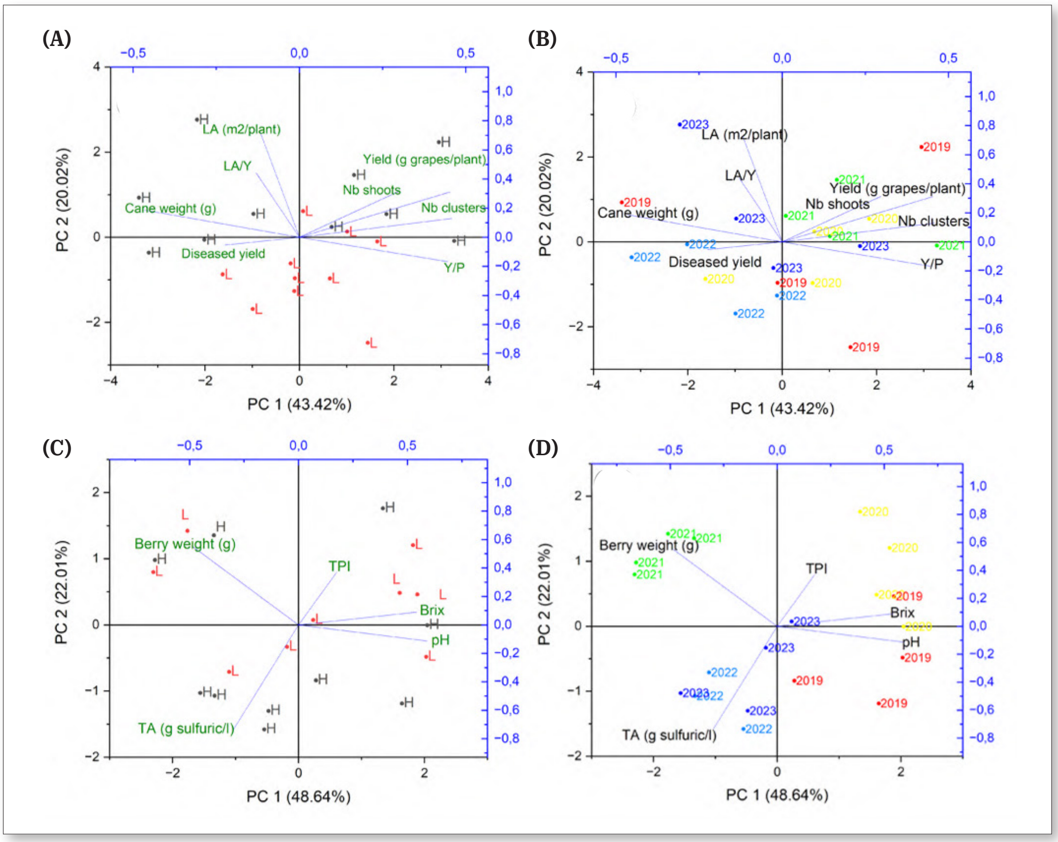


Figure 2. Principal Component Analysis.

(A) Yield components variables and plot location as score, (B) Yield components variables and year as score,
(C) Berry composition variables and plot location as score, (D) Berry composition variables and year as score.



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NOV 18, 2024 | 16 PM | SCIENTIFIC SESSION: **CLIMATE I - SCIENTIFIC ORAL**

Climate change adaptation strategy of Greco grapevine

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Keywords: **Greco grapevine, climate change, SWAP model, CWSI.**

ABSTRACT

In the southern Mediterranean regions, climate change (CC) increases air temperature, drought, and extreme events such as heat waves, limiting agricultural systems production. Among the various agricultural sectors, the viticultural sector has been hit hard by climate change. This is because it requires combining grape quality, grapevine cultivar acclimation, and farmers' future incomes.

In this context, it is necessary to study how climate change impacts specific wine-growing areas and which management approaches are necessary to adapt the production sectors and make the current DOCG areas resilient.

The main objective of this work is to study the responses of Greco grapevine (a native cultivar of southern Italy, Campania region) to climate change in order to provide practical support to farmers.

The field experiment was realized in Santa Paolina in a vineyard owned by Feudi di San Gregorio winery, within the GREASE project funded by the Campania region (Southern Italy) "Sustainable models of cultivation of the Greco grapevine: efficiency of use of resources and application of 'Footprint family' indicators" –PSR Campania 2014-2020; Measure 16 - Sub-measure 16.1.2.

Three soil management (cover cropping, natural grassing, and tillage) and two canopy management (double guyot and double guyot flipped) were compared over three years (2020-2022), during which the soil-plant-atmosphere system was monitored. The data collected were used to calibrate and validate the agro-hydrological model SWAP and to evaluate the impacts of climate change scenarios RCP 4.5 and 8.5 on the expected grape quality.

The results showed that water stress during veraison is the dominant factor influencing the attainment of oenological objectives, regardless of soil management practices. When the expected climate change is considered by means of simulation modelling application, a significant rise in water stress is expected. Therefore,

we highlight farmers will have to cope with irrigation to support quality in the scenario of increasing drought.

Introduction:

Vine productivity and profitability depend on several factors (e.g., soil fertility, climate, management practices, etc.) that drive soil-plant-atmosphere (SPA) processes. Among all, climate can be considered the most important factor that directly affects plant adaptation and, thus, agricultural systems resilience.

So, for current vineyards, a reliable assessment of the expected effects of climate change on both yield and quality of grapes become important by analyzing the components of different agricultural systems (e.g., soil, climate, plant) in an integrated way, as it can be properly done by a dynamic simulation modelling approach.

In the Campania region, southern Italy, Bonfante et al. carried out a study in 2018 based on the use of a simulation model of the SPA system on the effects of climate change on the adaptation of Aglianico grapevine. The applied methodology was based on the CWSI index (Crop Water Stress Index) and its correlation with the qualitative characteristics of the grapes.

The simulation model application is really important because it allows to study how climate change impacts specific wine-growing realities and which management approaches are necessary to adapt the production sectors and make the current DOCG areas resilient.

The main objective of this work is to study the Greco grapevine responses to climate change (a autochthonous cultivar of southern Italy, Campania region) when three soil managements (cover cropping, natural grassing, and tillage) and two canopy managements (double guyot and double guyot flipped) were applied in order to provide practical support to farmers.

Materials and methods:

The methodology applied consists of five steps:

1) Calibration and Validation of SWAP model on soil water balance on collected grapevine data.

2) Evaluation of CWSI correlation with plant responses and oenological field target.

3) Identification of management strategy to support Greco grapevine production.

4) Simulation of future CWSI and evaluation of the expected SPA system responses.

Study area and experimental design

The study area is located in a hilly environment of southern Italy (Santa Paolina -AV, Campania region: Lat. 41.019800°, Lon 14.830348°, elevation 90 m.a.s.l.), in a farm oriented to high-quality wine production named Feudi di San Gregorio. The studied vineyard hosted the Greco cultivar vines (controlled designation of origin –DOC / AOC), a standard clone population planted in the year 2008 on 420 A rootstock and grown in a bilateral spur-pruned guyot system and guyot flipped) (4347vines/ha).

The selected vineyard's representative soil is a Calcaric Cambisol, identified through a pedological survey and geophysical measurements conducted at the project's inception.

The experimental design was based on three soil managements (cover cropping, natural grassing, and tillage) and two canopy managements (double guyot and double guyot flipped): over three years (2020-2022), the soil, plant, and atmosphere system were monitored in the three areas.

Plant monitoring was conducted within each plot on 10 plants, randomly selected among those healthy-looking, weekly or biweekly depending on the measured parameter and the phenological phase. The Leaf Area Index (LAI), leaf water potential (LWP, measured with Scholander type pressure bomb), and grape traits at harvest were used to set up the simulation model application and evaluate the Greco grapevine acclimation capacity to climate change.

Simulation modeling.

The Soil–Water–Atmosphere–Plant (SWAP) model (Kroes et al., 2008) was applied to solve the soil water balance in each experimental plot during the three years of the project. It was previously used and tested in Italy and in the Campania Region and is very often used in viticulture by different authors (Minacapilli et al., 2009; Bonfante et al., 2011, 2015, and 2018; Rallo et al., 2011).

The soil water balance solved by SWAP was used to calculate the daily crop water stress index (CWSI) (Bonfante et al., 2011, 2015 and 2018) defined as follows:

CWSI= 1-Tr/Tp

where Tr is the daily actual water uptake and, Tp is the daily potential transpiration.

In each vine phenological stage, the sum of daily CWSI represents the cumulated plant water stress.

The calibrated and validated SWAP model was applied to simulate the vine response to climate change conditions.

The environmental information used in the simulation model application (e.g., temperature, rainfall, wind, solar radiation, etc.) and calibration (e.g., soil water content) was collected by means of a DAVIS instrument weather station placed in the middle of the vineyard. Moreover, a node in each experimental plot (six) measured the soil water content by means of TDR probes (at three depths).

Once the model was calibrated and validated, it was possible to simulate the effects on plant response to climate change conditions. To do this, future climate scenarios, obtained by using the high resolution regional climate model (RCM) COSMO-CLM (Rockel et al., 2008), optimized over the Italian area (Bucchignani et al., 2015, Zollo et al. 2015), of the Representative Concentration Pathway (RCP) 4.5 and 8.5, were applied; the SWAP simulation results were then reported in terms of Reference Climate - RC (1971–2005) and RCP 4.5 and 8.5 divided into three different time periods (2010–2040, 2040–2070 and 2070–2100).

Results and discussion:

The SWAP model has been calibrated and validated in each experimental plot over the three years of the experiment, comparing the soil water content (SWC) estimated by the model with the SWC measured in the field at three different depths by TDR probes (Fig.1).

The capacity of the SWAP model to simulate the soil water balance was good, as reported by the model performance indexes in Table 1.

From the simulations carried out, it was possible to calculate the CWSI in each phenological phase of the vine. This index was validated through comparison with the LWP measured in the field and the productive (e.g. average weight of the bunches) and vegetative responses of the vine (e.g., NDVI from drone). Once the relationship between CWSI and behaviour in the field was verified, it was possible to relate it to the characteristics of the grapes at harvest. The results showed that water stress during veraison is the dominant factor influencing the attainment of oenological objectives, regardless of soil management practices. In particular, a CWSI threshold of 20% was detected at veraison below which the production of ultra-quality grapes (UQG) is guaranteed.

This outcome becomes more significant when we take into account that varying climatic conditions occurred during the three years of experimentation. The rainfall during the growing season ranged from 190 mm (high stress) in 2021 to 573 mm in 2022, with average evapotranspiration being roughly the same at approximately 750 mm.

The analysis of the impacts of climate change indicates that water stress will increase in all vine growth phases. Specifically, during veraison, it is expected that the Crop Water Stress Index (CWSI) will increase by 7%, 9%, and 8% in the RCP 4.5 scenario, and by 4%, 9%, and 14% in the RCP 8.5 as compared to the Reference Condition (RC) in the time periods of 2010-2040, 2040-2070, and 2070-2100.

This will require the introduction of cultivation strategies to improve vines acclimation based on irrigation to support grape quality. On the one hand, the future scenarios analysed have indicated an increase in thermal regimes that are favourable for the cultivation of Greco vine (an increase of about 20% of current average value of Amerine and Winkler index - 1827 GDD is expected). However, it is important to note that a risk of extreme thermal events is present.

Conclusion:

Vine water stress represents the main factor affecting the current and future adaptation of the cultivation of the GRECO vine in the GRECO DOCG area in the Campania region.

In the pedoclimate analysed, the change in soil management did not give important signals in the water management of the vineyard, but it remains the first step to deal with problems relating to soil degradation processes (e.g., erosion). The change in canopy management only partially helps to improve the plant's water use efficiency. For these reasons, it can be concluded that in the current and near future, it will be necessary to be prepared for irrigation practices in the areas where the Greco vine is currently rainfed-cultivated to achieve the level of water stress required to reach the field oenological goal.

Table 1. The average value of the performance indices (Loague and Green, 1991) of the SWAP model application obtained from the comparison between the soil water content measured and estimated at three depths (-15, -35, and -65 cm) in the six experimental plots over the three years of the project. (RMSE= root mean squared error; CRM= coefficient of residual mass; r= coefficient of correlation; EF= modeling efficiency)

Index	-15 cm	-35 cm	-65 cm	Mean
RMSE	0.07	0.05	0.05	0.05
CRM	-0.15	-0.05	-0.07	-0.09
r	0.91	0.91	0.92	0.91
EF	0.16	0.67	0.54	0.46

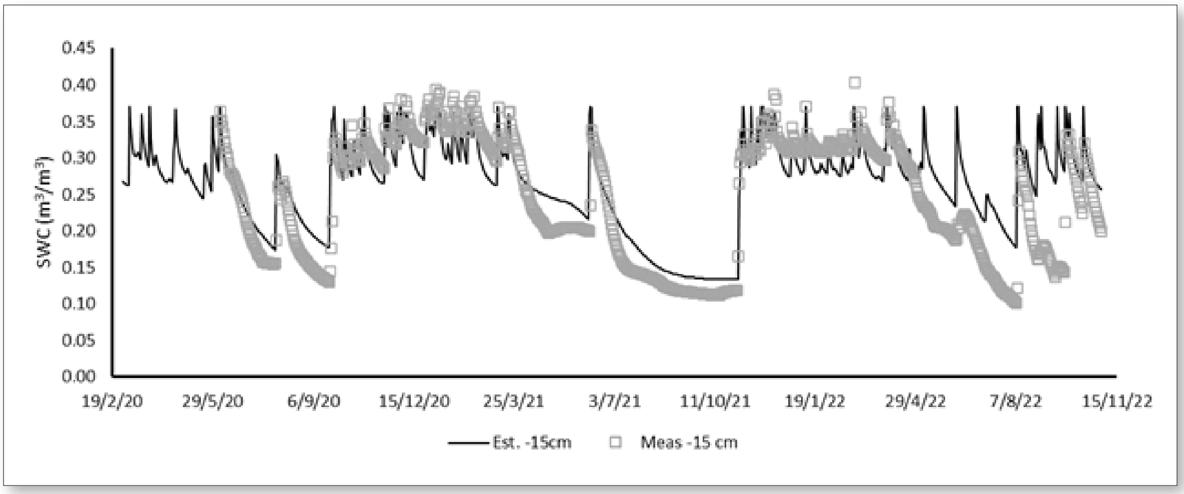

Figure 1. This is an example of a comparison between the soil water content (SWC) estimated (Est.) by the simulation model SWAP and measured (Meas.) with TDR probes at -15 cm below the soil surface during the three years of the experiment.

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NOV 18, 2024 | 16.15 PM | SCIENTIFIC SESSION: **CLIMATE I - SCIENTIFIC ORAL**

Physiological responses of Sauvignon Blanc to sequential extreme weather events: implications for vineyard management in a changing climate

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Keywords: ***Vitis vinifera*; RNA-Seq; drought; heat stress; transcriptomic analysis.**

ABSTRACT

Climate plays a predominant role in grapevine development, growth and productivity and several environmental variables are already known to pose challenges to grapevine production and the wine industry. In this context, a number of extreme weather events, already occurring and expected to occur in the next decades, even more frequently and with higher magnitude, results from current climate change scenario. The aim of this study was to examine the physiological responses of roots, leaves, and berries of *Vitis vinifera* cv. Sauvignon Blanc to consecutive and combined stressors simulated in a semi-controlled environment. We specifically investigated the effects of flooding during bud-break followed by multiple summer stresses, such as heatwaves and drought applied prior to *véraison*. High-throughput RNA-Seq and NMR technologies were used for transcriptomic and metabolomic analysis, respectively. A comprehensive hormone profiling was also carried out. The results pointed out that each of the three organs responded differently to the diverse stress factors and their combinations. Sequential stress in berries, such as a summer heatwave following a flooding event during bud-break, can affect phenological development and fruit ripening, impacting the quality of berries and potentially wine. A temporal difference in the transcription of genes between the roots and the leaves was also observed. Furthermore, heatwaves alone and in combination with flooding had an impact on the roots and leaves at metabolic, hormonal and transcription-

al levels. A physiological model was proposed that may support the development of sustainable vineyard management solutions to improve the water use efficiency and adaptation capacity of actual viticultural systems to future scenarios.

Introduction:
The grapevine *(Vitis vinifera)* plays a crucial economic role in many countries. Modern viticulture, however, faces significant agronomic and environmental challenges, particularly related to ongoing climate changes. In numerous European locations, average temperatures have increased by more than 1.5°C (Jones et al., 2005). These findings are concerning as they could lead to further shifts in phenological stages, alterations in growing conditions, and changes in crop yield and quality of the final product in the near future (Hannah et al., 2013). Therefore, new strategies to address these complex issues are essential.

The resistance of grapevines to environmental stresses has been extensively investigated, particularly regarding water (drought) and thermal stress (heat waves). However, less is known about the combination of two or more simultaneous stresses (Mittler, 2006). Indeed, the combination of two stresses is not always equal to the sum of the individual stresses. This is especially true for drought and thermal stress, which rarely occur as isolated events in nature but often follow one another or occur simultaneously (Suzuki et al., 2014), particularly in the context of climate change.

This study investigated the impact of combined environmental stresses on plants, focusing on water and thermal stresses, and including waterlogging stress to simulate spring flooding conditions. The primary objective was to explore the variations at the transcriptomic and metabolic levels under different stress conditions. To this aim, RNA sequencing (RNA-Seq) was used for transcriptomic analysis, while Nuclear Magnetic Resonance (NMR) was adopted for metabolic profiling, along with hormonal analysis. Samples were collected from berries, leaves, and roots to ensure a comprehensive understanding. The insights gained from this research are intended to develop a physiological response model that will aid in the creation of more sustainable vineyard management practices, especially regarding water resource management. Ultimately, this approach aims to enhance the fitness of grapevines, enabling them to better withstand the challenges posed by future climate change.

Materials and methods:
Plant Material, Experimental Setup, and Sampling
Experiments were carried out in 2017 and 2018 on potted grapevines, *Vitis vinifera* cv. Sauvignon Blanc. In brief, a suitable number (400) of three - years -old plants were grown in 10L pots filled with a sand–pumice-peat mixture (1:1:3 in volume) under partially controlled conditions in two plastic film tunnels under continuous ventilation (to avoid overheating) and optimal irrigation located at the Experimental Farm of the University of Padova "L. Toniolo" in Legnaro, north-east of Italy. Half of the plants for each tunnel underwent waterlogging stress during spring, approximately at budbreak (BBCH stage 09), as previously described. Just before véraison, at 46 DAA (BBCH stage 79–81) a heatwave was imposed in Tunnel n.1 by simulating the natural time course of such extreme events, i.e., an initial phase of drought and, when soil water content reached 30% of field capacity (after 9 days), a second phase during which temperatures were increased by setting up the thermostat at 5 °C higher than Tunnel n.2 for six consecutive days. Samples were collected from all four groups of plants (C, control; F, flooded; H, heatwave; FH, flooded plus heatwave) at the beginning of the stress (T0; 46

DAA), when the soil water content was at 30 % of Fc in stressed plants (T1; 55 DAA), at four days after temperature increase (T2; 59 DAA), at the end of the heatwave (T3; 61 DAA), and after 9 days of recovery (T4; 70 DAA) and, finally, at the ripening of the control grapes (T5; 74 DAA). At each sampling time point, berries, roots and leaves were collected from five randomly chosen grapevines per treatment, frozen in liquid nitrogen, and stored separately at -80°C as five biological replicates for the following analyses.

RNA Isolation and RNA-Seq Analyses

Total RNA was extracted using the method of (Rizzini et al., 2009) and used for RNA-Seq at the CRIBI center of the University of Padova using an Illumina NextSeq 500 platform (Illumina, San Diego, CA, United States). RNA-Seq reads were quality-checked using FastQC (Brabaham Bioinformatics, Cambridge, United Kingdom) and resulted of very high quality. Spliced alignments were performed with TopHat (Trapnell et al., 2012). Quantification was performed by using the Bedtools coverage program (Quinlan & Hall, 2010). A revised version of the Grape genome based on the 12X Genoscope Pinot Noir genome was used for reads mapping, along with the related gff file and GO functional annotation. The RNA-Seq counts were analyzed with the online bioinformatic pipeline iDEP version 0.96 (Ge et al., 2018). The Differentially Expressed Genes (DEGs) were identified using DESeq2 (Love et al., 2014) with an FDR < 0.05 and a minimum fold change of 1.5.

Hormone Analysis

For the phytohormones levels determination, berries, roots and leaves tissues from different time points and treatments were lyophilized before the analysis. Phytohormones, including abscisic acid (ABA), auxin indole-3-acetic acid (IAA), jasmonic acid (JA), and its conjugate jasmonoyl-isoleucine (JA-Ile), jasmonic acid precursor 12-oxo-phytodienoic acid (OPDA), salicylic acid (SA), cytokinins trans-zeatin (Z), its riboside trans-zeatin riboside (ZR), 2-isopentenyl adenine (2iP) and its riboside isopentenyl adenosine (IPA), gibberellins GA1, GA3, GA4 and GA7, and the precursor of ethylene 1-aminocyclopropane-1-carboxylic acid (ACC), were analyzed by UHPLC-ESI-MS/MS in MRM mode as previously described (Müller & Munné-Bosch, 2011). Quantification was made by calculating recovery rates for each sample by using deuterium-labeled compounds as internal standards (OlChemIm Ltd. (Olomouc, Czech Republic).

NMR Analysis

Pulverized samples were freeze-dried overnight, yielding 200 ± 5 mg of dried powder each and then stored at -80°C. Polar and hydrophobic metabolites were extracted with deuterated solvents by using a chloroform/water/methanol solution 10:10:1, similarly to Folch et al. (1957). NMR spectra were acquired with a Bruker Avance Neo 600 MHz spectrometer (Bruker BioSpin, Karlsruhe, Germany) equipped with a Prodigy cryoprobe and using Topspin 4.1.1 software, applying a noesypr1D pulse sequence with spectral width 12 kHz, acquisition time 2.99 s, 16 scans, relaxation delay 4 s, and four dummy scans. All spectra were processed with an ACD NMR processor 12.1 (shortened to ACD, ACD Labs). Spectra were grouped together, and intelligent bucketing was performed in ACD (the water suppression region was excluded). Signal area values were organized into a matrix to be processed using MetaboAnalyst 5.0.

Results and discussion:

Utilizing the web-based tool iDEP, we conducted a series of exploratory analyses. Given the constraints of this abstract, we will focus on summarizing the primary findings. DESeq2 package allowed us to identify the DEGs for each comparison and each organ (berries, leaves, and roots). Numerous DEGs were identified across the three analysed organs and contrasts. However, we will give priority to those exhibiting the most significant biological differences. In berries (Fig. 1A), we found a higher number of DEGs in T1, T2 and T5 contrasts. For the berries undergoing the heatwave, the highest number of DEGs was found between H and F at T1, with 2475 genes up-regulated and 1869 down-regulated, in which the GO term *"Photosynthesis"* was the most significantly enriched for the up-regulated genes (data not showed). Within the six contrasts at T2, the comparison between C and H berries presented a total of 2936 DEGs, 1656 genes up-regulated and 1280 down-regulated, followed by the contrast between H and F with a total of 2865 DEGs. A huge increase in total DEGs occurred at harvest (T5), in correspondence with physiological ripening. The biggest amount of DEGs was found for C/FH (3351), followed by FH/F (2795) and C/H (2679). GO terms related to sterol/steroid biosynthesis were detected that could be related to the basic components of cellular membranes rather than to a brassinosteroids signalling, since these hormones are usually active at the pre-*véraison* developmental stage (Symons et al., 2006). In leaves (Fig. 1B) and roots (Fig. 1C), the majority of identified DEGs were found in the T2 and T3 contrasts. Two major differences can be highlighted in roots. At T1 we observed a major number of DEGs in comparison to leaves and the down-regulated genes in general are higher than those up-regulated.

Analysis of the levels of key phytohormones in Sauvignon Blanc berry samples showed, as expected, highly significant differences in ABA content between treatments and sampling timepoints. As expected, T1, T2, and T3 were the ones presenting the highest ABA content, as its accumulation starts at the onset of the ripening process (Coombe & Hale, 1973). ACC showed a progressive increment from the beginning of the experiment, with statistically significant differences between timepoints, and reaching its maximum at T4 after the recovery period, followed by a slight decrease at harvest time in all four treatments. In roots we found high level of IPA, IAA, ACC and JA. Conversely, in the leaves, our analysis revealed higher concentrations of SA, ACC, ZR, and Z.

A metabolomic fingerprint was carried out through NMR on berry and leaf samples collected at T2 and T4. Differently from previous studies pointing out an increase in sugars, such as glucose, fructose, and sucrose, during drought stress (Kumar et al., 2021) a detailed view of these single compounds quantified through NMR did not point out any consistent trend. Concerning the other compounds detected through NMR, two main classes of metabolites were markedly shown to increase upon stress, i.e., the amino acids and chlorogenic acid (CGA). Concerning the former, we can further subdivide the amino acids into those produced by stressed berries mainly at T2, such as tyrosine, those mostly found at T4, such as proline, and those detected at both timepoints, such as alanine and -aminobutyric acid (GABA), while CGA was prevalently produced upon stress at T2. A relevant amount of literature reports several findings about the involvement of these compounds in response to different types of stress, although the reaction is often species-specific. For example, tyrosine was previously found to be involved in drought stress response in Arabidopsis (Fàbregas et al., 2018).

Conclusion:

The findings pointed out in the present research may impact wine production at different levels, from the agronomic man-

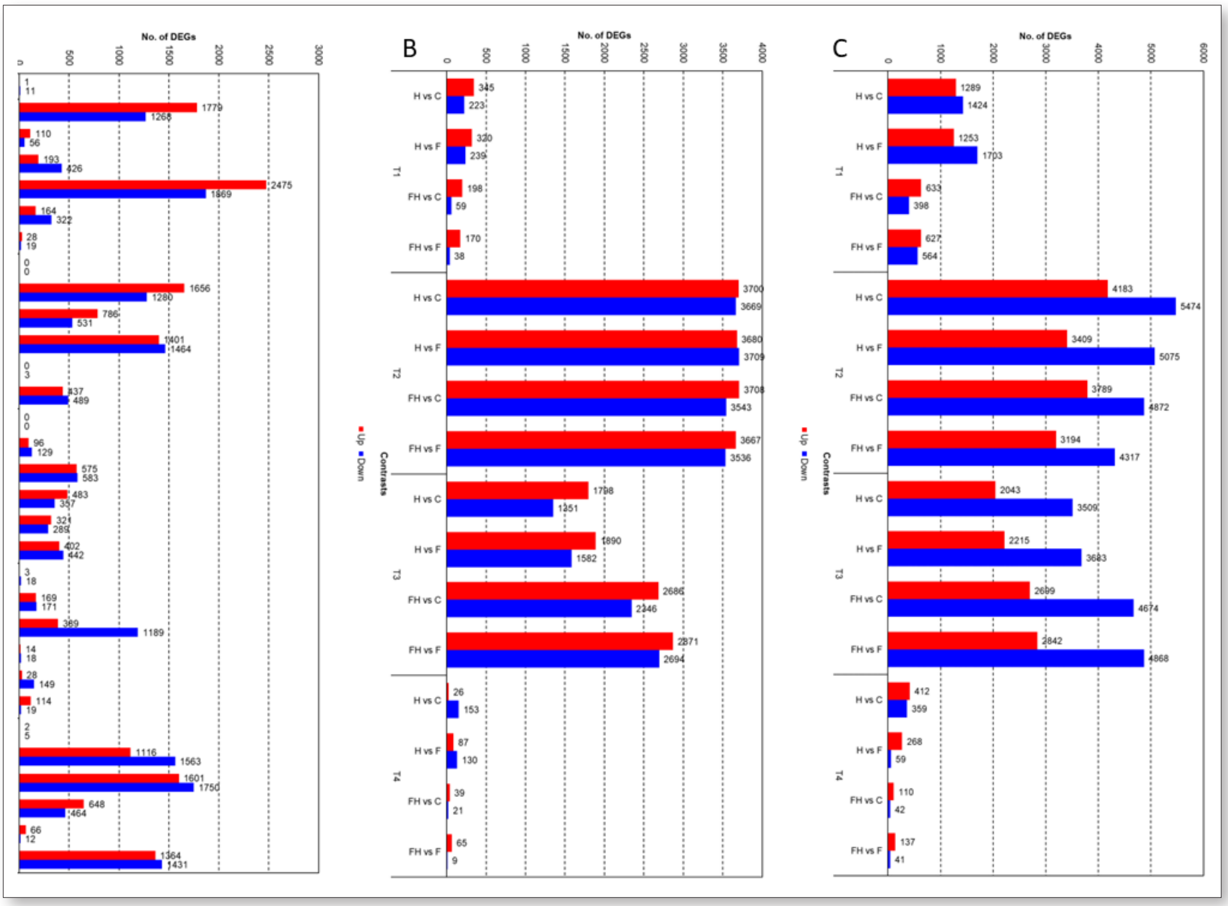

Figure 1. The number of differentially expressed genes (DEGs) in a selected number of contrasts from T0 to T5 in berries (A) and from T1 to T4 in leaves (B) and roots (C).
Up- (red) and down- (blue) regulated genes are shown for each comparison. Samples within each contrast are named according to the timepoint and treatment (C, control; F, flooded; H, heatwave; FH, flooded plus heatwave).

agement of the vineyard to wine quality, passing through a physiological characterization of the berry response to stress. Another important piece of information coming from our study is represented by the acceleration of berry ripening in the vines that underwent flooding stress at bud-break. Taken as a whole, our results may support the development of sustainable vineyard management solutions to improve the water use efficiency and adaptation capacity of actual viticultural systems to future climate scenarios, thus providing relevant information for the wine sector.

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NOV 19, 2024 | 9 AM | SCIENTIFIC SESSION: CLIMATE II - PLENARY CONFERENCE (KEYNOTE SPEAKER)

Climate diversity of vitivinicultural terroirs at local scale level

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Keywords: **topoclimatology, terrain, viticulture, spatial variability, review.**

ABSTRACT

The early 21st century saw a significant increase in climate measurement in vineyards, enabling the quantification of the contribution of climate variability to the diversity of terroirs. Temperature differences over just a few hundred meters are thus responsible for phenological differences and potential grape ripening by ten days or more, as well as varying exposures to thermal stress, both heat and frost. While temperature has been the subject of a predominantly extensive scientific literature, it is not the only climatic variable whose local variability plays a major role in the diversity of terroirs. Wind exposure, humidity, solar radiation, and precipitation are all elements whose local variability alters viticultural conditions and the oenological potential of grapes. This communication reviews (1) the geographical elements that shape the local variability of the climate, (2) the consequences of this local variability on viticultural terroirs, and (3) how to quantify and adapt to it.

Introduction:

Initially used to designate a geographical area, the link between terroir and wine quality was recognized from the late 16th century in a few works (Leturcq, 2020). Although detached from the notion of terroir, the role of climate, particularly local climate, has long been considered essential for producing good wines (de Serres, 1600). From the late 20th century, especially with the normalization of the concept of terroir by the International Organisation of Vine and Wine (OIV, 2010), climate characterization has been the subject of an increasing body of literature, though still largely overshadowed by studies on soil or plant-based zoning (Vaudour et al., 2015). The contribution of climate to wine quality is often studied through the lens of vintage effects (e.g. Davis et al., 2019; van Leeuwen et al., 2004). When climate's role in the terroir effect is evaluated, it is often at a very large scale, and it was only from the 20th century, with the advent of sensors that automatically and affordably record climate data, that local scale studies began (Bois, 2020; Quénol, 2014). Local (or fine) scale here refers to climate variations over a few tens of meters to a few tens of kilometers (Oke, 1987). Studying climate on such scales, referred to as topoclimatology means focusing on the climate at the site level (from the Greek “topos” meaning “place”). At this scale, substantial differences in temperature (de Rességuier et al., 2020) or precipitation (Bois et al., 2020) are observed. The consequences for phenology, diseases, or climatic hazards causing vine damage (frost, hail) can be significant (Bois et al., 2011; de Rességuier et al., 2020; Melyon-Delage et al., 2019). This communication reviews topoclimatic variability within wine-growing terroirs. It describes the geographical elements contributing to this variability and recalls some methodological elements for assessing it.

Climate Elements and Their Local Spatial Variability:

At the local scale, the role of topography and land use is crucial for most climate elements. However, for precipitation, these geographical characteristics have little influence over just a few kilometers, unless the relief variations are very pronounced. Hereafter, the spatial variability at the local scale of solar radiation, wind, temperature, relative humidity, and precipitation, along with their consequences for viticulture, is summarized.

Solar Radiation

At a large (macroclimatic) scale, incident solar radiation depends on latitude, atmospheric thickness, purity, and cloud cover (Oke, 1987). Its spatial variability can be reasonably estimated using simple astronomical geometry equations and satellite images to identify cloud cover over a location (Rigollier et al., 2004). At a finer scale, cloud cover is fairly homogeneous except in specific cases (fog in plains or near the sea, cloud cover due to orographic uplift, as in California, Terjung et al., 1969), and over distances of a few kilometers or tens of kilometers, solar radiation measured on flat terrain varies little (Huard, 2005). At this scale, topography strongly controls the amount of solar radiation received. Thus, using digital terrain models (DTMs), it is easy to model solar radiation variations at a vineyard parcel.

In Valtellina, a mountainous wine region in northern Italy, the spatial variability of simulated incident solar radiation (which can vary by about 15% annually between vineyard parcels) appears, combined with altitude, as a factor significantly correlated with the spatial differences in vine phenology and phenolic grape ripeness (Failla et al., 2004). In South Tyrol, links between an index based on incident solar radiation (varying by 16% between the studied parcels due to relief) and grape sugar content at ripeness have also been observed (Ferretti, 2021). Variations in incident solar radiation have also been used as a key input for modeling the water balance in the Rheingau region of Germany (Hofmann et al., 2014). In this region, climate simulations for the 21st century project significant differences in vine water stress due to terrain over short distances: from a few hundred meters to a few kilometers (Hofmann et al., 2022). These significant differences in incident radiation and their consequences on parcel-level evapotranspiration, as well as runoff, are elements contributing to these simulated differences. An analysis in Bordeaux relied on combining satellite-estimated solar irradiance data with a model of incident solar radiation based on relief. It notably shows that although the relief is not very pronounced in this wine region, local differences in solar radiation during grape maturation are around plus or minus 13% relative to the average for the Saint-Emilion and Côtes de Bourg production areas (Bois et al., 2008).

Wind

The speed and direction of winds at the local scale are largely influenced by topography and large water bodies. Diurnal variations in wind direction are observed: at night, mountain breezes form, also known as “katabatic” winds, corresponding to the flow of cold air. During the day, a few hours after sunrise, valley breezes (“anabatic” winds) are observed, flowing from lower altitudes to higher altitudes. This phenomenon is not confined to mountainous regions. In the Burgundy wine region, where the topography is relatively gentle, the average wind direction during each hour of the day is very clearly influenced by slope and valley breeze phenomena (Madelin et al., 2014).

At the local or microclimatic scale, wind is significantly affected by hedges and buildings. The well-known “windbreak” effect reduces wind speed downstream of a hedge or similar obstacle for a distance of up to 10 times the height of the obstacle, with the maximum effect occurring at a distance of 4 to 5 times the obstacle’s height (Guyot, 1987; Oke, 1987). In areas sheltered from the wind, temperature extremes are amplified. Since the air circulates less, the temperature near the ground is strongly linked to the soil’s radiative balance: it heats up on sunny days and cools down significantly during clear nights (Guyot, 1987).

Temperature

Local variations in air temperature have been extensively documented, particularly in viticultural environments (Quénol, 2014). Several studies report variations reaching 5 to 15°C on average over multiple years across distances of several hundred meters (Jones & Jones, 2016), kilometers (de Rességuier et al., 2020), and even tens of kilometers (Bois et al., 2018).
Local temperature differences depend on the atmospheric adiabatic gradient, the radiative balance at ground level, air advection, and the energy exchanges associated with latent heat and energy conduction at the ground level (Oke, 1987). These factors vary significantly depending on the topography: altitude, slope, the position of valleys or ridges, and exposure to solar radiation are all factors contributing to substantial local temperature differences (Joly et al., 2012). Land use also plays a crucial role in the energy balance at ground level: higher temperatures in urban areas, lower during the day in forested areas or near water bodies (Oke, 1987).

The impact of land use and relief on the spatial variability of temperatures is particularly pronounced in calm and dry weather, especially during nighttime. Conversely, these differences are smoothed out in overcast and windy conditions (Cantat, 2004; Le Roux et al., 2017).

Precipitation

At mesoscale level, differences of 200 to 400 mm during the growing season have been reported over areas covering 80 to 200 km in regions of northern Spain (Blanco-Ward et al., 2015; Sánchez et al., 2019) where relief is pronounced.

The spatial variability of precipitation has hardly been studied at the local scale in viticulture. In the Langhe wine region, differences in precipitation of around 20% have been reported between the villages of Barolo and La Morra, which are a few kilometers apart (Mania et al., 2021). In the Corton area (Burgundy, France), precipitation differences over a few kilometers can potentially lead to variations in vine water status between flowering and veraison that are sometimes as significant as those observed at the regional scale (200 km apart), and thus likely result in differences in grape quality and quantity produced (Bois et al., 2020). However, the wettest sectors vary from year to year and within the growing season. These two examples do not allow for a conclusion about the fine-scale spatial variability of rainfall and its impact for viticulture. Further scientific studies are needed to fill this knowledge gap, which will enable better understanding of the optimal distribution of climate stations for recording precipitation, thus aiding in the management of vine water status and phytosanitary pressure.

Humidity

For a given amount of water vapor contained in the atmosphere, relative humidity depends on air temperature. Therefore, areas where cold air tends to accumulate (wind-sheltered areas, topographical depressions) tend to have higher humidity. Proximity to water bodies (lakes, rivers, seas) also leads to higher humidity (Oke, 1987), while urban areas tend to have lower humidity (Cuadrat et al., 2015). There is a notable lack of literature on the study of spatial variability in air humidity at the local scale, which needs to be addressed.

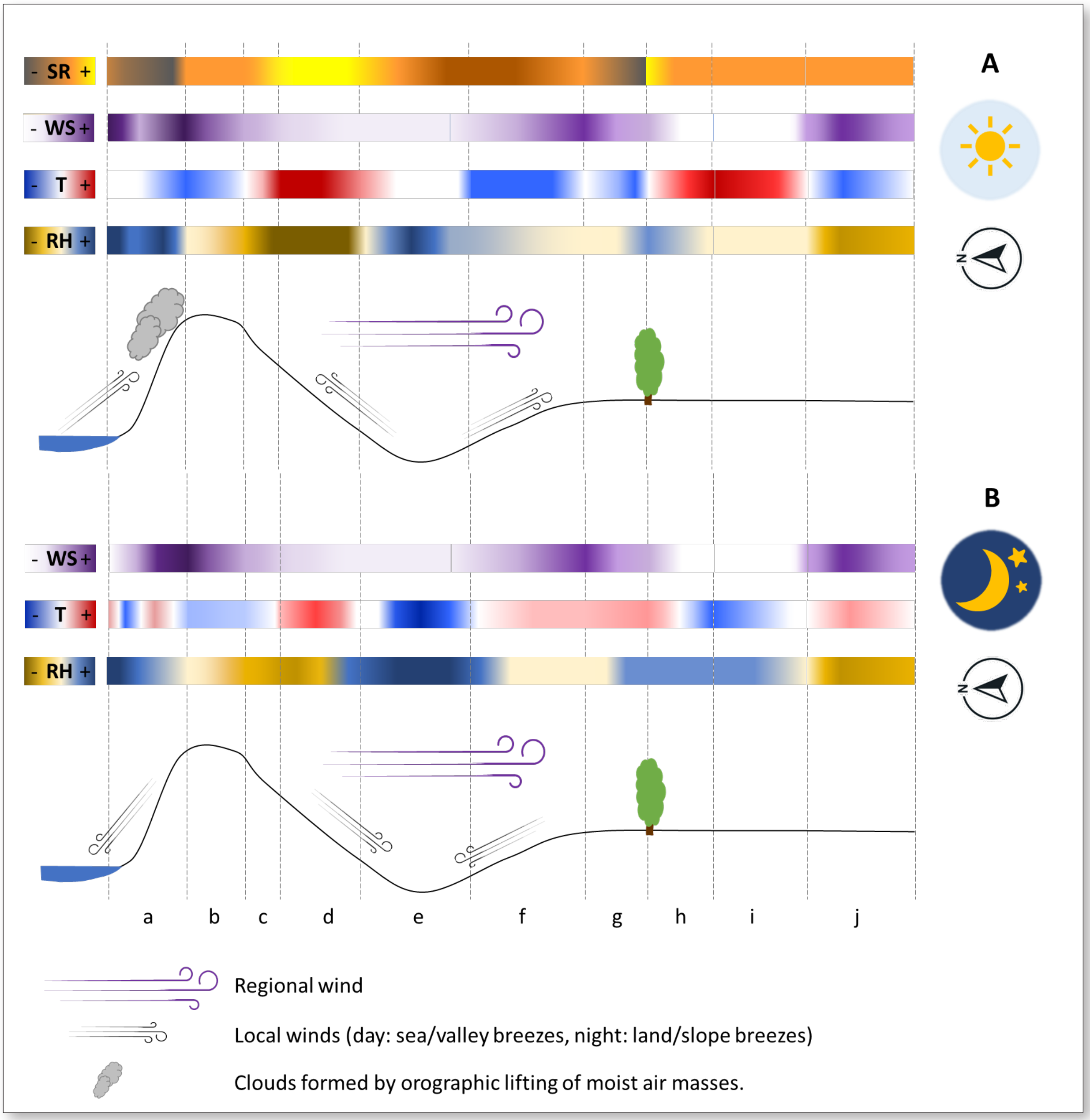

Figure 1. Local variations in solar radiation (SR), regional wind speed (WS), air temperature (T) and relative humidity (RH), based on topography, water bodies, and vegetation during the day (A) and at night (B). The vertical dotted lines mark several sites whose expected climatic conditions are described in Table 1. Compilation based upon various literature, amongst which Oke (1987) and Guyot (1987).

Consequences of Relief and Land Use on Spatial Variability of Climate Elements:

Figure 1 presents the expected daily (Figure 1A) and nightly (Figure 1B) variations in solar radiation (SR), relative humidity (HR), regional wind speed (WS), and air temperature (T) based on relief and land use for 10 hypothetical sites. The local variations of climate elements related to relief and land use are discussed in Table 1.

Table 1. Description of observed spatial variations for each of the four climate elements at the 10 sites indicated by lowercase letters in Figure 1. LR: Lapse rate, TI: thermal inversion, FE: Foehn effect.

Site	Solar Radiation (SR)	Regional Wind Speed (WS)	Temperature (T)	Relative humidity (RH)
a	Low: north aspect	Moderately low on the coast at night, stronger during the day (sea breeze). Increases due to airflow contraction encountering the relief	DAY: slightly low near the coast (sea breeze) and very low on the relief (LR though reduced by FE, low SR) NIGHT: mild near the coast (thermal regulation) and halfway up the slope (TI ceiling). Low inland down the hill (slope breeze) and slightly low at the top of the slope (LR)	DAY: high near the coast, high halfway up the slope due to condensation (FE) NIGHT: high near the coast and slightly lower towards inland
b	Medium: flat terrain	High: airflow contraction	DAY: low (LR) NIGHT: low (LR)	DAY: moderate NIGHT: moderate
c	High: south-exposed slope	Low: airflow expansion	DAY: moderate at the top of the slope (LR compensated by high SR), high at mid slope (high SR) NIGHT: low at the top of the slope (LR)	DAY: low (foehn effect with high SR and T) NIGHT: moderately low (drained soils)
d	High: south-exposed slope	Low: airflow expansion and turbulence	DAY: high (high SR and FE) NIGHT: high (heat stored in the soil and TI ceiling)	DAY: very low (high SR and T) NIGHT: moderately low (drained soils vs radiation storage during the day)
e	Low: sheltered area	Low: topographical depression sheltered from nearby reliefs	DAY: moderate (embedding, humidity) NIGHT: low (cold air lake)	DAY: high (low SR, water accumulation, low WS) NIGHT: very high (low T, low WS, water accumulation)
f	Low: north aspect	High: airflow contraction	DAY: moderately low (low SR, air mixing) NIGHT: moderately high (TI ceiling and air mixing)	DAY: moderate (low SR, low T, drained soils) NIGHT: moderate to low (mixing, drainage)

Site	Solar Radiation (SR)	Regional Wind Speed (WS)	Temperature (T)	Relative humidity (RH)
g	Very low in vegetation shade	High: uplift due to hedge and relief but low nearby the hedge (turbulence)	DAY: moderately low (low SR, air mixing, hedge shade) NIGHT: moderately high (radiative inputs from the hedge)	DAY: high near the hedge NIGHT: high near the hedge
h	High near vegetation (reflection) then moderate (flat terrain)	Low: windbreak hedge	DAY: moderately high (low wind) NIGHT: moderately high near the hedge (radiative inputs), then low (low wind)	DAY: moderately high (low WS, hedge humidity) NIGHT: moderately high (low WS, hedge humidity)
i	Medium: flat terrain	Very low: minimum for a distance of 4 times the height of the hedge	DAY: high (very low wind) NIGHT: low (very low wind)	DAY: moderate (high T, low WS) NIGHT: moderately high (low T, low WS)
j	Medium: flat terrain	Moderate: airflow deflection (distance of 6 to 8 times the height of the hedge)	DAY: moderately low (air mixing) NIGHT: moderately high (air mixing)	DAY: low (moderate WS) NIGHT: low (moderate WS)

How to Analyze the Spatial Variability of Climate in Viticulture at a Fine Scale:
The processes for analyzing the spatial variables of climate are the subject of a substantial number of scientific articles. However, the applications are often dedicated to climate spatialization at macro- or meso-climatic scales (Bois, 2020). At these scales, climate naturally varies more than at fine scales simply because, in the broader space, the probability of observing a greater number of elements causing climate variability increases: it is more common to see variations of several hundred meters in altitude across a continent than over a small wine appellation area. Furthermore, latitude, a determining factor of climate variability across a country or continent, does not contribute to climate diversity at the local scale (between 1 and 50 km). Although there is no clear established protocol for studying climate at the local scale, numerous studies conducted in recent years, focusing largely on air temperature in viticulture, allow us to outline the main lines of a study protocol for local climate. Local climate spatial analysis can be carried out by:

- Numerical climate modeling
- Remote sensing
- Station measurements

Numerical climate modeling can be extremely simple (estimating local climate variations based on relief, as in Irimia et al., 2018) or can rely on atmospheric models or coupled models simulating weather conditions at any point in space over a given time step, thus allowing the evaluation of local climate variability (e.g. Sturman et al., 2017).

Remote sensing allows for the production of information at relatively fine scales for certain parameters. Two widely used examples are: the use of satellite images to estimate solar radiation through cloud cover measurement (Bois et al., 2008) and the use of radar imaging to spatialize precipitation (Pauthier et al., 2016).

Station measurements do not provide exhaustive spatial information unless the collected data are interpolated across the studied space. However, they do allow for precise evaluation of differences between various measurement sites. If the conditions for setting up the stations conform to those used for calibrating agronomic models, the data produced can directly feed into these models for vineyard applications. Climate data measured at stations can be estimated at any point in space. To achieve this, one relies on so-called ancillary variables or environmental covariates. These are generally known variables at all points in space that describe the environment and will be used to predict the climate variable of interest: altitude, slope, theoretical exposure to solar radiation, landscape embedding, slope curvature, vegetation index, surface temperature measured through remote sensing, etc. These variables will calibrate spatial interpolation models at the measurement sites and project them to all other points in space. Such spatial interpolation models are typically regression-kriging (Bois et al., 2018) or machine learning approaches (Le Roux et al., 2017).

Conclusion

The instrumentation of the environment and space, along with a better understanding of atmospheric physics, and the increasing power of numerical computation and data storage offer datasets that allow for climate analysis with increasingly fine spatial resolution. Thus, recent scientific literature regarding local climate analysis is becoming denser and enables the identification of knowledge elements that outline a methodological framework for documenting climate at the local scale in viticulture. This is particularly the case for air temperature, where a significant number of studies now allow us to robustly assess the role of this climate element in wine terroirs. Conversely, the local spatial variability of other climate elements such as precipitation, wind, or air humidity and their consequences in viticulture are still poorly defined and quantified. Therefore, it is essential to address these gaps to provide knowledge that will enable vineyard operators to better adapt to local climatic conditions, whose implications for viticulture evolve in relation to climate change.

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NOV 19, 2024 | 9.30 AM | SCIENTIFIC SESSION: **CLIMATE II - SCIENTIFIC ORAL**

High spatial resolution modelling of spring frost risk in the Waipara wine region (New Zealand)

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Keywords: **spring frost, atmospheric modelling, geostatistical modelling, complex terrain, viticulture.**

ABSTRACT

This paper describes an international study into the climate variability within the Waipara region of Canterbury, New Zealand and its importance to viticulture. The complex terrain of the region results in intricate patterns of climate variability, which can create significant spatial variability in the optimal conditions needed for high quality wine production. This high spatial variability depends on climatic conditions throughout the vine's growing season, but also on the frequency and intensity of extreme weather events. Such is the case with spring frosts, which often occur after vine budburst and represent a major risk for winegrowers, potentially resulting in significant yield losses. Winegrowers require precise information at the scale of their vineyards, which means they need to improve their forecasting of the areas most exposed to the risk of frost, based in particular on local topographical features and atmospheric conditions. This research uses an advanced approach to map key climate parameters at high spatial resolution during spring frost events by applying a combination of field measurement (climate and phenology) and climate modelling techniques. This approach was initiated during the spring of 2020, when several frost episodes (e.g. 30 September, 2020 and 16 October, 2020) caused significant damage in New Zealand winegrowing regions, particularly in the Waipara region. The results have made it possible to map precisely the spatial variability of minimum temperatures identifying the most frost-sensitive areas as a function of atmospheric conditions. This information can then be used to identify optimal locations for varieties having later budburst in at-risk areas, or locations with reduced

frost risk. The outputs also provide a general framework within which to evaluate adaptation of viticulture to frost risk in other vineyard regions of New Zealand and elsewhere.

Introduction:

The Waipara region is a relatively new wine-growing region, where the first vines were planted in the early 1970s. It currently has around 1,250 hectares of vines. Located on the east coast of New Zealand's South Island, the Waipara wine region benefits from a unique climate created by the topography, which protects the vineyards from the cool sea breezes that affect the Canterbury region north of Christchurch. However, it is still considered a cool climate, which is reflected in the predominant grape varieties grown here (mainly Pinot noir, Riesling and Sauvignon blanc). In recent decades, the increase in global temperature has been favourable for this region, providing better conditions for the grapes to ripen. However, this has also had an impact on the growth characteristics of the vines, in particular with earlier budburst and a consequent increase in the plant's vulnerability to spring frosts (Molitor et al. 2014; Sgubin et al. 2018; Cukierman et al. 2024).

As most vineyards are regularly faced with the risk of spring frost, they are equipped with frost control systems such as sprinklers, wind machines (fixed and mobile), helicopters and heaters. In September 2020, southerly winds generated a severe cold period lasting several days. This was characterised by a perturbed atmospheric situation with cloudy and windy weather. On the night of 29 to 30 September 2020, the skies cleared and the southerly wind dropped considerably, causing a rapid drop in temperature and severe spring frosts. The vines suffered significant damage as budburst was around two weeks ahead of the normal time. The intensity of the cold snap (down to -5°C) severely reduced the effectiveness of the frost protection systems. These spring frosts had a significant impact, with yields around 30% below average for all South Island wine-growing regions (e.g., Marlborough, Waipara, and Central Otago).

A number of questions were raised following these events as vineyards that were thought to be well protected sustained significant damage due to the intensity and duration of the frost (up to 8 hours with a negative temperature). There was also significant spatial variability of temperature linked to local atmospheric conditions. Based on this event, we aimed to investigate how to improve simulation and forecasting of frost at high temporal and spatial resolution in the frostiest areas in order to optimise the effectiveness of frost protection systems.

Materials and methods:

An approach based on fine-scale climate measurement and modelling has been implemented in the Waipara wine region. The complex terrain of the region creates intricate patterns of climate variability, resulting in significant spatial disparity in temperature fields during spring frost events. In addition to the application of fine-scale climate models, a network of meteorological stations and temperature recorders was used to study the effects of the complex terrain on frost patterns in the region. Observations of the phenology of the vines (in particular, budburst) were carried out on several plots of Pinot noir near the climate measurement points.

Two climate modelling approaches were adopted in order to map the risk of frost at high spatial resolution as a function of synoptic weather conditions and their interaction with the terrain:

1. Numerical modelling using the Weather Research and Forecasting (WRF) model with a high temporal (hourly) and spatial (1 km) resolution

WRF is a regional climate model based on the physical equations of the atmosphere, which enables climate dynamics to be transcribed as a function of surface conditions (e.g. surface cover, topography, etc.). Hourly modelling of various meteorological parameters such as temperature, atmospheric pressure, wind speed and direction and relative humidity enables us to study the influence of local atmospheric conditions on the behaviour of air masses during spring frost episodes in September and October (Sturman et al. 2017). The hourly resolution of the simulations provides information on the spatial and temporal variability of temperatures during frost nights, such as the evolution of the thermal inversion at different points in the study area. WRF modelling was used to estimate the spatial variability of spring frost as a function of atmospheric conditions. Simulations were carried out during all frost episodes (<0°C) over the spring seasons of 2016-2020 (Figure 1).

2. Geostatistical modelling with a spatial resolution of 80 m

Geostatistical modelling is based on the statistical relationship between temperatures (recorded by sensors) and local factors (e.g. altitude, slope, exposure, etc.). This approach requires the installation of a network of measurements to both build and validate the model. Spatial resolution depends on the spacing of the measurement network (Le Roux et al. 2017). In the Waipara region, a network of meteorological stations and temperature sensors has been established within the vineyard area, enabling minimum temperatures during frost episodes to be mapped at a resolution of 80 m (Figure 2; Morin et al. 2018). The mapped temperatures enabled us to determine the areas with the lowest minimum temperatures. Phenological observations carried out during spring 2020 were used to integrate the spatial variability of vine budbreak in order to assess areas of highest risk of frost damage.

The vineyards most vulnerable to spring frost as a function of synoptic conditions and the local characteristics of the study site were mapped using these two complementary approaches of fine-scale numerical modelling and empirical analysis of sensor data.

Results and discussion:

The WRF modelling revealed different 'patterns' of spatial variability in the risk of frost depending on the atmospheric conditions specific to each frost event. Figure 1 provides a summary of the spatial variability in the number of spring frost events over the period 2016-2020. The WRF simulations indicate that the highest number of events (10-15 episodes per season with temperatures below 0°C) occurred in the northeastern area and also on the flat valley floor and terraces of the Waipara region, while the sectors with steeper slopes or strong exposure to local katabatic winds had fewer than 5-7 frost nights.

The influence of topography on the geostatistically mapped spatial distribution of minimum temperatures on the night of 30 September 2020[1] showed that the flat areas recorded minimum temperatures up to 2°C lower than on the sloping areas, even though they were only a few tens of metres apart (Figure 2). It should be pointed out that the highest temperatures (around 0°C) correspond to the highest slopes of the vineyard region, which are logically the least exposed to frost. The high spatial variability of damage occurred as a result of local factors and the timing of budburst. Observations of Pinot noir budburst in the spring of 2020 showed a difference of around one week between the coldest ar-

1 Temperature sensors are located far enough away from frost protection systems to limit their direct influence during frost events.

eas (the valley floor) and the warmest areas (plots on the hillslopes). Consequently, the plots with the worst damage were not necessarily in the coldest areas (experiencing -5°C on the Waipara valley bottom) but on the terraces and slopes (t_{min}=-3°C) where budburst was earliest.

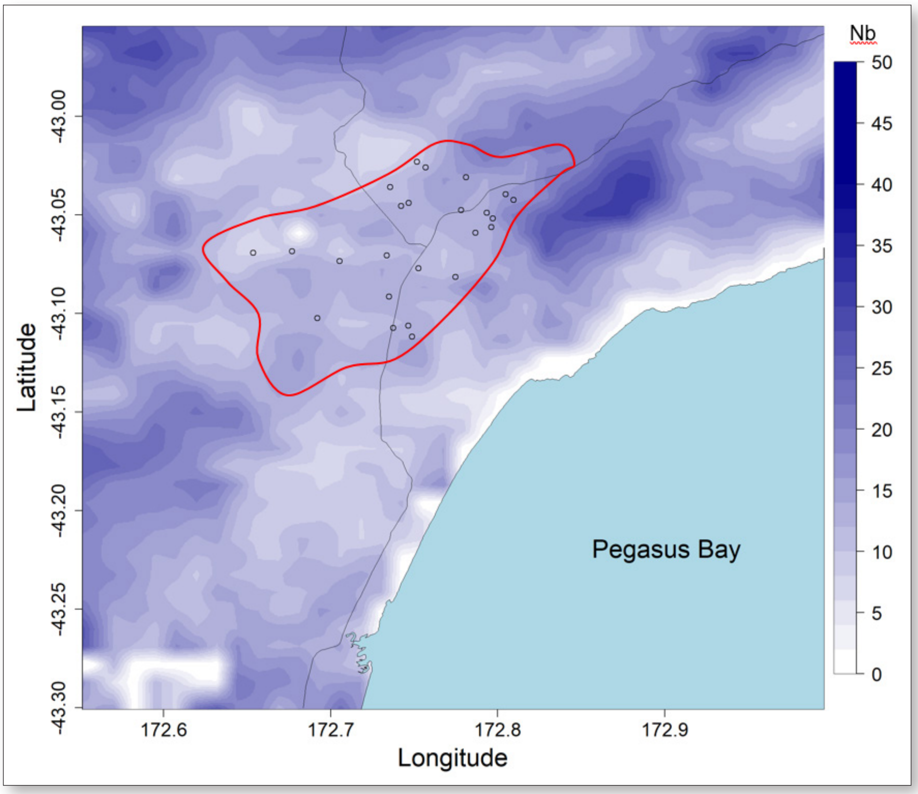

Figure 1. WRF numerical modelling of the number of spring ground frost events (September/October) mapped at 1 km resolution over the period 2016-2020 in the Waipara region. The red line indicates the approximate boundary of the vineyard area.

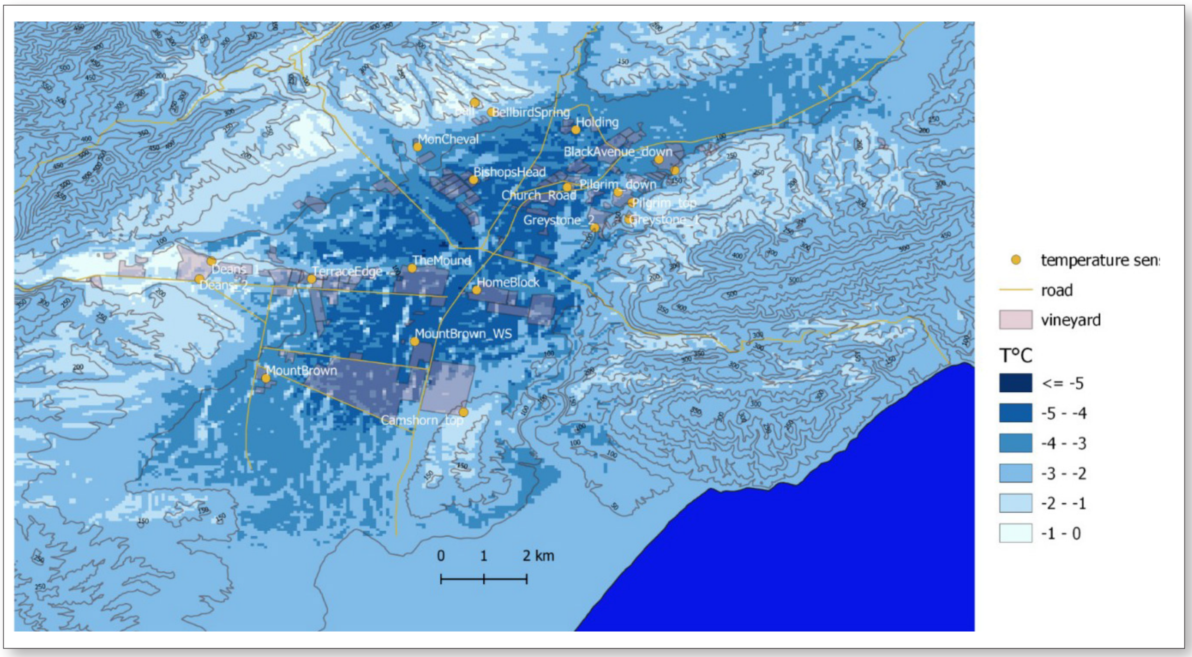

Figure 2. Geostatistical modelling at 80 m resolution of the minimum temperature in Waipara Region during the spring frost night of 30 September 2020.

Conclusion:

Our integrated approach to fine-scale climate analysis and modelling have demonstrated consistent a spatial pattern of frost occurrence over a five-year period that is affected by the local complex terrain. Temporal variability of the risk of frost has also been identified under different synoptic conditions. Our results highlight that a deeper understanding of the complexity of the local climate is essential for better forecasting of frost risk and for making decisions about frost control operations.

Further work is needed to improve our understanding for the impacts of frost risk on vine development, including investigating the relationship between budburst date and frost date and its likely change over time as global warming continues. By combining budburst models with our fine scale-climate modelling, we will be able to further evaluate the spatio-temporal variability of the risk of spring frost for different grapevine varieties.

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NOV 19, 2024 | 9.45 A M | SCIENTIFIC SESSION: **CLIMATE II - SCIENTIFIC ORAL**

The use of stable isotopes to assess the incidence of temperature and water status on aroma compounds of famous wines from Cabernet Sauvignon and Merlot

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Keywords: **wine, ripening level, temperature, aroma compounds, isotope.**

ABSTRACT

The stable isotopic composition of carbon ($\delta^{13}C$) and oxygen ($\delta^{18}O$) in wine was first used to detect adulteration. Due to their relationship with climatic parameters (*i.e.* temperature and water stress), these stable isotopes can also be used as a proxy for the climatic conditions during the ripening period, impacting the maturity level of the grapes. Because aroma compounds in red wine, especially those related to aromatic ripeness, depend on climatic conditions during the ripening period, stable isotopes can potentially be used to explore these relationships in bottled wines. In this study we compared the isotopic composition of 260 red wines (*Vitis vinifera var.* Merlot and Cabernet-Sauvignon) from different countries, locations and vintages (1990 to 2016): France (Bordeaux), Italy (Tuscany), Switzerland (Valais, Tessin), USA (Napa Valley, Virginia) and Chile (Maipo Valley). As expected, strong differences were observed according to the country and the vintage but, more surprisingly, also substantial differences were recorded between estates located at limited distances (~5 km), especially for $\delta^{18}O$ values. For non-irrigated vineyards, $\delta^{13}C$ and $\delta^{18}O$-values were correlated. Analyses of the aroma compound composition of red wines from the Napa Valley, produced under high temperatures, were carried out. Wines were also submitted to a panel for sensory analyses. These analyses revealed the wide spectrum of aroma balance in the 2000-2016 range, from bell pepper to cooked plum and dried figs linked, among others, with the concentration level of 3-isobutyl-2-methoxypyrazine (IBMP, bell pepper) and γ-nonalactone (cooked peach-

es). Finally, based on this large data set, we evidenced for red wines produced in the Napa Valley (warm climate) a $\delta^{18}O$-value threshold beyond which the concentration of γ-nonalactone (cooked peaches) is significantly higher.

Introduction

One of the main characteristics of famous red wines is their aromatic complexity, for which connoisseurs recognize many nuances, from herbaceous to fruity, reminiscent of green pepper, blackcurrant, blackberry, prune and figs. The aromatic expression of these wines is closely linked with the maturity level of the grapes as well as the grape variety, soil type and climatic conditions, *i.e.* the terroir (van Leeuwen et al., 2022). For example, overriding aromas of dried or cooked fruits, reminiscent of dried prune, fig or cooked peach, are characteristic of "extreme" vintages marked by very high temperatures. In Bordeaux, 2003 is a good example of this type of vintage. In general, these nuances are found in wines when grapes are harvested overripe, and most of the time owing to a delay in the harvesting date, as a result of a warm and dry late season. Molecular markers of these nuances have been identified and belong to several chemical families including lactones, furanones and carbonyls (Allamy et al., 2018). Among them, γ-nonalactone (coconut, cooked peach) is a good marker of grape ripeness (for Merlot and Cabernet-Sauvignon), as it is found at high levels in young and old red wines made from overripe grapes (Allamy et al., 2023).

In this sense, the terroir effect is multifactorial. For this reason, knowledge of integrative analytical parameters can help the winemakers and winegrowers to improve the quality of the vineyard management and the knowledge of wine composition. For many years, the scientific community has investigated the link between the stable isotopic signature of wine, as a proxy of past climatic conditions, the vine physiology and wine composition. In other words, how the analyses of mature bottles can teach us valuable information about past climate conditions and its effect on wine composition and its aging potential?

Stable isotopes ratios of wine constituents are expressed as $\delta^{13}C$-values measured on grape must or wine ethanol and $\delta^{18}O$-values of water. These ratios are indicative of the climatic conditions during the grape ripening period. The $\delta^{13}C$-value of grape must or wine ethanol is related to vine water status and therefore characterize vineyards for their soil capacity to provide water to grapevines or on the amount of supplementary irrigation applied (Christoph et al., 2015).

According to several studies on oxygen isotopic distribution in wines, its composition is modulated by several parameters linked with water losses through the stomata or through the grape skin. The level of enrichment may differ between years, but also between regions and is mainly influenced by isotopic content of air humidity and by climatic conditions and other factors of the geographic site (source of water, temperature and relative humidity). Moreover, the $\delta^{18}O$ of grape water is affected by precipitations during the final development of the grape, with a relatively rapid response, due to stable isotope exchange with water vapor (West et al., 2007). High extreme daily temperatures and average relative humidity produce high transpiration rates which, in turn, result in water enriched in heavy isotopes (Ingraham et al., 1999). According to Perini et al. (2015), withering of grapes on the plant and due to the relatively high temperature in Southern Italy, kinetic evapotranspiration induces an increase in the $\delta^{18}O$-value.

Some studies related links between the isotopic signature of the wine, the ripening conditions of the grapes and the aroma compound composition of the wine. Whereas the impact of terroir on the aroma balance has been reviewed by van Leeuwen et al. (2022), the link between stable isotopes and aroma compound composition in wine has received little attention in the literature (Picard et al., 2017).

This work aimed at studying the distribution of $\delta^{13}C$ and $\delta^{18}O$-values based on the analysis of 260 mature Merlot and Cabernet-Sauvignon wine samples (1990 to 2016) from five different countries. In a second step, we propose to investigate more precisely the relationship between the $\delta^{18}O$-value of Napa Valley wines and the distribution of aroma compounds with a focus on γ-nonalactone, 3-sufanylhexan-1-ol and IBMP. This analytical evaluation was compared to the sensory analysis of the wines.

Materials and methods

Red wines were from several wineries (W) located in different countries made mainly with Merlot (M) and Cabernet-Sauvignon (CS) grapes from multiple vintages (Table 1). In total, 260 samples were analyzed. The selection of wines was based on the reputation of the estates, representing some of the best producers of each appellation. For that reason, according to the appellation and the vintage, retail prices ranged from 30 to more than 1000 €/bottle and wines were kindly provided by each of the wineries involved in this project. Due to the difficulty to find old vintages for some of the wineries, the number of bottles analyzed per vintage was quite different, from 3 samples for the 2003 to 13 for the 2007 vintage in Bordeaux. In addition, despite the fact that the group "country" was not homogenous, we tried to include vintages corresponding to cool and wet or on the contrary warm and dry conditions in order to be able to cover a large range of climatic conditions during the maturation and the period close to the harvest.

For each sample, two isotopic ratios, *i.e.* $^{13}C/^{12}C$ (expressed as $\delta^{13}C$) and $^{18}O/^{16}O$ of water (expressed as $\delta^{18}O$) were measured using isotope ratio mass spectrometry (IRMS) according to (Guyon et al., 2015).

As a complement of this study, an estate from the Napa Valley (W3) was studied in more details. For each bottle, (R/S)-γ-nonalactone (cooked peach) was quantified by SPME-GC-MS, whereas 3-sufanylhexanol (passion fruit) and IBMP (bell pepper) were quantified by SPE-GC-MS/MS and SPME-GC-MS, respectively. The wines were sensory evaluated by an expert panel (n=10) to evaluate the intensity of several descriptors such as fresh fruit (strawberry, raspberry), cooked fruit (prune, dried fig), vegetative (bell pepper) and oxidation level on a 0 to 10 linear scale.

Table 1. Presentation of the selection of red wines from different countries and vintages for isotope and aroma compound analysis.

Country	Code	Location/ Appellation	Irrigation	Variety[1]	Estates	Vintage range	N.v.	Total
Switzerland	/	Valais	N	M	1	2009-2015	7	1
		Tessin	N	M	1	2003-2015	6	
USA (Napa Valley)	W1	Rutherford	Y	M	1	2004-2013	10	58
	W2	Rutherford	Y	CS	1	2000-2016	16	
	W3	Oakville	Y	CS	1	2001-2015	15	
	W4	Yountville	N	CS	1	2000-2016	17	
USA (Virginia)	/	/	Y	CS	1	2008-2016	9	9
France (Bordeaux)	/	Pomerol	N	M	4	1999-2014	14	146
		Saint-Julien	N	CS	1	2007-2013	7	
		Saint-Emilion	N	M	4	1990-2013	16	
		Pauillac	N	CS	4	1990-2014	19	
		Pessac-Leognan	N	M	1	1990-2007	12	
		Margaux	N	M	2	1995-2016	19	
Italy	/	Tuscany	Y	CS	1	2000-2016	17	17
Chile	/	Maipo Valley	Y	CS	1	2000-2016	17	17

[1] main variety, at least 65 % in the final blend. N.v.: number of vintages per estate. N = no; Y = yes.

Results and discussion

First, the overall distribution of $\delta^{18}O$ and $\delta^{13}C$ values were compared for red wines collected from different countries (Table 1). According to Camin et al. (2015), the grape variety effect found on $\delta^{18}O$ values in studies is normally a consequence of differences in the ripening period or harvest data or can be confused by different climates in the area of origin. For that reason, the data from the two grape varieties (Merlot and Cabernet-Sauvignon) were blended. As depicted in Figure 2, significant location effect was observed for $\delta^{18}O$ (Anova, F = 94.9, $p<0.001$) and $\delta^{13}C$ (Anova, F=46.8, $p<0.001$). Based on our selection, we showed that red wines from Napa Valley have significantly higher $\delta^{18}O$ values ($p<0.001$) than those from other regions whereas red wines from Bordeaux region have $\delta^{13}C$ values significantly higher ($p<0.001$) compared to rest of the selection. Regarding the $\delta^{13}C$ isotopic signature, it means that the water supply was different according to the vineyards, except in Chile where the irrigation protocol was more restrictive than that of other vineyards. The widest range of isotope distribution was obtained for Bordeaux wines: $-0.47 \leq \delta^{18}O \leq 6.4$ ‰ and $-28.1 \leq \delta^{13}C \leq -24.4$ ‰. This distribution illustrates the significant impact of the climatic conditions (including the temperature and water status) according to the vintage for both isotopes ($p<0.001$). According to the wine, highest average $\delta^{18}O$-values (> 4 ‰) were obtained for the 1990, 2003, 2005 and 2009 vintages, known to be generally warm and dry (Figure 1). This distribution was consistent with that found in European wines (Christoph et al., 2015). In comparison, the lowest $\delta^{18}O$-value in Napa Valley was 3.52 ‰ for the 2011 (cold vintage in Napa) and was close to the average value in Bordeaux of 3.09 ‰ (for the 1990-2016 period).

For Bordeaux wines, we showed that the linear correlation between the two isotopes was positive and low, but significant ($r = 0.364$, $p<0.001$, $n=146$). The correlation coefficient was higher for red wines from Switzerland ($r = 0.658$, $p<0.05$, $n=13$), while for irrigated vineyards these parameters were not correlated. Such results are consistent with the fact that warm and dry climatic conditions induce high water deficit and at the same time, high evapotranspiration.

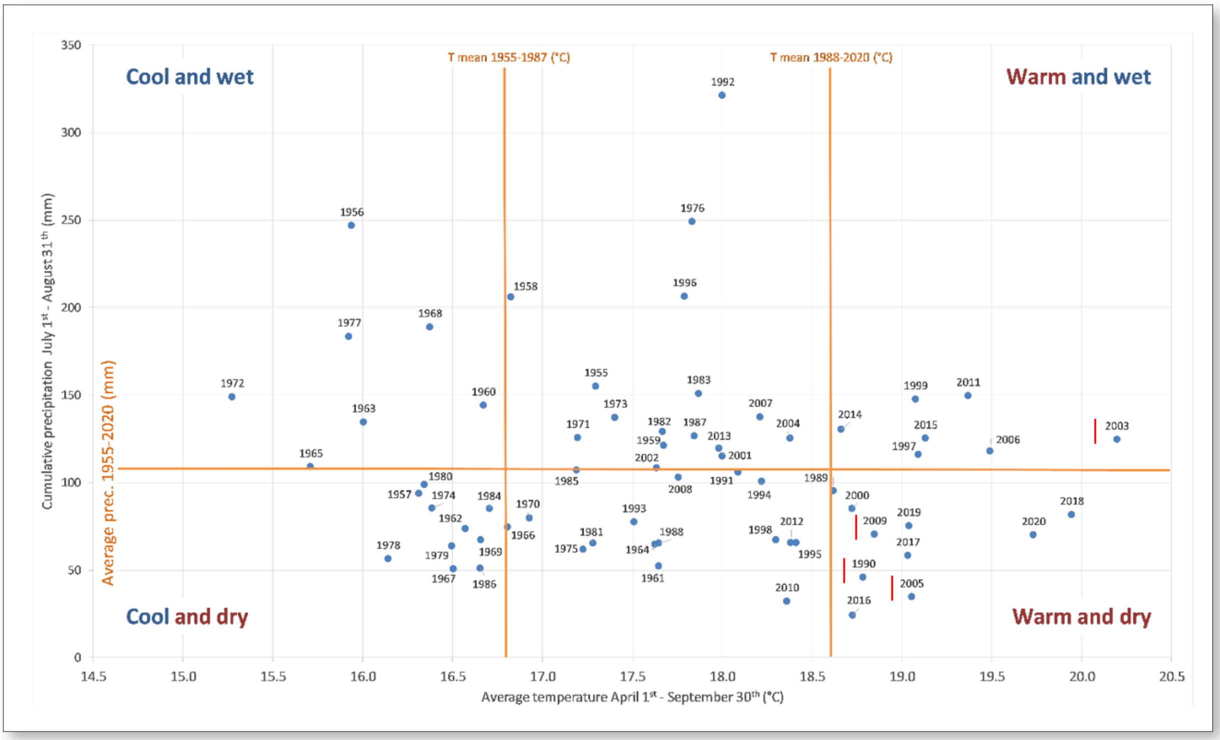

Figure 1 : Classification of vintages in Bordeaux (from 1955 to 2020) according to the climatic conditions (van Leeuwen et al., 2023). Specific warm vintages were underlined in red.

Based on our large dataset, we focused on three wineries located on the right bank of the Dordogne river (Pomerol, Saint-Emilion) and three on the left bank of the Garonne river (Pauillac, Pessac-Leognan) producing high quality red wines from the same vintage (12 vintages between 1990 and 2007). $\delta^{18}O$ and $\delta^{13}C$-values were assayed for each vintage and were highly and significantly correlated between estate according to their location and appellation, with R^2 ranging from 0.698 ($\delta^{18}O$, Pauillac vs. Pessac-Leognan) to 0.946 ($\delta^{18}O$, Pauillac vs. Pauillac). According to the localization of the estate and the vintage, $\delta^{18}O$-value were quite different; for example, ranged from 2.67 ‰ in Saint-Emilion (limestone plateau) to 6.43 ‰ in Pomerol in 1990 or from 2.73 ‰ to 5.0 ‰ in 2005. These results are consistent with results from de Rességuier et al. (2020), who showed lower maximum temperatures in the plateau of Saint-Emilion compared to Pomerol. Similar observations were made regarding the $\delta^{13}C$-distribution values, which reflect the impact of the soil water holding capacity on vine water status.

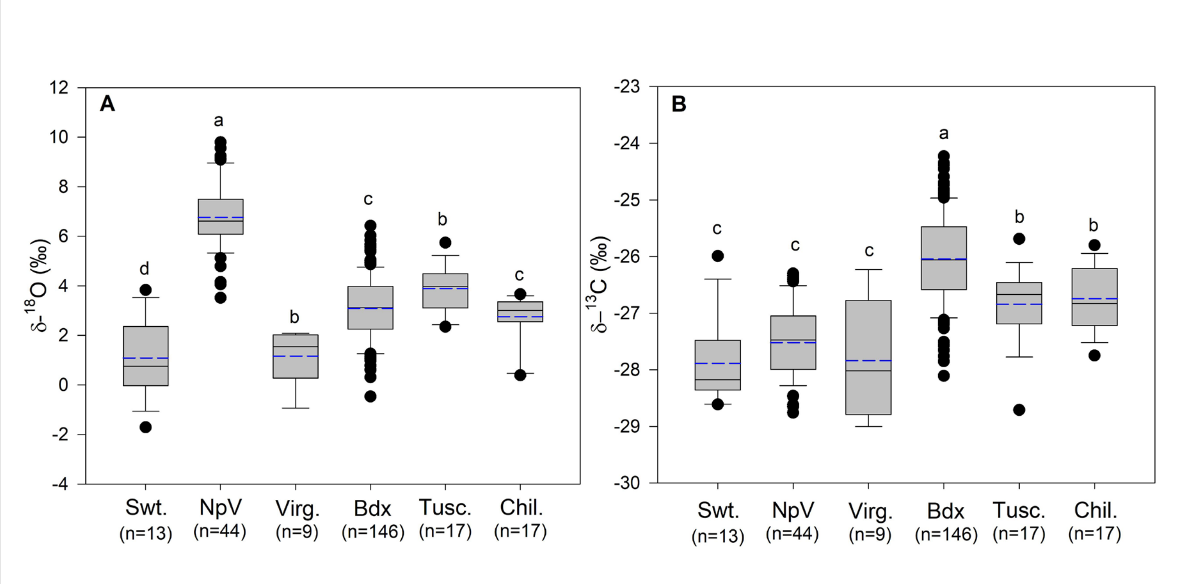

Figure 2. Distribution of stable isotope values of $\delta^{18}O$ (A) and $\delta^{13}C$ (B) assayed in red wines according to the country or production region:

Swt (Switzerland), NpV (Napa Valley), Virg (Virginia), Bdx (Bordeaux), Tusc (Tuscany), Chil (Chile). Different letters correspond to differences at *p*<0.05 (Anova, post hoc Student test). The horizontal black line corresponds to the mediane, the dashed blue, the average values.

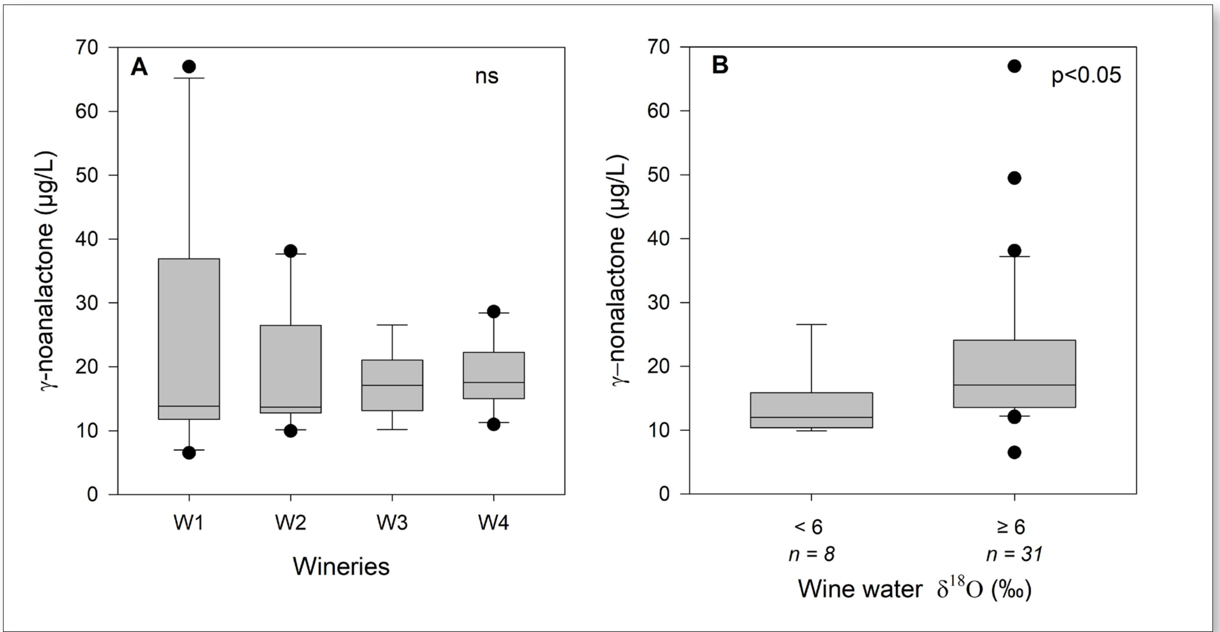

Figure 3. A. Box plot of γ-nonalactone distribution detected in the four Napa Valley red wine estates (2004 to 2013, n=10). B. γ-nonalactone distribution for the same red wine selection according to the $\delta^{18}O$-values.

The threshold value was 6 ‰. The horizontal line represents the mediane of the distribution. Box plot indicates 25, 50 and 75th percentiles. Each point corresponds to outliers. Differences between groups were evaluated by an Anova (post hoc Student test).

The last part of the discussion focuses on the link between $\delta^{18}O$-values and the concentration of aroma compounds with a particular interest with γ-nonalactone, an aroma chemical marker of late harvest or grapes overipening, quantified in old red wines from Napa Valley (W1 to W4, Figure 3). We demonstrated that this lactone is found at high level (up to 67 µg/L) in red wines made with grapes grown in warm climates. Although there is no significant correlation with $\delta^{18}O$ values (not shown), we show that beyond a threshold estimated at 6 ‰, γ-nonalactone was detected at significantly higher levels. According to West et al. (2007), grape water isotopic ratio should primarily reflect the evaporative conditions of the grape water prior to harvest. Therefore, the isotopic "signature" corresponding to the evaporative conditions experienced by the grape seem to be associated with the formation of this lactone in wine corresponding to the biotransformation of precursors produced due to an oxidative cascade in the berry (Allamy et al., 2023).

Additional analytical parameters such as 3-SH and IBMP were determined in red wines from W3. A significant vintage effect on their concentrations was shown, with for example highest IBMP levels (18.4 ng/L) for 2011, known to be wet and cold during the maturation stage in Napa (results not shown). Such distribution was consistent with the sensory balance of the red wines (bell pepper vs. cooked fruit).

Conclusion

In this study we compared the isotopic composition ($\delta^{13}C$ and $\delta^{18}O$-values) of 260 red wines *(Vitis vinifera var.* Merlot and Cabernet-Sauvignon) from different countries, locations and vintages (1990 to 2016). Additional aroma compound analysis was also carried out on a smaller data set. We demonstrated that the vintage effect was very strong for these analytical parameters with respect to specific temperature levels and vine water status conditions. The effect of average temperature or maximum temperature as well as the impact, occurrence and duration of heat waves just before the harvest need to be deeper investigated in light of these findings. Furthermore, this work demonstrated that isotopic analysis of old red wines can provide a retrospective picture of the temperatures and the physiology of the vine and the grapes during the ripening period, with implications on the aroma balance of the wine.

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NOV 19, 2024 | 10 AM | SCIENTIFIC SESSION: CLIMATE II - FLASH ORAL

How can we best use econometrics to quantify the impact of climate change on the wine industry? A case study for Australia

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Keywords: **climate change, climate impacts, adaptation, statistical modelling.**

ABSTRACT

Climate change is a major threat to vignerons in key wine-producing regions. In Australia, a country that is on average warmer and drier than other wine-producing countries, all wine regions are projected to become even warmer and drier in coming decades. The aim of this study is to review how best to estimate the potential impact that climate change could have on wine grape yields and prices, and apply that to Australia. We use a novel panel dataset to estimate the impact of weather shocks on wine grape yields and prices in Australia, and then use those estimates to quantify the potential impact of climate change projections on those outputs. Preliminary results suggest wine grape yields are expected to decrease as all regions become warmer and drier, and despite a lower incidence of frosts. Further, winegrape quality is expected to decrease due to higher temperatures. These results suggest that for maintaining wine styles, Australian wine growers may need to grow varieties that perform better in warmer and drier climates, and/or to plant their vineyards in cooler-climate regions, such as at higher elevations or latitudes, or closer to coastlines. We discuss ways to deal with three key challenges when applying climate econometrics to wine: 1- choosing appropriate weather variables and functional forms; 2- modelling outputs as static or dynamic processes; and 3- appropriately accounting for adaptation and the impact of the intensification of climatic events.

NOV 19, 2024 | 10.05 AM | SCIENTIFIC SESSION: **CLIMATE II - FLASH ORAL**

Ri.Vi.Vi Valle d'Itria: a strategic project to relaunch the viticulture in an area with structural and phytosanitary problems

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Keywords: **viticultural zoning, climate change, Valle d'Itria, breeding for resistance.**

ABSTRACT

Valle d'Itria, an internal hilly area of Apulia region, is an important touristic destination famous for the typical stone house called Trulli, and several very attractive historical city centres. The valley, also known and vocated for the production of white wines with PDO and PGI denominations obtained from native and unique varieties, is characterised by a high fractionation of agricultural land that in the last 50 years, with the ageing of farmers, the impossibility of mechanising the vineyards and the increase of planting costs, suffered a dramatic loss of area under vines with a profound change in the agricultural landscape. The recent phytosanitary emergency of the xylella epidemic affecting olives in the area and the evident negative effects of climate change on the vineyards required an urgent strategic project for the future. The ambitious 3-years pilot project "RELAUNCHING OF VINE GROWING IN VALLE D'ITRIA - Viticultural zoning and development of tools for sustainability, valorisation of territorial resources and mitigation of the effects of climate change", funded by the Puglia government for 3 years, will be implemented by 5 partners leaded by CNR through seven priority actions. The project, through a participatory approach open to the involvement of multiple territorial stakeholders, aims to achieve important innovative results: the first viticultural meso-zoning of the area according to the official OIV procedures; a new development strategy based on a SWOT analysis and the synergy among viticulture-tourism-landscape-environment; the creation of a widespread infrastructure with gemels experimental vineyards planted by farmers in all the homogeneous zones identified; the starting of a breeding program to obtain resistant germplasm from autochthonous grapevine cvs; the experimental evaluation of adaptation systems to reduce the impacts of climate change on grape quality; the valorisation of local germplasm through the development of communication tools to promote local foods and wines and to attract new investments.

NOV 19, 2024 | 10.10 AM | SCIENTIFIC SESSION: **CLIMATE II - FLASH ORAL**

Impacts of climate change-induced temperature rise on phenology, physiology, and yield in Malbec, Bonarda, and Syrah cultivars

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Keywords: **increasing temperature, climate change, Malbec, Bonarda, Syrah.**

ABSTRACT

Climate change is a phenomenon that has profound implications for agriculture, particularly in viticulture, where temperature plays a critical role in the growth and development of grapevines. The climatic characteristics of Mendoza are conducive to producing high-quality wines; however, the effects of XXI century climate change will negatively impact. The objectives of this project were to evaluate the effect of increased temperature on phenology, physiological variables and yield of Malbec, Bonarda and Syrah cultivars. A field trial was conducted over two seasons: 2019-2020 and 2020-2021 in an experimental vineyard where an active canopy heating system was installed (+2-4ºC (HT)). During the two seasons, budburst, flowering, fruit set, veraison, and harvest dates were recorded. Shoot growth (SG), number of shoots (NS), stomatal conductance (gs), chlorophyll content (CC), chlorophyll fluorescence (CF), and predawn and midday water potential (ψa) were measured. Temperature, relative humidity and light intensity were recorded with a digital meteorological station located in the vineyard, and canopy temperature was registered with I-buttons. Furthermore, Ravaz index, fruit set, number of clusters/plant, cluster-weight, N° of berries/cluster, berry weight, fruit yield, pH and °Brix were recorded. HT advanced the phenological phases of the three cultivars. in terms of budburst, flowering, fruit set, veraison, and harvest by around two weeks in both growing seasons. SG and NS increased with HT. Conversely, over the two seasons, gs decreased with the treatment in the hottest months, as did the predawn and midday water potential, while CC and CF did not change with the treatments applied. During both growing seasons a decrease in yield, acidity, and an increase in °Brix were observed with the treatment. Increasing temperature due to climate change advances the phenological phases of Malbec, Syrah and Bonarda, resulting in lower yields, higher °Brix and lower acidity, although it does not substantially modify the measured physiological variables.

NOV 19, 2024 | 10.15 AM | SCIENTIFIC SESSION: **CLIMATE II - FLASH ORAL**

Improving viticulture sustainability with simplified, region-specific LCA models: a focus on Germany and California

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Keywords: **sustainable viticulture; simplified LCA models, organic vs conventional; regionalized environmental impact.**

ABSTRACT

The environmental sustainability of viticulture is heavily influenced by regional variations in climate, soil type, and water availability. An adequate strategy to improve sustainability of the wine industry must start with an accurate and objective quantification of its sustainability performance. Life Cycle Assessment (LCA) is a widely accepted tool for this. Conducting LCA is highly context-specific, labor-intensive, and require expertise of the LCA methodology. Therefore, it is not yet a hands-on tool to assess sustainability of production processes for many wineries. Simplifying LCA models could increase its use as a management and decision tool in the wine industry. Simplified models must consider specific regional aspects and individual management decisions but require just a few specific key parameters to obtain representative results. For the remaining input data, which is needed to build models with high predictive power, fixed generic data can be used. This study aimed to develop simplified, region-specific LCA models tailored to both cold-climate and warm-climate viticultural regions, including variations due to organic and conventional practices in these distinct environments. Indicators and methods defined in the Product Environmental Footprint Standard of the EU were used. Germany and California were chosen as representative regions, respectively for cold-climate and warm-climate. These regions were chosen for their significant contributions to global wine production and their distinct environmental conditions. Average input data for vineyard management and its probabilistic distribution was collected from literature and expert interviews from research and practice. The resulting inventory was analyzed in Brightway2 using Monte Carlo simulation and global sensitivity analysis to establish a parametrized inventory. By providing a detailed comparison of the different impact factors, this research aims to offer actionable insights for viticulturists and policymakers to promote region-specific sustainable practices in the wine industry, ultimately contributing to the global effort of reducing the environmental impact of viticulture.

NOV 19, 2024 | 11 AM | SCIENTIFIC SESSION: CLIMATE III - SCIENTIFIC ORAL

Zoning and sustainability: future-proofing prosecco DOC against climate change

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Keywords: **zoning, soil, climate, acidity, Prosecco.**

ABSTRACT

This study focuses on the zoning of the Prosecco DOC area to evaluate specific territorial features through the mapping of climatic indices and soil characteristics, aiming to address climate change challenges. The research involved calculating climatic indices and applying them to the identification of 20 vineyards across the DOC territory. Yield and quality parameters, including titratable acidity and malic acid, were measured to assess the impact of zoning. The results indicated that zoning provided a valuable perspective on the variation of key quality parameters, particularly titratable acidity and malic acid, across different zones. These findings underscore the significant influence of localized climatic and soil conditions on grape quality. The zoning approach demonstrated its utility in managing extensive vineyard areas, offering a sustainable strategy to optimize vineyard practices in response to climate change. In conclusion, zoning within the Prosecco DOC region is an effective tool for enhancing plant health and vineyard productivity. By offering detailed insights into environmental variability, zoning supports a sustainable approach to viticulture, equipping winegrowers to meet future challenges. This study confirms that zoning is an essential strategy for maintaining the quality and sustainability of Prosecco DOC wines in the face of climate change.

Introduction:

To enhance the capabilities of winegrowers to effectively face the challenges posed by climate change and fluctuating market demands, a climate risk zoning is crucial especially in vast and diverse areas like Prosecco DOC. As climate patterns shift and market preferences evolve, the traditional approaches to viticulture must be re-evaluated and adapted. A zoning strategy that incorporates detailed mapping of soil types, climate conditions, and especially water risk susceptibility offers an innovative and efficient pathway toward a sustainable future in winemaking. Viticultural zoning involves categorizing regions based on their unique environmental characteristics and their influence on grape production. For an extensive and varied appellation like Prosecco DOC, which spans different altitudes, soil compositions, and microclimates, zoning is particularly important (Galletto et al., 2020). This approach enables winegrowers to understand the specific strengths and weaknesses of their vineyards, facilitating more informed decisions regarding cultivation practices, grape selection, and resource management. Climate change presents one of the most significant threats to viticulture worldwide. Increasing temperatures, altered precipitation patterns, and extreme weather events can drastically affect grape quality and yield (Jones et al., 2022). By zoning the Prosecco DOC region, winegrowers can identify areas that are more resilient to these changes and those that are more vulnerable. This knowledge allows for the implementation of targeted strategies such as selecting drought-resistant grape varieties, optimizing irrigation systems, and adjusting canopy management practices to mitigate heat stress. For instance, vineyards in higher altitude zones may benefit from cooler temperatures that offset the rising heat, while lower altitude areas might require enhanced irrigation to cope with increased evapotranspiration. Understanding these zonal differences is essential for maintaining the quality and consistency of Prosecco DOC wines in the face of a changing climate. In addition to environmental challenges, the wine market is increasingly competitive, with consumers demanding higher quality and more sustainable production practices. Zoning supports market competitiveness by enabling winegrowers to optimize their production processes and improve wine quality (Dominici et al., 2024). By tailoring vineyard management to the specific conditions of each zone, growers can produce grapes that best express the terroir, leading to wines with distinctive and desirable characteristics. Moreover, zoning can help in branding and marketing efforts. Wines from specific zones can be marketed for their unique qualities, such as the mineral complexity of wines from karst soil regions or the vibrant acidity of grapes from cooler, higher altitude areas. This differentiation can appeal to consumers seeking unique and high-quality wines, thereby enhancing the market position of Prosecco DOC. The zoning of the Prosecco DOC region based on soil, climate, and water risk susceptibility is a forward-thinking strategy that aligns with the principles of sustainable agriculture. It promotes efficient resource use, enhances resilience to climate change, and supports the production of high-quality wines that meet market demands.

Materials and methods:

This project focuses on the extensive DOC Prosecco area, which spans 28,100 hectares across the Veneto and Friuli Venezia Giulia regions, encompassing 9 provinces with a wide variety of soils and meteorological conditions. The project specifically targets the Glera variety, the primary grape used to produce Prosecco with Denomination of Controlled Origin (DOC) status.

1. Map Creation

The zoning project began with the identification of key variables essential for defining the characteristics of the territory. The initial phase focused on selecting the key variables and divide them into “risk” classes:

- **Seasonal Precipitation:** Evaluated from March to September, it was ranked in four classes of 200 mm span, from a minimum of less than 500 mm to over 900 mm.
- **Available Water Capacity (AWC):** indicating soil's capacity to retain water and supply it to plants during the dry season, was ranked in four classes of 50 mm span, from a minimum of less than 80 mm to over 180 mm.

• **Huglin Index:** Used to assess thermal levels and their impact on grape quality, was ranked in four classes with a span of 200, from a minimum of less than 2200 to over 2600.

The selected variables were combined to create aggregated "risk" classes. The AWC was combined with precipitation levels in a new variable (P_AWC), ranked in five classes based on drought risk and potential water reserves, which are correlated with precipitation and represents decreasing levels of water stress risk. In this context, vineyards located in areas with lower P and AWC classes are more susceptible to water stress due to prolonged drought periods and limited soil water reserves, potentially requiring irrigation support.

Water stress risk was integrated with thermal risk by considering that a Huglin Index below 2200 can still be beneficial for grape quality, despite potential plant water stress. Above this threshold, higher Huglin Index values increase the potential risk to both grape quality and overall plant health due to water stress. The final zoning classification results as follows:

Table1. Final classification of vineyard zones based on combined risk factors of water stress and thermal stress (Huglin Index).

		Huglin			
		<2200	2200-2400	2400-2600	>2600
		1	2	3	4
P_AWC	1	2	1	1	1
	2	3	2	2	1
	3	4	3	3	2
	4	5	4	3	3
	5	5	5	4	3

This classification identifies areas requiring varying levels of irrigation support and management strategies to maintain grape quality and plant health:

Class 1: Zone with high Huglin Index and low P_AWC, indicating a significant need for irrigation due to both low water reserves and high temperatures.
Class 2: Zone with medium-low P_AWC and high temperatures, indicating a high risk of water stress, potentially requiring supplemental irrigation during certain periods.
Class 3: Zone with a balance of medium P_ AWC and temperatures, presenting a low to moderate risk of water stress, with potential risk only during specific periods or with a high Huglin Index.
Class 4: Zone with minimal water stress risk due to moderate to high water supply and non-elevated Huglin Index.
Class 5: Zone with no water stress risk, abundant water supply, and optimal Huglin Index.
The map in Figure 1 is the result.

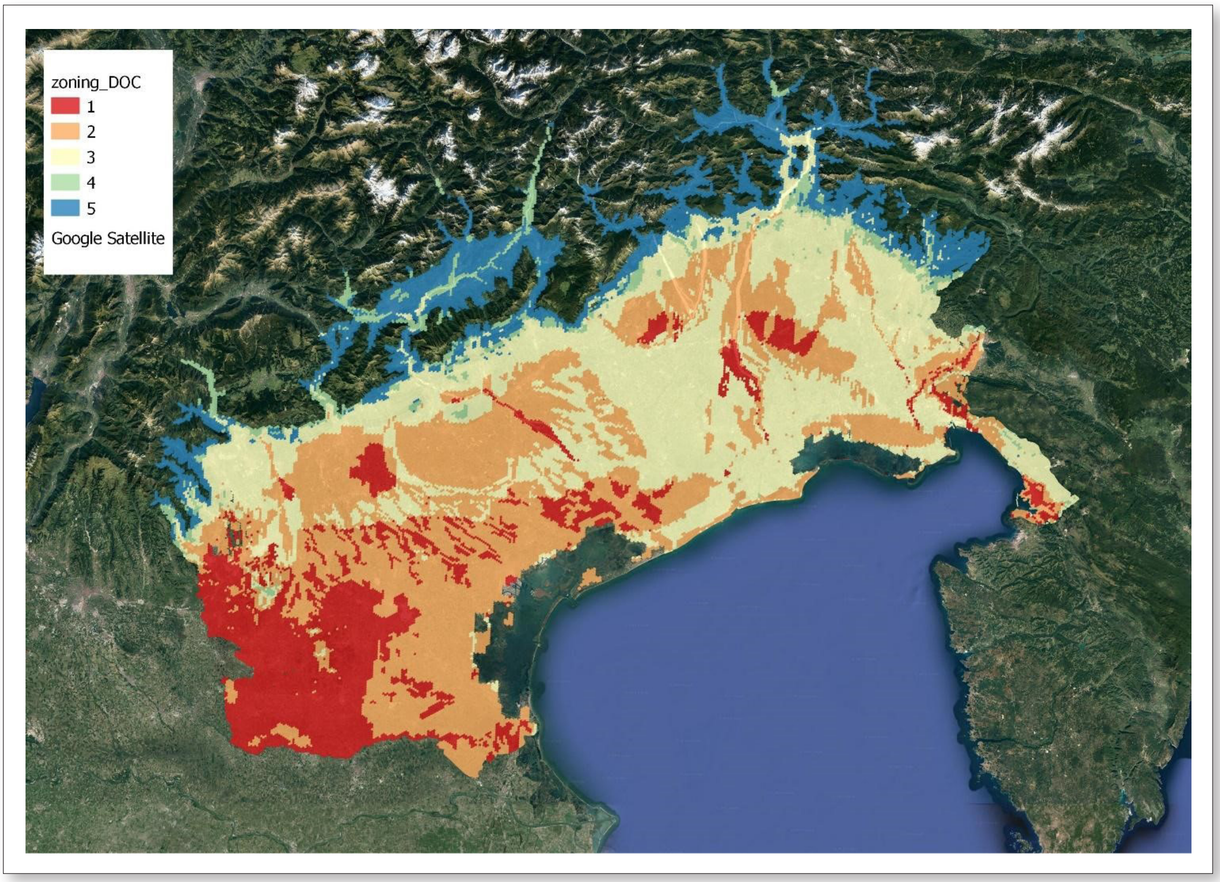

Figure 1 The five identified classes, represented by their respective colours, indicate varying levels of water stress tolerance.

The geographical zones are categorized as follows: Zone 1 Euganean and Berici Hills, Zone 2 Gravel Plain, Zone 3 Loose Clay Soil Plain, Zone 4 Foothill Area, Zone 5: Pre-Alps.

2. Vineyards management

The map is clear in its delineation of the various zones, each reflecting a specific geographical feature. Recently, an additional zone, Zone 3T, representing the province of Trieste, has been added. This zone has been created to distinguish its anthropic characteristics, which are so distinctive as to require a subdivision within Zone 3 to preserve its unique features. In light of the aforementioned considerations, a total of 20 vines were selected for the experimental design. In each vineyard, an experimental plot was identified with identical management of the agronomic practices for all the resulting plots. The farmers were responsible for the nutrition, irrigation and pest management of the vines. During the winter pruning, the buds were equally regulated in order to moderate the variability and homogenise the production, thereby reducing the effects of unequal management. Green pruning was then performed in the middle of spring, and finally, the harvest was conducted on 5 vines per three replicates within the experimental plots. Grape harvest occurred when the grapes reached technological maturity, which is defined as having a total soluble solids (TSS) content of at least 14 Babo (approximately 17 Brix (Benucci et al., 2022)). Yield per vine and average cluster weight were measured with a hanging scale from CH, Kern, Germany. Cluster weight was determined by dividing the amount of fruit produced per vine by the total number of clusters collected.

2.1 Statistical analysis

XLSTAT 2023, version 2023 1.4 from Lumivero (2024) statistical and data analysis solution (Paris, France), was used for Statistical analysis, specifically for Analysis of Variance with Tukey Post Hoc Test and significance set at p values of 0.05. Sigmaplot 14.2 (Sigmaplot, 2023, Grafiti, California, U.S.A.) was utilized for creating graphs and charts.

Results

The harvest was conducted at 14 Babo. In Table 2 the yield parameter results highlight a notable trend: the Trieste area is significantly less productive compared to other regions, with the exception of the Pre-Alps. The two-year average yield in these areas was adversely affected by the severe impact of powdery mildew in Trieste and downy mildew in the Pre-Alps (Gessler et al., 2011; Rienth et al., 2021). In contrast, the other regions performed consistently with the planned bud load, showing significantly higher fertility in the plains compared to the hilly areas, which produced slightly less, this is consistent with common situations in hilly areas due to low fertility and better drained soil (“Ode to the Hills,”).

Table 2. Statistical analysis of quantitative data by zone. A Tukey Post Hoc was conducted following Analysis of Variance with n=5 ($p<0.05$). ABW stands for average bunch weight. Current fertility is the quantity of clusters produced per bud remaining after winter pruning.

Area	Zone	Buds (n°)	Bunches (n°)	Yield per vine (kg)	ABW (kg)	Actual fertility
1	Euganean and Berici Hills	24	26 b	6,1 bc	0,23 b	1,1 ab
2	Gravel Plain	24	29 ab	9,1 a	0,33 a	1,2 a
3	Clay Plain	25	35 a	10,6 a	0,31 a	1,4 a
3 T	Trieste	21	16 cd	3,4 cd	0,20 b	0,8 bc
4	Foothill	24	25 bc	6,0 c	0,24 b	1,0 ab
5	Pre-Alps	24	12 d	1,7 d	0,15 b	0,5 c

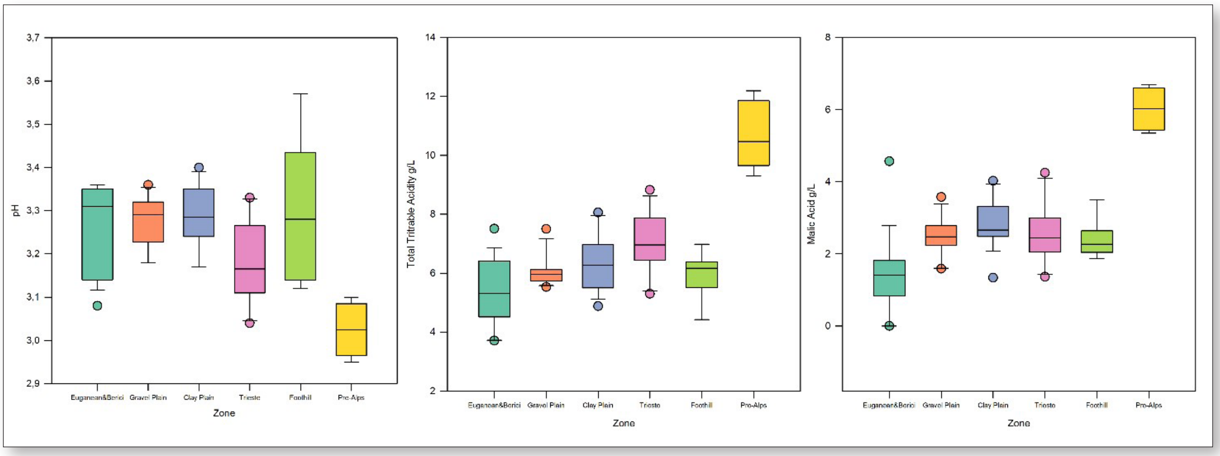

Figure 2. The figure shows box plots for each zone representing the parameters of pH, titratable acidity, and malic acid. The values represent means with standard deviation as the whiskers of the boxes. The graphs depict the results of a one-way analysis of variance (ANOVA) with Tukey's Post Hoc Test ($p<0.05$). Each replicate consists of a minimum of 5 samples.

As shown in Figure 2, the key results for the quality parameters in Glera, the primary variety used to produce Prosecco DOC sparkling wine, are particularly noteworthy across different zones. The box plots reveal an intriguing trend in the evolution of acidity levels in grape musts, which tend to increase from low-rainfall, water-stress-prone areas to cooler, wetter, and rainier areas. This trend is corroborated by corresponding pH levels. A significant aspect in this context is the role of malic acid, which appears to follow the acidity levels of Glera depending on the sampled zone. An exception is observed in the foothill area, which behaves more like a warm and dry region. This trend is highly significant, and the relationship between these variables is well-documented, as explained by Boulton (1980). These results underscore the substantial impact of soil and climate on influencing quality parameters in vineyards.

The results of the sugar content analysis highlight the timeliness and efficiency of the harvest over such a vast area and have allowed for the identification of differences in other parameters by region. The highest average value for tartaric acid content is found in the Trieste area, compared to the clay plain, which is its sub-region. This finding underscores the unique characteristics of the Karst area (Bastianich & Lynch, 2012). Yeast assimilable nitrogen (YAN) is a crucial parameter for natural fermentation during the vinification process. It is closely related to the nutritional status of the vineyard. In this study, the selected vineyards exhibited similar YAN levels, with the notable exception of the Pre-Alps region. Specifically, only the Pre-Alps region reached a level considered optimal for the vinification process (Butzke, 1998). Generally, YAN levels are significantly influenced by nitrogen fertilization. It can be hypothesized that the Pre-Alps region was less prone to nitrogen loss in its various forms, thereby maintaining higher YAN levels.

Conclusion:

The zoning of Prosecco DOC through detailed mapping of soil, climate, and water risk has elucidated significant regional differences in production quality and yield. Plains, with their fertile soils, stable microclimate, and consistent water availability, demonstrated higher fertility and productivity. In contrast, foothill areas, characterized by rocky soils, variable climate, showed lower yields. These findings underscore the importance of tailored vineyard management practices to optimize production in each zone. The detailed zoning map provides a valuable tool for producers to enhance vineyard performance by leveraging regional strengths and addressing specific challenges, ultimately improving the overall quality and consistency of Prosecco DOC wines.

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NOV 19, 2024 | 11.15 AM | SCIENTIFIC SESSION: **CLIMATE III - SCIENTIFIC ORAL**

Terroir discrimination of Pinot Noir wines across multiple sites in Mendoza, Argentina

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Keywords: **Pinot noir, FT-ICR MS, terroir, Uco valley.**

ABSTRACT

The composition of wine is influenced by various factors such as environmental conditions, grape varieties, and vineyard / winemaking practices. Together, these factors contribute to the concept of "terroir," which encompasses the unique qualities imparted to food products by the soil and microclimate of a specific area. Recent studies have aimed to identify Argentina terroir of Malbec, with a focus on understanding how different vineyard sites impact the chemical and taste properties of the wines. Nevertheless, little is still know on the Uco valley "terroir" effect for Pinot noir. In this study, using Fourier transform ion cyclotron mass spectrometry (FTICR-MS), of 18 wines from 2 vintages and 3 vineyards, we characterizes the terroir signatures of Pinot noir in Argentina. Our results reveal that the primary distinguishing factor for these wines is the production site, above the vintage effect. Futhermore, we are able to identify unique chemical fingerprints of hundreds of metabolites for each production site as well as for the 2 vintages. This study provides a remarkable holistic molecular description of the terroir of Argentinan's pinot noir wines.

Introduction:

The composition of wine is influenced by various factors such as environmental conditions, grape varieties, and vineyard practices (Atanassov et al., 2009). The effect of climate in viticulture is widely documented and climatic conditions, including the annual weather conditions, associated with vintage effects, significantly impact the composition of grapes (Morlat et al., 2001; Pereira et al., 2006; van Leeuwen et al., 2024). In viticulture, the combination of these factors contributes to the "terroir" concept (Barham, 2003, Van Leeuwen & Seguin, 2006), and it is now acknowledged that the properties of wine can be linked to its terroir. Analyzing the distinct features of each terroir or site for a given vintage can reveal important differences in the resulting wines. However, establishing consistent patterns for specific terroirs across different vintages has proven to be a challenging task when attempting to validate the concept of typical wines associated with a particular terroir (Bonfante & Brillante, 2022).

In Argentina, recent studies have tried to identify the unique characteristics of Malbec (*Vitis vinifera L.* cv. Malbec), which is emblematic of the Argentinian wine industry. Malbec is the most widely cultivated grape in the country, covering an area of 43,000 ha and representing 73.5% of the world's production (Urvieta et al., 2021). While Malbec is the dominant grape variety, Pinot Noir produced in Argentina is also globally recognized for its exceptional organoleptic qualities, and research has indicated that consumers appreciate its unique characteristics (Darnal et al., 2024). Furthermore, studies have indicated that Pinot Noir is highly influenced by the specific vineyard sites (Longo et al., 2021), making it an ideal variety for questionning the terroir concept (Roullier-Gall et al., 2014). Despite being the most widely grown grape variety in the world (De Rosas et al., 2022), the high cultivation and harvest costs mean that optimizing yields through producing high-quality, expensive wines is necessary (Longo et al., 2021). Yet, the impact of different vineyard sites in the Uco Valley on the chemical and taste properties of single-varietal Pinot Noir wines produced in this region is still not well understood.

In previous research, we demonstrated how Fourier transform ion cyclotron mass spectrometry (FTICR-MS), a fast and reliable analytical tool, can be used to analyze the terroirs of Burgundy (Roullier-Gall et al., 2014). In this study, we captured chemical images of Pinot Noir wines from three different sites in the Uco Valley over two successive vintages, obtained with controlled vinification process. Through non-targeted metabolomics and various chemometric tools, we found that the primary distinguishing factor for these wines is the production site, above the vintage effect. In addition, this study allowed us to identify the remarxable diversity of chemical fingerprints for each site as well as the impact of the vintage effet on the chemical composition.

Materials and methods:
Sampling sites & methods

The experiment was set up in 2019 and 2020 in three Pinot noir vineyards in Uco valley (Argentina), including the Domingo, the Gualtallary and Gualtallary alto wineyards (Figure 1). In each plot, 900 kg of grapes were collected. Three vinification replicates were carried out for each plot by separating grapes in three tanks of 300 Kg. All micro-vinifications were performed using the same yeast (Uvaferm 43) and lactic acid bacteria (Viniflora oenos) and wines were sampled 1 year after bottling.

FT-ICR-MS

For metabolomics analysis, Fourier Transform Ion Cyclotron Resonance Mass Spectrometry with Direct Infusion (DI-FT-ICR MS) was used after dilution of wines (1/20) in methanol. Mass spectra were acquired in negative ionization mode with a Bruker SolariX 12T FT-ICR-MS. Spectra were acquired with 400 scans accumulation and over a 92 - 1000 m/z mass range. Raw Spectra were calibrated and peaks with a signal-to-noise ratio (S/N) of at least 3 were considered. All spectra were align within a range of 0.5 ppm and molecular formula molecular formulae were assigned to their elemental composition in C carbon (C), hydrogen (H), nitrogen (N), oxygen (O), nitrogen (N) and sulfur (S) using an in-house developed software tool.

Statistical analyses

All statistical analyses and post treatments were performed within the R environment (v 4.3.0). Prior to any statistical analysis, data sanity was investigated, and batch effect was corrected for the grape juice dataset. Zero values were replaced using 2/3 of the minimum value for the considered feature. Datasets were then Log10 transformed, mean-centered and unit-variance scaled and filtered to keep m/z present in more than 33% of the samples. For multivariate analysis, Principal component analysis (PCA) was done using the ropls package (Thévenot et al., 2015). Anova Multiblock Orthogonal Partial Least Square (AMOPLS) was used to decompose and quantify the contribution of the different sites and the vintages (Boccard & Rudaz, 2016). A clustering has also been performd usind Euclidian distance and Ward.D2 agglomeration method. Finaly, univariate statistic where performed with Wilcoxon test. Differences in the intensity between sites or vintages were tested and p-value were adjust using the holm method.

Results and discussion:

After dataset cleaning, the analysis of the 18 Pinot noir wines by Founier-Transform Icon Clyclotron Resonance Mass Spectrometry (FT-ICR MS) allows the detection of a remarkable chemical diversity composed of 3430 formula molecular formulae with carbon (C), hydrogen (H), nitrogen (N), oxygen (O), nitrogen (N) and sulfur (S) elemental compositions. The total composition of these Pinot noir wines from Argentina appeared dominated by carbon, hydrogen and oxygen containing compound (CHO : 34.75%). Sulfur containing metabolites also represented a significant proportion of the identified masses (46.99 %) with 23.70 % of CHNOS and 23.29 % of CHOS. Among these 3430 masses, 19 masses where found only in the Domingo vineyard, 12 only in Gualtallary Alto and 1 only in Gualtallary.

The analysis of the impact of terroir on these wines, investigated with Anova Multiblock Orthogonal Partial Least Square analysis (AMOPLS) highlighted the major contribution of the site (41.2%, $p<0.01$) on the dataset variance. The vintage effect represented 19.0% of the dataset variance and 14.5 % could not be discriminated between the two factors (Table 1). As the vinification process was standardized, yeast or malo lactic bacteria impacts could be partially excluded as a source of variation in this study. Thus the 23,3% of residual share of variance could partially be attributed to Plant material and other factors not included in this model. With contrasted clones and rootstocks used in the three plots (clone 777 and SO4 rootstock for Gualtallary alone, along with clone 667 and 1103 rootstock for Gualtallary Alto and Domingo), the plant material factors where confounded making it imposible to consider them for discrimination.

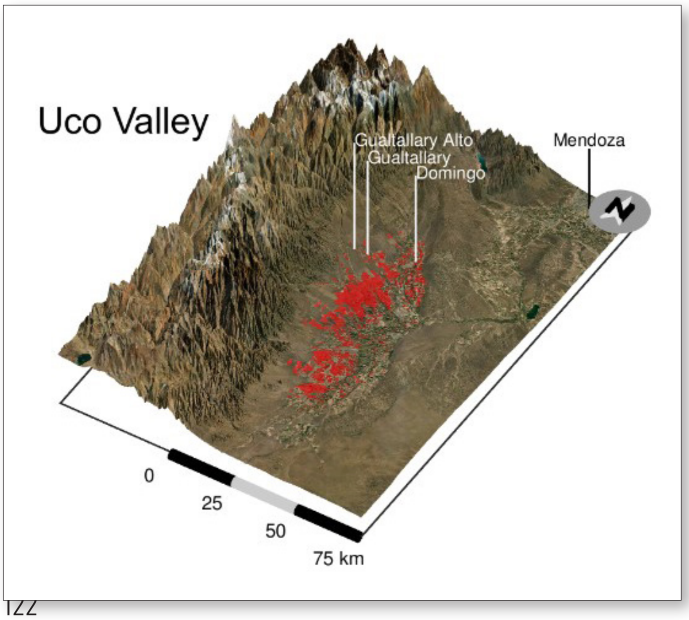

Figure 1: Sampling sites map. White lines are pointing the sampling sites. Red areas represent all the Uco valley vineyards.

Table 1. Relative variability and variable contributions of the AMOPLS analysis of metabolomics data

RSS: Relative sum of squares tp1-5: predictive components, to: orthogonal component.

Factor	RSS	p-value	Main component
Appellation	41.2%	<0.01	Tp 1 : 99.1%
Year	19.0%	>0.05	Tp2 : 99.7%
Appellation x Year	14.5%	>0.05	Tp5 : 99.2%
Residuals	23.3%	N/A	To : 44.6%

Still based on the metabolomic composition measured by FT-ICR MS, sampling sites clustering allowed to split samples in two main groups. The first one consisting of Gualtallary Alto samples alone. Within this cluster, samples were subsequently splitted according to their year of production. Within the second group, wines from Domingo vineyard where found within a subgroup and the same vintage effect could be observed. As for the wines produced from the vineyards located in Gualtallary, this clustering showed that wines obtainted in 2020 where closer from the one produced in Domingo, while the one obtained in 2019 formed a distinct subgroup. In addition, the main contribution of the vineyard on the wines composition, as well as a proximity of the Gualtallary 2020 wines with the ones produced in Domingo, were also shown using Principal Component Analysis (PCA). The first component (31,1%) clearly discriminated sites whereas the second (18%) discriminated vintages. This unsupervised multivariate method also showed a higher variation between Gualtallary Alto and Domingo, Gualtallary wines being distributed between these to sites

In order to identify the chemical fingerprints characteristics of each vineyard, pairwise wilcox mean tests where performed between each sites. Each mass was consided representative of a given site if its intensity was significantly different ($p<0.01$) from the two other vineyards. Doing so, 256 CHNOS elemental compositions, with mainly CHO compounds (41.8%) were identified as representative for Domingo (Figure 2.a) with a potential high contribution of carbohydrates (Gougeon et al., 2009). Interestingly, for Gualtallary Alto, a high contribution of CHNO (51.1%) coumpounds, mainly in the amino acid-peptide like area (Figure 2.b) was identified the as the main contribution to the 262 masses. Finally Gualtallary's wines, with 136 CHNOS elemental compositions, were also caracterized by a slightly higher proportion of CHNO elemental compositions (36.8 %). In addition, for these wines, the relative high contribution of CHO (33.1%). These results therefore revealed a clear discrimination of the chemical fingerprints characteristic of each site with potential specific organoleptic profiles, on the basis of several hundred compounds.

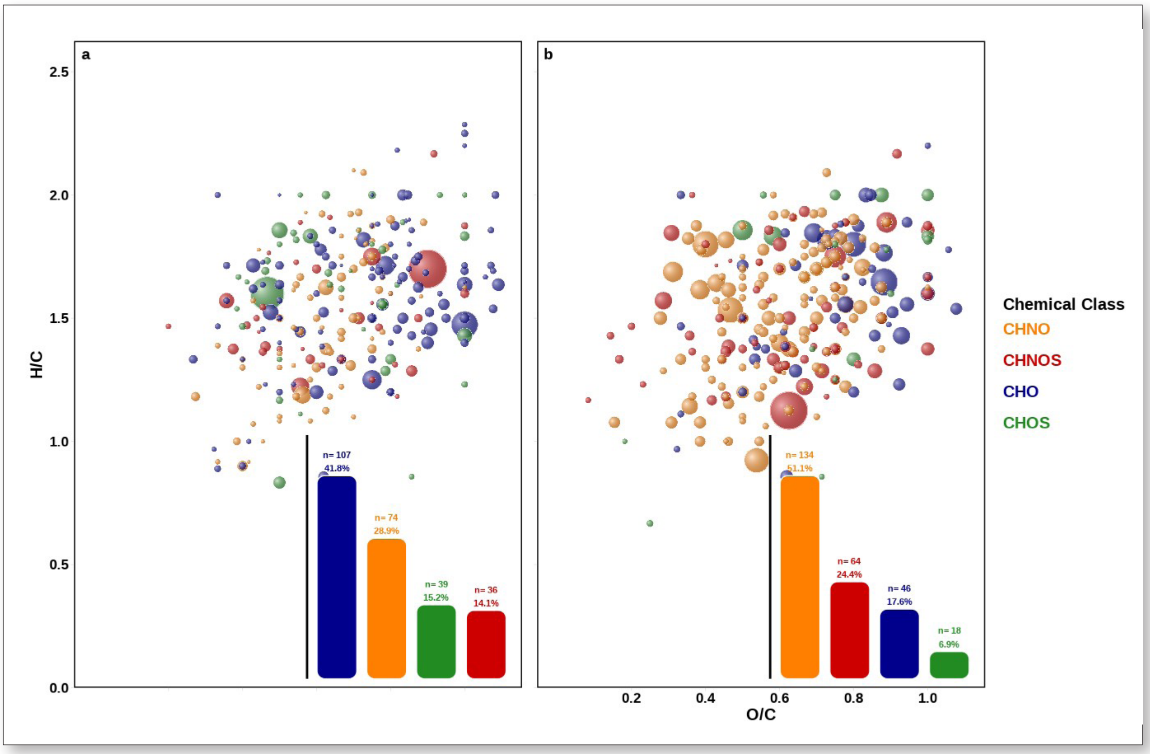

Figure 2 : van Krevelen diagrams representation of Domingo (a) and Gualtallary Alto (b) discriminant masses, with the following color code for elemental compositions: CHO (blue), CHON (orange), CHOS (green), CHONS (red). These diagrams represent mass peaks annotated into assigned elemental composition with an error below 0.5 ppm, an O/C ratio below 1.1, a H/C ratio below 1.5. Dot sizes are proportional to the relative intensity of corresponding mass peaks.

In addition to terroir effects, it is also particularly interesting to note that among the 538 elemental compositions identified as marker for a vintage effect (wilcox test, $p<0.01$), none of these masses were found in the 654 CHNOS identified compositions for the sites. Futhermore, the vintage chemical fingerprints was composed by 44.2 % of CHO compounds, with a potential high contribution of polyphenols, highlighting an alternative contribution of hundreds of compounds for the vintage, significantly distinct from those previously identified.

Conclusion:

In this study, the analysis of 18 Pinot Noir wines from Argentina, obtained with a controled vinification process, and analysed using Fourier-Transform Ion Cyclotron Resonance Mass Spectrometry (FT-ICR MS) has revealed a remarkable chemical diversity, comprising 3430 unambiguously-assigned elemental formulas. The investigation of the terroir effect has lead to the identification of the site as the major factor of chemical diversity change between wines. While polyphenols were found to be impacted by the vintage, this study also identified hundreds of compound in the CHNOS chemical space that can be linked to each vineyard.

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NOV 19, 2024 | 11.30 AM | SCIENTIFIC SESSION: CLIMATE III - SCIENTIFIC ORAL

Application of irrigation in pre-sprouting versus deficit irrigation during the summer: water and physiological effects in Tempranillo vineyards in the D.O. Ribera del Duero

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Keywords: **water stress, photosynthesis, rainfall, water potential, grapevine.**

ABSTRACT

The application of irrigation in grapevine growing continues to be a highly debated aspect in terms of the amount of water and its time of application throughout the vegetative cycl. So, it requires a deeper understanding of the cycle water and physiological effects that the alternative of the irrigation recharge of soil profile at the beginning of the cycle can have in comparison with the alternative of the deficit irrigation applied exclusively during the summer, in a context of climatic variation such as the one currently existing.

Throughout the 2021-2023 period, a trial was carried out on the water status and physiological response of the vineyard to the application of irrigation in two completely separate periods: complete water recharge of the soil before sprouting (about 130 mm) against deficit irrigation (30% ETo) during the summer (approximate total dose of 130 mm) through weekly drip irrigation. The work was carried out in a vineyard of cv. Tempranillo, grafted onto 110R, located in the D.O. Ribera del Duero, with 3.0 x 1.2 vine distances, trained as vertical trellis and pruned as bilateral Royat cordon, where 4 random blocks were established, with elementary plots of 48 vines, distributed in 4 rows of 12 vines. The results show a clear and favorable response of the vineyard to the application of deficit irrigation during the summer in comparison with the application of soil water recharge in sprouting, both in water potential and in photosynthetic activity. Nevertheless, as the soil water recharge can favor temporarily the physiological activity, a more solid evaluation of these irrigation alternatives requires an expansion of its study in different types of soil and a climate monitoring in each zone.

Introduction

The rain collected during the winter period in many wine-growing areas of Spain is generally not enough to cover the water needs of the vine during the vegetative cycle, from budbreak to maturity, which is why a large part of the vineyards cultivated in Mediterranean climatic conditions must be irrigated to achieve appropriate yield and quality. Although in the initial phase of shoot growth the water requirement is not high for the development of the vine, as the season progresses its water deficit increases progressively until the harvest, so irrigation usually begins when the vineyard has developed most of its leaf surface (Yuste et al. 2024).

The interannual variability of rainfall sometimes generates the need to start the irrigation early in the cycle, depending on the level of water stress suffered by the vines (Santesteban et al. 2019), to avoid a decrease in physiological activity and in production and grape quality (Vilanova et al. 2019). The disparity in criteria regarding the time of application of irrigation continues to exist in Spain, including those who argue that abundant winter rain is sufficient for the entire vineyard growing season. Logically, the capacity for maintaining water availability in the soil for the vines depends not only on previous rainfall but also on the type of soil and the rain that is collected during the vegetative cycle (Ramos and Yuste 2023), so the alternative application of irrigation in pre-sprouting or during summer deserves to be studied deeply, given the scarcity of references related to the irrigation dates in the vineyard.

The water status of the vineyard is decisive for the crop in the current context of climatic variation, so knowing the effect that the management of water resources has on the water and physiological relationships of the vineyard is important to facilitate the making of cultivation decisions (Uriarte et al. 2023). For this reason, this work is aimed at quantifying the hydric and physiological effects that the alternative application of irrigation in pre-sprouting or during the summer can have on the cv. Tempranillo in the D.O. Ribera del Duero.

Material and methods

The work was carried out in the period 2021-2023 in Pesquera de Duero (Valladolid), in a vineyard belonging to the De los Ríos Prieto winery, within the D.O. Ribera del Duero. The material used is *Vitis vinifera L.*, cv. Tempranillo, on 110 Richter rootstock, planted in 2006, with vine distances of 3.00 m x 1.20 m (2,778 vines/ha). The row orientation is N-S. The training system is a vertical trellis, using bilateral Royat cordon pruning with 3 spurs of 2 buds on each arm (12 buds per vine). The soil has sandy loam texture, being deep and with hardly any slope, with the lower part of profile (from approximately 50 cm down) of gravel type, with considerably more coarse elements than the upper part, presenting an estimated field capacity of 130 mm/m and good drainage in general.

The experimental treatments applied consisted of the following descriptions:

T0P: water recharge (126 mm average) of the soil before sprouting, applied by drip until field capacity is saturated, without any application of irrigation during the rest of the vegetative cycle.

T07: without soil water recharge before sprouting, but application of weekly deficit irrigation (30% ETo) by drip during the summer (from berry pea size stage to maturity).

Four random blocks were established in the vineyard, with elementary plots of 48 vines (4 rows of 12 vines), of which 2 were taken for the individualized measurement on each date. The water status of the vine was determined by measuring stem water potential, at 12 h (solar time), in 2 leaves on the east side of the trellis, bagged 1 hour before the measurement, using a Scholander-type pressure chamber. The physiological activity was estimated by measuring net photosynthesis at 9 h (solar time), in 2 leaves also on the east side of the trellis, completely sunny, of the same vines as water potential, with IRGA Li-6400. The monthly temperature and precipitation data are indicated in Table 1 and the amount of water provided and the dates of its application are indicated in Table 2.

Table 1. Medium temperature, Tm (ºC) and precipitation, P (mm) in 2021-2023 in Valbuena de Duero (Valladolid).

		Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Annual
Tm	2021	10.7	8.7	5.1	2.4	7.9	8.3	10.3	14.2	18.5	21.2	21.9	17.2	12.2
Tm	2022	12.5	5.1	6.1	2.8	5.5	8.0	9.5	17.1	20.6	24.8	23.5	17.2	12.7
Tm	2023	15.3	8.6	7.5	3.6	3.9	9.5	12.9	14.7	19.6	22.6	22.9	17.6	13.2
P	2021	79	13	54	33	68	5	46	36	40	0	1	33	408
P	2022	36	61	36	12	8	69	37	4	11	8	33	8	323
P	2023	67	67	107	37	12	15	9	22	47	1	1	83	467

Table 2. Water amount (mm) and date of irrigation in each treatment in 2021-2023.

	2021		2022		2023	
	T0P	T07	T0P	T07	T0P	T07
Irrigation	110	126	132	147	136	133
Date	29-31 mar.	6-jul./24-sep.	18-20 apr.	28-jun./27-sep.	10-12 apr.	27-jun./19-sep.

Results and discussion

Stem water potential before weekly irrigation.

The vines generally showed significant differences in the measurements carried out on monday - the day before the weekly irrigation of T07 -, from the beginning of the summer irrigation, totally favorable to T07 treatment with respect to T0P, which had not received irrigation contribution after the water recharge carried out in pre-sprouting (Table 3). However, in the second year (2022), which was the least rainy, although the T07 values always corresponded to a lower level of water stress, the differences between both treatments were only statistically significant on the last measurement date. In the last year (2023), some measurements carried out in august were also not statistically significant, although the T0P was always below T07.

Table 3. Stem water potential (MPa) at 12 h on monday, in 2021-2023. Sig. *p<0,05.

2021	12-jul.	19-jul.	26-jul.	9-aug.	23-aug.	30-aug.				
T0P	-0.64	-0.75	-0.85	-1.09	-1.16	-1.22				
T07	-0.55	-0.47*	-0.60*	-0.80*	-0.93*	-0.92*				
2022	27-jun.	11-jul.	18-jul.	25-jul.	8-aug.	26-sep.				
T0P	-0.52	-1.07	-1.24	-1.14	-1.32	-1.72				
T07	-0.54	-0.99	-1.11	-1.12	-1.27	-1.64*				
2023	3-jul.	10-jul.	17-jul.	31-jul.	7-aug.	21-aug.	28-aug.	12-sep.	25-sep.	2-oct.
T0P	-0.81	-1.14	-1.23	-1.27	-1.30	-1.53	-1.64	-0.73	-1.28	-1.17
T07	-0.70*	-0.95*	-1.04*	-1.16	-1.22	-1.34*	-1.61	-0.56*	-0.97*	-0.99*

Stem water potential after weekly irrigation

Analogously to that observed in the monitoring on monday, the vines showed in the majority of measurements carried out on thursday - two days after the weekly irrigation - statistically significant differences favorable to the T07 treatment with respect to the T0P treatment, which was clearly more disadvantaged due to not have received irrigation contributions during the summer, but only the complete water recharge in pre-sprouting (Table 4). However, in the 2nd year (2022), although the T07 values always presented a lower level of water stress, the differences with respect to the T0P treatment were only statistically significant on the last measurement date. Likewise, some measurements carried out in july and august of 2021 and 2023 were also not statistically significant, although T0P always showed lower values than T07.

Table 4. Stem water potential (MPa) at 12 h on thursday, in 2021-2023. Sig. *p<0,05.

2021	15-jul.	22-jul.	29-jul.	5-aug.	12-aug.	26-aug.	23-sep.	30-sep.
T0P	-0.69	-1.00	-1.04	-0.96	-0.99	-1.29	-1.55	-1,28
T07	-0.56*	-0.88*	-0.93	-0.70*	-0.89	-1.16*	-0.97*	-1,01*
2022	7-jul.	14-jul.	25-aug.	1-sep.				
T0P	-0.97	-1.35	-1.37	-1.52				
T07	-0.83	-1.19	-1.26	-1.11*				
2023	7-jul.	13-jul.	3-aug.	17-aug.	24-aug.	31-aug.	14-sep.	
T0P	-0.81	-1.14	-1.23	-1.27	-1.30	-1.53	-1.64	
T07	-0.70*	-0.95*	-1.04*	-1.16	-1.22	-1.34*	-1.61	

Photosynthesis activity before weekly irrigation

The photosynthesis values in leaves exposed to the sun (at 9 h, solar time) generally showed significant differences in the measurements carried out on monday - the day before weekly irrigation -, throughout the summer irrigation period, in favor of the T07 treatment compared to the T0P treatment, clearly disadvantaged by not having received irrigation contributions after the water recharge that was applied in pre-sprouting (Table 5). However, the differences were not statistically significant until the end of july, despite the fact that the T07 values were always above those of the T0P. The smaller margin of difference favorable to T07 until close to veraison could be due to the water benefit that pre-sprouting recharge brings to T0P with respect to T07, whose irrigation start did not occur until summer.

Table 5. Photosynthesis (umol CO_2.m^{-2}.s^{-1}) at 9 h on monday, in 2021-2023. Sig. *p<0,05.

2021	19-jul.	9-aug.	23-aug.	30-aug.					
T0P	22.9	15.6	10.7	7.4					
T07	25.7	25.1*	18.7*	18.9*					
2022	27-jun.	11-jul.	18-jul.	25-jul.	8-aug.	22-aug.	5-sep.	12-sep.	26-sep.
T0P	23.4	6.81	2.19	2.52	1.53	2.96	1.78	2.25	3.22
T07	23.9	9.22	2.74	5.57*	4.50*	6.99*	8.07*	5.60*	8.62*
2023	3-jul.	10-jul.	17-jul.	31-jul.	7-aug.	21-aug.	28-aug.	25-sep.	2-oct.
T0P	21.8	21.2	10.8	7.8	3.27	0.80	4.75	14.8	15.2
T07	24.3	24.1	14.9	11.9*	8.62*	3.67*	9.16*	19.2*	16.6

Photosynthesis activity after weekly irrigation

In a more constant tendence than that observed in the monday monitoring, the photosynthesis values showed in the vast majority of the measurements carried out on thursday - two days after the weekly irrigation - significant differences favorable to the T07 treatment with respect to the T0P treatment, clearly disadvantaged by not having received irrigation contributions during the summer, except only for complete water recharge in pre-sprouting (Table 6). The differences between both treatments were clearer than in the measurements on monday, practically from the start date of irrigation in T07, favored by the fact that the measurements were carried out only 2 days after the time of irrigation, on tuesday, which represents a temporary benefit for the water status of the T07 plants with respect to those of T0P.

Table 6. Photosynthesis (umol CO_2.m^{-2}.s^{-1}) at 9 h on thursday, in 2021-2023. Sig. *p<0,05.

2021	15-jul.	22-jul.	5-ago.	12-aug.	26-aug.	23-sep.	30-sep.
T0P	17.8	23.9	17.9	13.4	5.4	7.0	9.5
T07	20.6*	25.8	25.4*	22.7*	20.2*	15.2*	16.0*
2022	7-jul.	14-jul.	18-aug.	25-aug.	1-sep.		
T0P	19.2	2.4	5.1	2.8	3.7		
T07	22.3	17.6*	17.1*	16.7*	16.1*		
2023	7-jul.	13-jul.	3-aug.	17-aug.	24-aug.	31-ago.	14-sep.
T0P	22.1	17.5	9.8	7.8	1.0	5.2	17.0
T07	24.7	22.7*	20.4*	20.1*	12.1*	16.7*	19.8

Conclusions

The stem water potential has responded with significant differences in favor of the T07 treatment from the beginning of its summer irrigation, compared to the T0P, which did not receive irrigation contributions after water recharge in pre-sprouting. Photosynthesis, at mid-morning, showed a similar trend to the water potential, offering significant differences favorable to the T07 treatment, due to the lack of irrigation of the T0P during the summer. The water status and photosynthetic activity presented similar trends in the measurements carried out on monday - one day before the weekly irrigation - and on thursday - two days after the weekly irrigation -, although the thursday measurement more clearly reflected the differences favorable to the T07 treatment with respect to T0P.

The results show a notable water and physiological impact of the application of deficit irrigation in summer compared to the exclusive application of soil water recharge before sprouting. On the other hand, the application of water recharge before sprouting, which can be assimilated to abundant precipitation at the end of winter or beginning of spring, can partially and temporarily favor photosynthetic activity, depending on the meteorological conditions of the vegetative cycle period. In any case, the alternative application of irrigation in pre-sprouting or during the summer requires in-depth experimentation in different types of soil and, of course, the consideration of annual climatic conditions, to optimize efficiency in water use and the response of the vineyard.

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NOV 19, 2024 | 11.45 AM | SCIENTIFIC SESSION: **CLIMATE III - FLASH ORAL**

Development of cv. Tannat under extreme heat events in Uruguayan coastal terroirs

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Keywords: **climate change, crapevine composition, heat wave, sea breeze, Uruguay.**

ABSTRACT

Climate change is causing increasing extreme heat events, with negative consequences on both quality and quantity of grape production. In order to study the Ocean influences as a means for grapevine to face the heat in Uruguay, the development of Tannat, situated at similar latitude (34°35'S) but at different altitudes, distances and exposure to the Atlantic Ocean was studied during the growing season (GS) 2022-23, the warmest season of the past 32 years. The mesoclimate was described using temperature data from 12 sensors and was subdivided in: 6 sensors at high altitude exposed to the ocean "H"; 4 sensors at low altitude shelter to the ocean "L" and 2 sensors at the traditional region "C". The evolution of grape metabolites was evaluated during the ripening period. H recorded up to 90 fewer hours than L with temperature above 30°C, and 408 less than C. H and L recorded no hours above 40°C, while in C, there were 13 hours. During a 4-day heat wave, the sea breeze caused a temperature decrease in H of 4°C at 13:00 local time leading to a maximum difference with C at 16:00 of 7.9 °C. C shows an earlier harvest by 15 days, -25% in berry size, -28% in titratable acidity, +13% in soluble solids concentration (gTSS/L) and -46% in potential anthocyanins (ApH1) compared to H and L. L obtained +16 gTSS/L, +1202 mg/L ApH1, and -1 g/L malic than H. During the heat wave, the accumulation of soluble solids (gTSS/berry) and ApH1 slowed down in H and L, while C stopped completely. Plots exposed to the ocean better controlled the thermal excesses, reducing the impact on final berry metabolites. In the context of climate change, cooler oceanic terroirs become an option for the production of wines with acidity, aroma, colour and lower alcohol.

NOV 19, 2024 | 11.50 AM | SCIENTIFIC SESSION: **CLIMATE III - FLASH ORAL**

Microclimatic characterisation in pre-planting projects for vineyards on slope which conserve native vegetation at Gualtallary and Agrelo, Mendoza Argentina

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Keywords: **Pre-planting studies, viticulture of conservation, slope, microclimate, native vegetation.**

ABSTRACT

Vineyards with distinctive features (e.g. soil types, microclimates) has lead viticulturists of Mendoza to explore new areas for vine plantings, specially at higher altitudes, as well as to re-think plantations conserving pristine conditions. With that philosophy, this work investigates the microclimatic conditions for two pre-planting vineyard projects located in different main viticulture regions of Mendoza. One is located at 1400-1500 m a.s.l. in Gualtallary, Tupungato, and the other vineyard is located at 950 m a.s.l. in Agrelo, Luján de Cuyo. In both vineyards, 15 sensors of air temperature were distributed over 15 hectares to generate data for delimiting parcels for vine planting. Analyses of data from two vine growing seasons (2022-2023 and 2023-2024) show large variations of the microclimatic conditions within each vineyard and between seasons, regarding seasonal heat accumulated, heat waves, diurnal temperature cycles, among others. Different land exposures, slope percentages and keeping the surrounded native vegetation influence the observed diversity of microlimatic conditions. Overall, it was found that considering the climatic variation in pre-planting studies it is key, not only for understanding the suitability of a place for vine growing, but also regarding choosing the correct varieties and thus, to achieve the best terroir expression at a site.

NOV 19, 2024 | 11.55 AM | SCIENTIFIC SESSION: **CLIMATE III - FLASH ORAL**

Do climate factors explain the variation of symptoms and vine yields due to wood diseases?

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Keywords: **Esca, temperature, yield, incidence.**

ABSTRACT

Global viticulture has faced declining fruit yields and vine longevity in recent decades. Esca disease is one of the causes identified which leads to yield loss and a shortened plant lifespan. Research has improved the understanding of this complex disease but the losses linked to this disease have been poorly quantified and the factors inducing the appearance of esca leaf symptoms are still debated.

Esca incidence, vine yield loss, and fruit composition were assessed as part of an extensive esca surveying program which monitored approximately 57,000 vines annually in 12 estates from the Bordeaux region across 9 years. Climate data from localized daily weather stations were integrated into this database to quantify the impact of climate on esca incidence.

Even though yield losses from vines with esca can reach up to 50%, individual diseased vines are rarely unproductive. At the plot level, yield losses remain low and, moreover, the majority of mortality observed in the vineyards was not due to esca, with only 40% of dead vines having a previous history of esca. The incidence of esca varies greatly from one vineyard to another with a significant change in the behavior of the disease in plots planted over the last 10-15 years. The data show that the amount of precipitation early in the season and the temperature dynamics later in the season have a clear relationship with disease incidence. By isolating the effect of plot age, we uncovered disease patterns that suggest hidden factors unrelated to climate, which could potentially include changes in management techniques. These results suggest that there is a need to study other factors contributing to vine mortality and dieback more broadly.

NOV 19, 2024 | 12 PM | SCIENTIFIC SESSION: CLIMATE III - FLASH ORAL

Smart Wines 4.0 Inclusive. Climate change adaptation strategies in Northern Patagonia, Chile

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Keywords: **climate change adaptation strategies, small wine farmers, northern Patagonia, Chile, inclusive innovation and smart viticulture.**

ABSTRACT

Climate change is having a significant impact on wine production in the world (Van Leeuwen, 2024 & Grazia, et. al., 2021). In this scenario, winegrowers are facing agro-environmental disturbances where the development of climate change adaptation strategies is imperative (Naulleau, 2021). Alterations in climatic conditions, such as rising temperatures, changes in precipitation patterns, and extreme weather events, are affecting the quality and quantity of harvests. These variations are particularly influencing the grape ripening cycles, the incidence of pests and diseases, and the availability of water for irrigation.

Wine producers in Chile, especially in regions like Northern Patagonia, are adopting various adaptation strategies to address these challenges. These include the implementation of advanced technologies such as agrometeorological sensors, automated irrigation systems, and monitoring tools based on artificial intelligence. Additionally, they are exploring crop diversification and using grape varieties more resistant to climatic stress.

In summary, adaptation to climate change is crucial for the sustainability and competitiveness of the wine industry in Chile. The combination of advanced technologies, innovative management strategies, and an inclusive approach to technological development is helping to adapt the effects of climate change and secure the future of wine production in the country.

Introduction

En Chile, agriculture 4.0 is characterized by delivering solutions with an excessive focus on technological developments without a comprehensive consideration of the relational processes involved in technology adoption. Additionally, there is a high cost associated with the development and access to these technologies (Rose et. al., 2018; Klerk & Rose, 2020).

The transition towards Agriculture 4.0, with a focus on a "just technological transition," aims not only to improve economic efficiency and productivity but also to ensure that small producers have access to these technologies (Rolandi, et.al., 2021).

Projects like Smart Wines 4.0 Inclusive are designed to be affordable, scalable, and relevant for small-scale production, enhancing farmers' quality of life and increasing their capacity to adapt to adverse climatic conditions.

Viticulture is an activity that, due to environmental conditions and the impact of climate change, is proving to be innovative in the rural world of the Northern Patagonia.

This research aims to develop a prototype, under the framework of a just technological transition, based on an integrated digital platform called **Smart Wines 4.0** Inclusive for small-scale viticulture, aiming to increase economic efficiency and improve the quality of life for small wine producers in C Northern Patagonia, Chile.

This prototype revolutionizes the way small farmers can design and implement productive diversification strategies in the context of climate change in the Chilean Northern Patagonia.

In this context and based on the phenomenon of "just technological transition", Smart Wines 4.0 Inclusive was born in the chilean northern patagon, with the purpose of improving economic efficiency, the capacity to adapt to critical climatic events, and enhancing the quality of life of small agricultural producers in the region, enabling productive diversification in a historically livestock-oriented area.

Materials and methods

The development of the prototype for small wine farmers was carried out participatively through an open innovation process in five vineyards of the Northern Patagonia (Table 1). These production units produce sparkling wine from the varieties Pinot Noir, Gewürztraminer, and Chardonnay. The average area they manage is 0.7 hectares.

The research considers the following phases: Characterization of the socio-cyber-physical system (SCPS) (Metta et.al., 2022) of small-scale wine production that identifies conditions for the impact of digital transition, modeling of the Smart Wines 4.0 Inclusive prototype based on an SCPS, through co-design between an expert team and small winegrowers from Northern Patagonia, Chile and validation of Smart Wines 4.0 Inclusive prototype at experimental level, analyzing results to refine the design and develop an intellectual property protection and industrial property strategy that can support the project.

Smart Wines 4.0 Inclusive is a prototype based on an integrated digital platform that promotes productive diversification by encouraging emerging agricultural activities such as viticulture in the southernmost macrozone of Chile. It reduces operational production costs and increases gross production margins. Moreover, it enhances farmers' quality of life by increasing their income and reducing their workload, allowing more time for non-agricultural activities. This prototype is installed on a commonly accessible Android or IOS mobile device for farmers in general.

Results

The Smart Wines 4.0 Inclusive prototype reduces operational production costs and increases gross production margins, enhancing the economic efficiency of viticulture management in an affordable, scalable, and contextually relevant manner for small-scale production. Our predictive model has generated a 20% reduction in operational costs. Currently, the experimental vineyards are systematizing data to generate comparisons between vineyards. Through co-creation with small agricultural producers that reflects the specificity of their enabling operating conditions and applying an analytical framework to identify key performance indicators, the socio-technical system generated will improve farmers' quality of life by offering a digital vineyard management transition process that reduces workload, thus increasing time for other non-agricultural activities. Additionally, it enhances their capacity to adapt to adverse climatic events through an early warning system for adverse weather conditions, enabling preventive actions.

Smart Wines 4.0 Inclusive embraces the technological challenge of designing solutions that consider small-scale co-design, recognizing that small agricultural producers have limited capacity, access, and adoption of technologies. It promotes R&D processes that develop affordable, scalable, and contextually relevant technology.

Smart Wines 4.0 Inclusive is characterized by being affordable for small agricultural producers, developing digital agricultural competencies, adapting the technology to the socio-economic and productive reality of the users, providing access to meaningful data and analysis to improve the decision-making process, and finally creating virtual learning communities that generate collective knowledge and collaborative agricultural practices.

The mechanisms and conditions for using and accessing Smart Wines 4.0 Inclusive focus on its affordability, technology adaptable to the needs of small farmers, development of digital agricultural competencies with purpose, intuitive interface, and contribution to diversifying production by fostering an emerging activity in the southern Austral macrozone, such as the growing viticultural activity.

Currently, the prototype is in the technical validation stage at TRL 4 level with small wine farmers in northern Patagonia, aiming to begin the commercial validation stage in early 2025.

Conclusions

Smart Wines 4.0 is not just a technological development but also builds technological management capabilities among small viticultural agricultural producers in emerging areas. Additionally, it creates a virtual learning community where spaces for effective co-construction of the prototype are generated, considering the socio-technical system that is part of the prototype development.

The prototype emphasizes a co-construction approach with small agricultural producers, tailored to their specific enabling conditions, and applies an analytical framework to identify key performance indicators. The core technological components of Smart Wines 4.0 are centered on critical viticulture metrics, leveraging meteorological data, vineyard management, and harvest optimization to enhance productivity and improve farmers' quality of life by digitizing vineyard operations. This shift reduces the physical workload, increases leisure time, and strengthens resilience to adverse weather through early warning systems, enabling proactive measures against climatic risks. What interests us, in addition to reducing costs and improving the lives of winegrowers, is being able to validate and scale up the open innovation model so that it can be applied in other contexts in Patagonia.

Smart Wines 4.0 tackles the challenge of designing solutions considering co-design at a small scale, acknowledging that small agricultural producers have limited capacity, access, and adoption of technologies. It promotes R&D processes that develop affordable, scalable, and relevant technology.

Table 1. Modelling Smart Wines 4.0

Process	Description	Key performance indicator - KPI	Intelligent Monitoring
Capture of agrometeorological data	This component gathers real-time data on weather and meteorological conditions, such as temperature, humidity, precipitation, wind speed, and solar radiation. It includes an environmental alert system.	Cumulative Temperature Index over 10°C, Precipitation, Sunshine Hours, Maximum and Minimum Extreme Temperatures, Wind Speed.	Sensors connected in automated weather stations.
Crop management	Controls the quantity and optimal timing of irrigation to ensure an adequate supply of water to the grapevines. Records the energy used.	Water consumption, soil moisture level, irrigation efficiency.	Soil temperature and humidity sensors. Hyperspectral and multispectral imaging. Predictive algorithms. Artificial Intelligence.
Harvest management	Monitors the ripening status of grapes and plans the harvest at the optimal moment.	Brix degrees, acidity, pH, harvest date, grape quality.	Brix degrees, geographic information systems (GIS), tracking applications.
Integrated data management and reporting.	Processes and analyzes collected data to make informed decisions and generate reports.	Overall performance, trends over time, projections.	Data analysis software, custom dashboards.

Figure 1. Open innovation design "Smart Wines 4.0 Inclusive"

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SCIENTIFIC SESSION: **CLIMATE - POSTER**

Influence of the climatic component of the terroir on the typicity of Tannat grapes

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Keywords: **Tannat, climate, composition.**

ABSTRACT

In Uruguay, six viticultural climatic types were defined based on a multi-criteria climatic system adapted to the conditions of the crop. To determine the influence of the climate component on the typicity of the Tannat red grape variety, trials were set up in two contrasting climatic situations, in 2018 and 2019. The vineyards were trellised, dry-farmed, one installed in a warm climate, warm nights and moderate drought (IH5 IF1 IS1), and the other in a warm-temperate climate, warm nights and moderate drought (IH4 IF2 IS1). For each terroir and per year, on duplicate samples of 100 berries, the primary composition during ripening, growth dynamics, accumulation rate and solute reduction were analyzed, and at 23 °Brix, the secondary composition was determined. It was analyzed by multivariate and mean comparison (Fisher's LSD test). The thermal components (HI and FI) were stable in the two years analyzed, while the water factor (SI) showed a marked annual variability, with direct influence on the phases (I and II) of sugar accumulation (F_{value}- 15.14; p< 0.01 in phase I and F_{value}- 9.77; p< 0.1). The composition at 23° Brix determines differences in total acidity (7.82 H_2SO_4 L^{-1}; p< 0.01), and in anthocyanins (4.19 mg $berry^{-1}$; p< 0.1), with the highest values in the warm-temperate climate. Phenolic richness values are higher in the warm climate (82 ua; p< 0.1). The warm-temperate climate presents greater stability between years, resulting in favorable thermal and hydric conditions for ripening processes and for the main components of the berry. The thermal component allows differentiating the Tannat grapes from each terroir.

SCIENTIFIC SESSION: **CLIMATE - POSTER**

Increasing microalgae biomass feedstock by valorizing wine gaseous and liquids residues

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Keywords: **CO_2 sequestration, microalgae, vineyards, wine making.**

ABSTRACT

Global warming due to greenhouse gases (GHG) has become a serious worldwide concern. The new EU Green Deal aims t0 achieve GHG emissions reduction by at least 55% by 2030 and a climate neutral EU economy by 2050. The deal strongly encourages GHG reducing measures at local, national and European levels. The REDWine project will demonstrate the technical, economic and environmental feasibility of reducing by, at least, 31% of the CO_2 eq. emissions produced in the winery industry value chain by using biogenic CO_2 produced by fermentation for microalgae biomass production.

REDWine concept will be realized through the establishment of an integrated Living Lab demonstrating the viability of the system at TRL 7. The Living Lab will be able to utilize two tons of fermentation off-gas/year (90% of total CO_2 produced in the fermenter) and 80 m3 of liquid effluent (100% of the liquid effluent generated during fermenter washing) to produce one ton (dry weight) of *Chlorella* biomass/year. This biomass will be processed under a downstream extraction process to obtain added-value extracts and applied in food, cosmetic and agricultural end-products and to generate a new EcoWine. REDWine will focus on the recovery of off-gas from a 20.000L fermenter of red wine production existing in Adega Cooperativa de Palmela (ACP, located in Palmela, Portugal).

REDWine's microalgae were tested in 2022 and 2023 with four purposes in vineyard: improve flowering stages, contribute to high temperature resistance, act as a biofungicide against downy mildew and increase nitrogen content in ripening, to help fermentation and improve aromatic compounds. It was also used in winemaking processes as a clarificant and anti-oxidant. Results showed that algae can work as an anti-oxidant and clarificant. Effect as biofungicide or prevent heat stress didn't show any positive result and, on the effect, to increase N contente in grapes, more studies are needed. Even thou the idea to capture CO_2 from fermentation is not new, the idea to use it on the development of algae on a circular economy approach is.

SCIENTIFIC SESSION: **CLIMATE - POSTER**

Water and physiological influence of recharge irrigation in pre-sprouting in Tempranillo vineyard, subjected to deficit irrigation during the summer, in the D.O. Ribera del Duero

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Keywords: **water stress, photosynthesis, rainfall, water potential, grapevine.**

ABSTRACT

The availability of water is usually greater at the beginning of spring than in the subsequent months, until the end of summer, in most wine-growing areas in Spain. The development of the sequential phenological stages from sprouting can be benefited by the water available in the soil for the plant, but it is important to know what subsequent physiological effects the use of the water provided to the soil at sprouting can have in the vineyard, in growing situations in which the vineyard can be deficitary irrigated during the summer, when it suffers greater evapotranspirative demand and need for irrigation to reduce excessive water stress.

Throughout the 2021-2023 period, the water status and physiological response of the grapevine to the application of irrigation for complete water recharge (126 mm average) of the soil profile before sprouting were analyzed in a vineyard cultivated during the summer through deficitary irrigation (30% ETo), applied weekly by dripping from pea size to harvest. The work was carried out in a vineyard of cv. Tempranillo, grafted on 110R, located in the D.O. Ribera del Duero, with 3.0 x 1.2 vine distances, trained as vertical trellis and pruned as bilateral Royat cordon, where 4 random blocks were established, with elementary plots of 48 vines, distributed in 4 rows of 12 vines.

The impact of the recharge irrigation during the sprouting period, in vineyard subjected to déficit irrigation during the summer, was scarce, both in water potential and in photosynthetic activity, which could only be verified in the campaign with the greatest rainfall scarcity. These results suggest the convenience of spatially expanding the study in different types of soil, in order to contrast the possible limitation related to the soil profile structure in terms of the use of water by the vineyard, depending on weather conditions.

Introduction

The availability of water is usually greater at the beginning of spring than in the subsequent months, until the end of summer, in the wine-growing areas of Spain. The majority of vineyards cultivated in a Mediterranean climate show the need for irrigation as the season progresses, increasing their water deficit progressively, due to the increasing development of their leaf surface, in many cases until the harvest, to reduce water stress and alleviate the loss of yield and, possibly, grape quality (Vilanova et al. 2019).

The phenological development from sprouting can be benefited by the water available in the soil at that time, but it is important to know what subsequent physiological effects the possible use of the water provided to the soil during the sprouting season can have, in situations in which the vineyard can be subjected to déficit irrigation later, during the summer, when it suffers greater evapotranspirative demand, to reduce excessive water stress and avoid a decrease in physiological activity (Pellegrino et al. 2005).

Some producers in various wine-growing areas say that usual winter rain is enough for the vineyard to perform properly in productive and qualitative terms. However, the possibility of maintaining sufficient water availability in the soil to be used by the vines depends, in addition to previous rainfall, on the type of soil and the rain collected during the vegetative cycle (Pereyra et al. 2023), in such a way that the application of irrigation in pre-sprouting, ensuring water recharge of the soil profile up to field capacity, should also be studied when the cultivation regime allows the application of deficit irrigation during the summer, when water is most scarce (Ramos & Yuste 2023).

In the current context of climatic variation, it is interesting to know the influence of water resource management on the physiological activity of the vineyard to improve its cultivation (Yuste et al. 2024). Thus, this work tries to quantify the hydric and physiological effects that irrigation applied in pre-sprouting can have on the cv. Tempranillo in the D.O. Ribera del Duero.

Material and methods

The work was carried out in the period 2021-2023 in Pesquera de Duero (Valladolid), in a vineyard belonging to the De los Ríos Prieto winery, within the D.O. Ribera del Duero. The material used is *Vitis vinifera* L., cv. Tempranillo, on 110 Richter rootstock, planted in 2006, with vine distances of 3.00 m x 1.20 m (2,778 vines/ha). The row orientation is N-S. The training system is a vertical trellis, using bilateral Royat cordon pruning with 3 spurs of 2 buds on each arm (12 buds per vine). The soil has sandy loam texture, being deep and with hardly any slope, with the lower part (from approximately 50 cm down) of gravel type, with considerably more coarse elements than the upper part, presenting an estimated field capacity of 130 mm/m and good drainage in general.

The experimental treatments applied consisted of the following descriptions:

T7P: water recharge (126 mm average) of the soil before sprouting, drip applied until field capacity is saturated, and application of weekly deficit irrigation (30% ETo) during the summer.

T07: without soil water recharge before sprouting, but application of weekly deficit irrigation (30% ETo) during the summer (from berry pea size stage to maturity).

Four random blocks were established in the vineyard, with elementary plots of 48 vines (4 rows of 12 vines), of which 2 were taken for the individualized measurement on each date. The water status of the vine was determined by measuring stem water potential, at 12 h (solar time), in 2 leaves on the east side of the trellis, bagged 1 hour before the measurement, using a Scholander-type pressure chamber. Physiological activity was estimated by measuring net photosynthesis at 9 h (solar time), in 2 leaves also on the east side of the trellis, completely sunny, of the same vines, with IRGA Li-6400. The monthly temperature and precipitation data are indicated in table 1 and the amount of water provided and the dates of its application are indicated in table 2.

Table 1. Medium temperature, Tm (ºC) and precipitation, P (mm) in 2021-2023 in Valbuena de Duero (Valladolid).

		Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Annual
Tm	2021	10.7	8.7	5.1	2.4	7.9	8.3	10.3	14.2	18.5	21.2	21.9	17.2	12.2
Tm	2022	12.5	5.1	6.1	2.8	5.5	8.0	9.5	17.1	20.6	24.8	23.5	17.2	12.7
Tm	2023	15.3	8.6	7.5	3.6	3.9	9.5	12.9	14.7	19.6	22.6	22.9	17.6	13.2
P	2021	79	13	54	33	68	5	46	36	40	0	1	33	408
P	2022	36	61	36	12	8	69	37	4	11	8	33	8	323
P	2023	67	67	107	37	12	15	9	22	47	1	1	83	467

Table 2. Water amount (mm) and date of irrigation in each treatment in 2021-2023.

	2021			2022			2023		
	T7P	T07	Date	T7P	T07	Date	T7P	T07	Date
Recharge	110	-	29-31 mar.	132	-	18-20 apr.	136	-	10-12 apr.
Irrigation	126	126	6-jul./24-sep.	147	147	28-jun./27-sep.	133	133	27-jun./19-sep.

Water potential before weekly irrigation

The vines did not show significant differences in the measurements carried out on monday - the day before weekly irrigation -, with some exceptions favorable to one or the other treatment (table 3). The first year (2021), T07 showed some less negative values than T7P, although the difference was only significant in the mid-july measurement. The second year (2022), which was the least rainy, the T7P values tended to correspond with a level of water stress slightly lower than that of T07, although the difference between both treatments was only statistically significant at the end of july. The last year (2023), the trend was similar to the first one, with some values slightly higher in T07. (Table 3)

Water potential after weekly irrigation

In the thursday measurements - two days after weekly irrigation - no statistically significant differences were observed between treatments in any measure (table 4). Analogously to what was observed in the monday measurements, in the first year the T07 treatment showed some less negative values than the T7P, while in the second year and the third year the T7P tended to present slightly less negative values than the T07. (Table 4)

Table 3. Stem water potential (MPa) at 12 h on monday, in 2021-2023. Sig. *p<0,05.

2021	12-jul.	19-jul.	26-jul.	9-aug.	23-aug.	30-aug.				
T07	-0.55	-0.47*	-0.60	-0.80	-0.93	-0.92				
T7P	-0.53	-0.60	-0.62	-0.86	-0.91	-0.98				
2022	27-jun.	11-jul.	18-jul.	25-jul.	8-aug.	26-sep.				
T07	-0.54	-0.99	-1.11	-1.12	-1.27	-1.64				
T7P	-0.47	-1.02	-1.12	-1.06*	-1.17	-1.58				
2023	3-jul.	10-jul.	17-jul.	31-jul.	7-aug.	21-aug.	28-aug.	12-sep.	25-sep.	2-oct.
T07	-0.70	-0.95	-1.04	-1.16	-1.22	-1.34	-1.61	-0.56	-0.97	-0.99*
T7P	-0.72	-0.98	-1.07	-1.21	-1.25	-1.36	-1.55	-0.66	-0.99	-1.10

Table 4. Stem water potential (MPa) at 12 h on thursday, in 2021-2023. Sig. *p<0,05.

2021	15-jul.	22-jul.	29-jul.	5-aug.	12-aug.	26-aug.	23-sep.	30-sep.
T07	-0.56	-0.88	-0.93	-0.70	-0.89	-1.16	-0.97	-1.01
T7P	-0.60	-0.93	-0.98	-0.83	-0.96	-1.02	-0.98	-1.02
2022	7-jul.	14-jul.	25-aug.	1-sep.				
T07	-0.83	-1.19	-1.26	-1.11				
T7P	-0.75	-1.24	-1.24	-1.06				
2023	7-jul.	13-jul.	3-aug.	17-aug.	24-aug.	31-aug.	14-sep.	
T07	-0.87	-0.90	-0.97	-1.34	-1.44	-1.08	-0.70	
T7P	-0.85	-0.91	-0.94	-1.32	-1.43	-1.15	-0.69	

Photosynthetic activity before weekly irrigation

The photosynthesis values at 9 h (a.m.) did not show significant differences in the measurements carried out on monday - the day before weekly irrigation -, with one exception, in the 1st measurement of 2023 (table 5). The first year and the second year, the trend of photosynthesis between treatments was similar to that of the water potential measured on monday, slightly favorable to T07 the first year and slightly favorable to T7P the second year, this having been the least rainy year of the study period. In the third year, no defined trend was observed between both treatments, with slightly higher values alternating between T7P and T07.

Table 5. Photosynthesis (umol $CO_2.m^{-2}.s^{-1}$) at 9 h on monday, in 2021-2023. Sig. *p<0,05.

2021	19-jul.	9-aug.	23-aug.	30-aug.					
T07	25.7	25.1	18.7	18.9					
T7P	25.2	22.4	17.4	18.3					
2022	27-jun.	11-jul.	18-jul.	25-jul.	8-aug.	22-aug.	5-sep.	12-sep.	26-sep.
T07	23.9	9.2	2.74	5.57	4.50	6.99	8.07	5.60	8.62
T7P	24.3	10.8	5.44	7.20	5.95	8.16	7.25	6.32	8.68
2023	3-jul.	10-jul.	17-jul.	31-jul.	7-aug.	21-aug.	28-aug.	25-sep.	2-oct.
T07	24.3	24.1	14.9	11.9	8.62	3.67	9.16	19.2	16.6
T7P	26.6*	23.5	13.3	12.5	8.24	4.40	8.26	20.2	17.5

Photosynthetic activity after weekly irrigation

The vines presented net photosynthesis values, in the measurements carried out on thursday - two days after weekly irrigation -, without significant differences between treatments, except only in the 2nd measurement of july 2022, favorable to the T7P treatment (table 6). The first year (2021), the trend was similar to that of the water potential measured on thursday, with the T07 treatment presenting some slightly higher values than the T7P. In the second year and in the third year, a tendency for the T7P treatment to present slightly higher values than T07 was observed. This trend may have responded to a water situation presumably more favorable to T7P, derived from the water recharge applied in pre-sprouting in this treatment, which would mean a temporary benefit for the water status of the T7P plants with respect to those of T07.

Table 6. Photosynthesis (umol $CO_2.m^{-2}.s^{-1}$) at 9 h on thursday, in 2021-2023. Sig. *p<0,05.

2021	15-jul.	22-jul.	5-ago.	12-aug.	26-aug.	23-sep.	30-sep.
T07	20.6	25.8	25.4	22.7	20.2	15.2	16.0
T7P	20.3	25.6	23.9	22.5	18.7	14.2	16.0
2022	7-jul.	14-jul.	18-aug.	25-aug.	1-sep.		
T07	22.3	17.6	17.1	16.7	16.1		
T7P	23.5	21.0*	17.6	16.8	17.1		
2023	7-jul.	13-jul.	3-aug.	17-aug.	24-aug.	31-ago.	14-sep.
T07	24.7	22.7	20.4	20.1	12.1	16.7	19.8
T7P	25.8	23.7	21.7	20.9	11.9	17.5	20.5

Conclusions

The stem water potential has not responded significantly to the water recharge irrigation in pre-sprouting in the vineyard that is subjected later to deficit irrigation during the summer. However, a variable interannual trend was observed between treatments, which was more favorable to T7P in the least rainy year. Photosynthesis, at mid-morning, showed a similar trend to stem water potential, without significant differences between treatments, although with variable alternation of values between them.

The water status and photosynthetic activity presented similar trends in the measurements carried out on monday - one day before the weekly irrigation - and on thursday - two days after the weekly irrigation -, although the thursday measurement reflected a trend somewhat more favorable to the T7P treatment with respect to T07 than the measurement carried out on monday.

The results show little water and physiological impact of the application of soil water recharge before sprouting when the vineyard is subjected later to deficit irrigation during the summer. However, the water recharge before sprouting, which can be assimilated to abundant precipitation at the end of winter or beginning of spring, can slightly favor, temporarily, photosynthetic activity, depending on the weather conditions of the vegetative cycle period. In any case, the analysis of the application of recharge irrigation in pre-sprouting requires in-depth experimentation in different types of soil and, of course, under consideration of the weather conditions, to also contrast the productive and qualitative response of the vineyard.

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SCIENTIFIC SESSION: **CLIMATE - POSTER**

Impacts of climate change on viticulture practices in the Douro Valley Region - Portugal: a review

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Keywords: **Douro, Climate change, Mitigation strategies.**

ABSTRACT

This review aims to examine the effects of climate change on the Douro Valley and its vineyards. An overview of the Douro Valley's characteristics and terroir is analyzed by the geography, climate, and land use within the area. This contextualization of the area further sets the stage for exploring climate-induced challenges faced by the vineyards in the region. The primary consequence of climate change is the increase in temperature and its impact on the levels of precipitation and the occurrence of extreme weather patterns. The drier and warmer climate trend can be seen in the Douro Valley. This shift in climate within the region will result in possible losses of yield and productivity within the vineyards unless certain practices are altered to better fit the changing environment. By synthesising relevant studies and research, our poster seeks to demonstrate the multifaceted implications of climate change on the region's viticulture and identify potential mitigation strategies. These strategies include technological advancements, viticultural practices, and approaches to vineyard resilience and biodiversity conservation.

SCIENTIFIC SESSION: **CLIMATE - POSTER**

Abscisic Acid: a tool to enhance grape quality and manage high temperatures in Malbec cv. in a context of climate change

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Keywords: **abscisic acid, increasing temperature, climate change, anthocyanins, Malbec.**

ABSTRACT

Anthocyanins (Anto), are crucial for berry coloration, wine quality, and health benefits. In the context of climate change, rising temperatures pose a threat to grape quality by reducing Anto levels. This study investigates how the application of abscisic acid (+ABA) on grape bunches and 3°C increased temperatures (+T) influence Anto accumulation and gene expression in Malbec berries. A factorial experiment was conducted with four treatments: +ABA -T, +ABA +T, -ABA +T, and -ABA -T. At harvest, berry skin Anto levels were analysed, and gene expression was measured. ABA application alone increased the levels of several Anto including delphinidin (Df), cyanidin (Cn), peonidin (Po), petunidin (Pt), malvidin (Mv), malvidin acetylated (Mv-Ac), peonidin coumaroylated (Po-Cu), , malvidin coumaroylated (Mv-Cu), and total Anto (TA), with the exception of peonidin acetylated (Po-Ac). An increase in +T led to a decrease in the levels of Df, Cn, Po, Mv Ac, Po-Cu, Mv-Cu and TA. However, Pt, Mv, and Po-Ac levels remained unaffected by the temperature increase. No interactions between ABA and T were observed. At harvest, +ABA -T resulted in upregulation of CHS2 and UFGT genes, aligning with the increase in total and individual Anto. Additionally, ABA itself upregulated the expression of F3′5′H and F3′H genes, corresponding with the increase in Po, Mv, Pt, Df and Cn levels. Meanwhile, the elevated T downregulated F3′H expression, aligning with decreased Cn and Po levels. The T increases also downregulated AT3 expression, corresponding to the observed decrease in Mv-Ac and Po levels. The dynamics of these genes, as well as MYBA1, MYB14, and MYBC2L, across different sampling dates are presented. These findings suggest that precise management of ABA can mitigate the negative effects of rising temperatures due to climate change by upregulating key genes involved in Anto biosynthesis, ensuring better colour stability and overall quality of Malbec grapes.

SCIENTIFIC SESSION: **CLIMATE - POSTER**

Impact of Abscisic acid on berry texture properties, color characteristics, anthocyanin concentration, berry growth and technological parameters in "Red Globe" table grape cultivar, Sicily, Italy

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Keywords: **Red Globe, abscisic acid, climate change, Sicily.**

ABSTRACT

Red Globe is a table grape cultivar that often fails to develop adequate red color in Mediterranean climates, specially under increasing temperature due to climate change. The application of abscisic acid (S-ABA) may help improve coloration, but its potential effects on overall grape quality need to be thoroughly evaluated. In our study, we applied 1 mM concentration of S-ABA (ProTone®) to grape bunches at 7, 21 and 35 days post-veraison in a commercial vineyard located in Favara, Sicily, Italy, to verify its effects on the evolution of texture properties using a texture analyzer (berry skin strength, thickness and TPA), berry color characteristics using a chroma meter (CIELab test), anthoyacinins concentration and their profile using HPLC, size (transversal and longitudinal diameters), and weight. Additionally, technological parameters (pH, titratable acidity, and total soluble solid) were recorded. It was found that the berry skin strength and thickness significantly decreased with S-ABA, although springiness, chewiness, resilience, gumminess, cohesiveness remained the same. The hormone treatment positively affected berry skin color by significantly decreasing L and b* value, while increasing a* value at the apical, medium, and basal levels of the berry. This treatment made the grapes darker, redder, and less yellow, accelerating the coloring process and making the berries harvestable about 15 days earlier compared to untreated ones. Furthermore, S-ABA significantly increased the anthocyanin concentration and modified their profile towards more stable forms. Additionally, the treatment increased berry weight by increasing the transversal berry diameter only, while ripening parameters were not statistically affected, except for the titratable acidity, which was lower with S-ABA. This study provides new information about the positive effects of S-ABA on Red Globe color, size, anthocyanin content, their profile, and acidity that can be used in a context of climate change without affecting significantly technological maturation and some texture parameters.

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SCIENTIFIC SESSION: **CLIMATE - POSTER**

Mapping temperature and grapevine phenology at local scale in Burgundy using environmental co-variates

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Keywords: **temperature, spatial interpolation, phenology, Bourgogne, Pinot noir.**

ABSTRACT

Air temperature is a key element of wine terroirs. This article documents its spatial variability at local-scale and its consequences for grapevine phenology within the vineyards of Morey-Saint-Denis and Chambolle-Musigny, two villages of Burgundy wine-growing regions. Air temperature at 60 cm above ground level was measured from March 1st to October 30th, 2023, using 104 temperature sensors. Terrain descriptors (slope, elevation, potential radiation, etc.) were used to map daily temperatures via regression-kriging, achieving high precision for minimum temperatures (daily average R^2 of 0.61 between observed and predicted temperatures) and lower precision for maximum temperatures (average R^2=0.31). Predicted véraison dates using a heat summation model (GFV) were on average underestimated but showed strong spatial consistency with field observations for Pinot noir, suggesting significant local-scale effects of temperature variations on vine development and grape ripening.

SCIENTIFIC SESSION: **CLIMATE - POSTER**

Climate characterization and determination of the vine-growing suitability of emerging and traditional areas from Chile

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Keywords: **climate change, cool-viticulture, winckler index, huglin index, growing season temperature.**

ABSTRACT

In Chile, vines have traditionally been grown in the central valleys of the country [1]. However, increases in average temperature, as well as the intense and prolonged drought [2], have forced the industry to look for new productive areas, both in coastal valleys and in the South of the country. Despite this, efforts to evaluate the viticultural potential of these new areas have been limited [3-4]. Consequently, the aim of this research was to characterize the climate of the traditional and emerging areas for wine production in Chile. Averaged temperature (ta), minimum temperature (tn), maximum temperature (tx), and precipitation (pp) data from 233 weather stations between the years 1963 and 2023 were extracted from the database of the *Centro de Ciencias del Clima y la Resiliencia* (CR)2. These data were used to characterize the wine-growing regions of Chile by estimating classical bioclimatic indices, as well as their temporal variations and correlations. The latitude and altitude of the different weather stations showed good correlations with the climatic variables and bioclimatic indices studied. The Winkler index showed an increase of 57 units on average over the past 30 years, with the areas showing the greatest increases being those located in the traditional wine-growing valleys (central zone). The heliothermic index (HI), the Growing Season Temperature (GST) index, and the Night Coldness index (NCI) exhibit the same trend. The traditional production areas have recorded a decrease of up to 300 mm of rainfall, with an average decrease of 60 mm.

The current climate change scenario will force the industry to seek for new wine-growing areas that allow the cultivation of existing varieties or to replace them with new varieties resistant to extreme temperatures and prolongated drought. In that sense, Chile's diverse climate regions make it an ideal location for researching potential new viticultural areas.

SCIENTIFIC SESSION: **CLIMATE - POSTER**

Climate mediated metabolomics profile of Chardonnay grape juices and Wine

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Keywords: **Chardonnay, climate change, metabolomic, Burgundy, Uco valley.**

ABSTRACT

In the context of rapid climate change, which is reflected in the increasing temperatures and water deficits, it is essential to understand the impact of climate on the evolution of vine phenology and the chemical composition of grapes. This understanding will allow for the anticipation and implementation of adaptation strategies to cope with these new constraints. Chardonnay, an emblematic grape variety of Burgundy and Champagne, is grown worldwide under various climatic conditions, producing quality wines. This study aims to explore the adaptability of the Chardonnay grape variety to climate change by comparing samples from two distinct wine regions: the Uco Valley in Argentina and Burgundy in France. Based on climatic projections, the current climatic conditions of the Uco Valley could be a good model for the future climatic conditions that Burgundy and Champagne may encounter by 2050. By comparing must and wine from these two regions, obtained using a standardized protocol, we aim to evaluate how climate influences the chemical diversity of grape juices and wines using metabolomic analysis techniques. To identify how climate impacts the oenological potential of Chardonnay, ultra high-resolution mass spectrometry was used to provide a complete metabolic fingerprint of the grape juices and wine, incorporating the instantaneous contributions of all possible plant-environment interactions associated with the multiple natural conditions of the vineyard. Our study reveals that if the grape juices and wines obtained in these two regions are both impacted by similar environmental parameters, they develop distinct metabolomic imprints of hundreds of compounds according to the environmental parameters considered. These results provide an unprecedented representation of the metabolic diversity of Chardonnay, contributing to a better understanding of grapevine mitigation strategies in the context of climate change.

Plant material and management

SCIENTIFIC SESSION

NOV 19, 2024 | 13.30 PM | SCIENTIFIC SESSION: **PLANT MATERIAL AND MANAGEMENT I - CONFERENCE (KEYNOTE SPEAKER)**

Epigenetic as a reflection of the complexity of grapevine terroir?

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Keywords: **epigenetic, plant memory, DNA methylation, environment, epigenomes.**

ABSTRACT

Terroir is a French term that designs the complex interactions that take place between climate, soil, microbiomes, agricultural and oenological practices and plant genotypes that generate plant phenotypes and determine the specific characteristics of wines in a given region. While genetics focuses on the study of genes and of their functions, epigenetics aims at investigating the changes in gene functioning that are heritable or stable and that do not entail a change in DNA sequence. As such, epigenetic mechanisms are major contributors to the response of plants to the environment, and to the memory they keep of them. How epigenetics may shape the "terroir" of grapevine is an exciting yet underexplored research area that requires thorough analyses of the epigenetic parameters of grapevine plants grown in diverse environments.

Introduction:

Epigenetics was initially defined by C Wadington as "the branch of biology which studies the causal interactions between genes and their products, which bring the phenotype into being" (Waddington 1942). Epigenetics now refers to the study of changes in genome functioning that are stable or mitotically and/or meiotically heritable, an inheritance that do not rely on a change in DNA sequence (Eichten, Schmitz, and Springer 2014). Epigenetic mechanisms include histone post-translational modifications (HPTMs), histone variants, DNA methylation, and require small RNAs. They are major regulatory processes involved in the control of plant growth and development, and in their responses and adaptation to the environment (Lämke and Bäurle, 2017). In addition, epigenetic processes, together with other molecular and biochemical networks, contribute to the memory of plants (Gallusci *et al*, 2022). Plants have acquired the ability to store, reuse, and eventually forget information generated by the previous situations, which provides them with an efficient way to adapt to environmental changes. In perennials, this epigenetic information can be stored during one growing season and most likely over years (Gallusci *et al*, 2022). This is also true for grapevines, and epigenetics may provide means to adapt to the specific environmental conditions of vineyards (Berger *et al*, 2023).

From a plant perspective, the diversity of vineyard environmental conditions include climate, soil, pathogen and symbiotic interactions, viticulture practices, graft combinations that together interact with the plant genotypes and influence grapevine development, phenotypes, and ultimately wine characteristics. This complex combination of factors likely shapes the epigenetic landscapes of grapevine plants in the long term. In this oral presentation, I will discuss recent evidence and provide preliminary data suggesting that various environmental factors impact the grapevine epigenomes and may contribute to defining an epigenetic signature of the grapevine Terroir.

Epigenetic information:

Epigenetic mechanisms are based on the methylation of cytosines, the posttranslational modifications of histones (HPTMs) and histone variants, and involve small RNAs and enzymes participating to the remodelling of chromatin (Feng, Jacobsen, & Reik, 2010). When set up during development or in response to environment signals, epigenetic marks determine chromatin organisation and dynamic, thereby gene expression patterns. In plants, DNA methylation can occur at the symmetrical CG and CHG (H=C, T or A), where methylation occurs on both strands, and at the non-symmetrical CHH sequence context, where only one strand is methylated (Law and Jacobsen, 2010). DNA methylation dynamics that take place during plant development or in response to environmental stresses is controlled by DNA methyltransferases (DNMTs) of three different classes. De novo DNA methylation is established by a mechanism called the RdDM pathway (RNA directed DNA methylation) that involves the Domain Rearranged Methyltransferases 1, 2 (DRM1/2) that are guided to their targets by 24 nt-long small RNAs. In addition, the chromomethylase 2 (CMT2) will establish DNA methylation at CHH, which is located in heterochromatic regions). Once established DNA methylation is maintained after replication of DNA by DNMTs which are sequence context specific. The MET1 enzyme will add the methyl group on the newly incorporated cytosine at CG hemimethylated sites, whereas the CHG methylation maintenance depends on plant specific enzymes, called the chromomethylases (CMT), mainly CMT3. At CHH sequences, methylation of the newly synthesised DNA strands is performed by the RdDM pathway and by CMT2 (Zhang *et al*, 2018). Finally, methylated cytosine can be removed by DNA demethylases (DMT) in an active process, or passively diluted following replication when the maintenance methylation is not working after cell division (Liu and Lang, 2020). Additional epigenetic marks include histone-post translational modifications (HPTMs). The HPTMs occur at various amino acids located essentially, but not exclusively, on histone H3 tail. They include lysine, threonine and serine residues. The main HPTMs are acetylation, methylation and phosphorylation. Whereas the acetylation of histones is usually associated with transcriptionally active genes, methylation is either an active or a negative mark depending on the residue which is methylated. In addition, histone variants can affect the nucleosome composition, and together with HPTMs, influence chromatin structure and activity (Lauria and Rossi, 2010). The distribution over the genome of the different epigenetic marks will define the plant epigenomes which are established during the development of plants and therefore differ between organs, cell types, and are influenced by environmental conditions.

Epigenetic memories: the foundation of a Terroir signature?

Epigenetic memories and Terroir:

Epigenetic is the molecular support of important aspects of the memory of cells, contributing to their ability to store, and re-use information of previous experiments. Consistently, epigenetic marks are maintained during mitosis, which allows a somatic memory of epigenetic changes, whether they are developmentally determined or generated by environmental signals. This memory can be maintained over years in individual plants and eventually transmitted to the next generation through clonal propagation and to a lower extend sexual reproduction (Gallusci *et al*, 2022). In the case of grapevine, the epigenetic landscapes depend on many different factors that include but are not limited to the epigenetic information inherited from the mother plants during clonal propagation (Rootstock and scion), the interactions between RS and scion, the influence of the environment (soil, microbiome, climate etc..) and the trans-annual memory of this environment.

Studies in poplar, a woody perennial, have shown that ramets originating from the same plants but grown in contrasted environments displayed different methylation landscapes consistent with DNA methylation imprints reflecting the environment in which the new plants are grown, whereas the parental origin seems to have little influence (Guarino et al., 2015). The phenotypic consequences were not studied, neither was the link between the new environment and the epigenetic landscape. Concerning grapevines, the study of methylation variations across the Barossa region in Australia showed that methylation patterns varied with the geographical location of plants and vineyard management methods, also suggesting that the environment was shaping the plant methylome over the origin of plants, and reflecting the Terroir (Xie *et al*, 2017). However, different clones were compared, which may have generated epigenetic differences unrelated to the Terroir. In another study, the methylation profiles of Merlot and Pinot Noir (PN) seemed to be more affected by their location than by their clonal origin (Baránková et al., 2021). These results would suggest that the environment of the plant defines in part its methylome and thereby gene expression patterns and plant phenotypes. In contrast, when cuttings from adult poplars from different places were grown in a single location, parental epigenetic marks were transferred from parents to the progeny suggesting that the parental epigenetic imprints were maintained over those of the environment (Vanden Broeck et al., 2018). Similarly, DNA methylation patterns of grapevine (cv Malbec) grown in different Argentinian vineyards suggests that the clonal origin was more important than the growth location (Varela et al., 2021). Hence, it is unclear whether the parental origin or the environment will define the epigenetic landscapes of plants, and most likely both of them will contribute to different levels, depending on plant age and environmental conditions.

An additional layer of complexity is due to grafting because in a grafted plant, both partners may react differently to the local environment of the plant and influence each other. Since there is a clear epigenetic dialogue between the graft partners in grapevine as in other plants (Rubio *et al*, 2022), the graft combination will also contribute to the scion and RS epigenetic signatures in a specific environment, and to its evolution.

In addition, in grapevine, as in other perennials, plants may maintain their epigenetic landscape in meristems over years, a process that can generate an epigenetic drift reflecting the environmental and growing conditions of each individual plant. In the case of poplar under drought stress, epigenetic changes induced by summer stress periods were maintained in winter-dormant shoot apical meristem, consistent with an epigenetic memory of environmental conditions that occurred during the preceding year (Le Gac *et al*, 2018).

So far, there is growing evidence of an epigenetic signature that depends not only on the genotypes of plants, their parental origin, but also on their growing conditions. It remains unclear how the environment shapes the plant epigenetic landscapes in the long term. Also the relative importance of different factors to the plant epigenomes (plant genotypes, parental origin, soil, climate etc..- the graft combination), and their influence on plant phenotypes and typicity of wines in a specific region awaits additional studies.

Toward an epigenetic signature of grapevine terroir: what strategies?

A terroir signature implies that from the initial parental epigenetic imprints that is inherited during clonal propagation of grapevines, the growing conditions (soil, microbiome, climate, viticulture practise, grafting etc.) will lead to changes in the epigenetic information that will be memorised by plants over years and lead to new epigenetic landscapes in the different organs of the plant. Although epigenomes may evolve with plant age, they should be stable enough to define a terroir specific epigenetic signature that may reflect the main traits of the plant and the wine typicity in a specific location.

In addition to the epigenetic characterisation of plants in a specific environment, we think that it is necessary to develop complementary research strategies to define possible links between Terroir and the plant epigenetic information, as well as the relative contribution of factors determining the Terroir. So far our research addresses the following questions: (1) What part of the parental epigenome is transmitted to the progeny during plant clonal propagation and how stable is this information? (2) What is the influence of the environment on clone plants generated from the same mother plant? (3) Can we determine a trans-annual epigenetic memory of grapevines and determine the stability of the transmitted epigenetic information over years; (4) How the epigenetic dialogue between rootstock and scion contribute to the epigenetic signature of a plant? (5) Is the microbiome of the plant, which may depend on the environment and reflect the Terroir, influencing the epigenomes and contributing to an epigenetic signature of plants in a specific environment?

I will present some of the evidence we have obtained that suggest that the epigenomes of plants are influenced by these different parameters that may define the epigenetic landscapes of organs at a specific time and in a given environment. We expect that these approaches in combination will allow determining the part of the epigenetic information that is acquired in a specific environment and allow defining a signature specific to this environment.

Conclusion:

Terroir embodies the intimate interactions between climate, soil, agricultural and enological practices and plant genotypes (rootstock and scion and their interaction), that influence plant phenotypes and determine the specific characteristics of wines in a given region. In this context, epigenetics, which does not rely on changes in the DNA sequence, has been associated with phenotypic variations that are stable and or heritable. They play a major role in the memory that plants have of their past and contribute to their acclimation and/or adaptation to their environments (reviewed in Berger et al. 2023). As such they may reflect the "terroir" of grapevines.

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NOV 19, 2024 | 14 PM | SCIENTIFIC SESSION: **PLANT MATERIAL AND MANAGEMENT I - SCIENTIFIC ORAL**

Environmental impact on small RNA expression in Cabernet Sauvignon and Aglianico varieties grown in southern Italy

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Keywords: **grapevine, miRNAs, phasiRNAs, GxE interaction, regulatory network.**

ABSTRACT

Grapevine *(Vitis vinifera L.)* is a perennial crop widely cultivated around the world and characterized by a remarkable phenotypic plasticity. Understanding the molecular basis of this phenomenon is crucial for modern viticulture, as climatic conditions are becoming increasingly unpredictable with rapid climatic change. Although these molecular mechanisms are crucial, they remain poorly understood due to their complexity. This study aims to explore the role of small RNAs in influencing the phenotypic plasticity of grape berries grown in different environments. We used two varieties, Aglianico and Cabernet Sauvignon, cultivated in three different Italian sites. Using two different pipelines, we identified miRNAs and phasiRNAs across 18 samples. We assessed how these varieties respond to different environmental conditions by conducting differential expression analysis among the vineyards and carrying out a PCA using the expression profiles of the small RNAs. Our findings indicate that the two varieties display a different sensitivity to the surrounding environment. Moreover, the in-silico prediction of small RNA targets suggested their role in secondary metabolites production pathways. Using WGCNA, we correlated clusters of co-expressed small RNAs to climatic data underscoring the significant role of small RNAs in the genotype x environment interaction in grapevine.

Introduction:

Phenotypic plasticity, the ability of a single genotype to express different phenotypes in response to environmental variations, is a key adaptive strategy for sessile organisms like plants (Bradshaw, 1965). This capability is particularly vital in the face of climate change, where increasing variability and extremity in weather patterns necessitate flexible phenotypic responses for plant survival. Thus, understanding the molecular mechanisms underpinning phenotypic plasticity is crucial, especially for advancements in modern agriculture.

It has been suggested that phenotypic

plasticity may involve a combination of genetic and epigenetic regulation of gene expression. This regulation can occur through mechanisms such as DNA methylation/demethylation, histone modifications, chromatin remodeling, and the involvement of small and long non-coding RNAs (ncRNAs) (Fortes and Gallusci, 2017). Among these, small RNAs – short, non-coding RNA molecules ranging from 19 to 24 nucleotides – are pivotal. They primarily regulate gene expression through post-transcriptional gene silencing (PTGS) and RNA-directed DNA methylation (RdDM) (Borges and Martienssen, 2015) playing a crucial role in shaping the phenotypic plasticity of plants.

Grapevine *(Vitis vinifera L.)* is characterized by remarkable phenotypic plasticity, which is closely tangled with the concept of terroir in viticulture – where unique environmental factors of a specific area influence vine growth and fruit characteristics (Van Leeuwen & Seguin, 2005). In this work, we explored the role of small RNAs in the plasticity of grapevine berries of two varieties, Aglianico and Cabernet Sauvignon, cultivated in three different vineyards of southern Italy. We focused on two classes of small RNAs: microRNAs and phasiRNAs, the latter being a subclass of endogenous secondary siRNAs (Axtell, 2013). First, we used two pipelines to detect small RNAs across the genome, then we conducted a differential expression analysis among vineyards. Using in-silico approaches, we predicted the putative targets of differentially expressed small RNAs. Finally, we employed Weighted Gene Co-expression Network Analysis (WGCNA) to correlate groups of small RNAs with climatic data, aiming to elucidate their roles in the genotype x environment interaction in *V. vinifera*.

Our findings provide new insights into the complex mechanisms by which small RNAs influence plant adaptation to environmental changes, offering implications for both agricultural practices and sustainability in the era of climate change.

Materials and methods:

This study we used two grape varieties, Aglianico, a traditional southern Italian red cultivar, and Cabernet Sauvignon, an international cultivar of French descent, grown in three Italian vineyards located at different altitudes, namely: San Biase in Molise (600m asl), Galluccio in Campania (125m asl), and Zafferrana Etnea in Sicily (720m asl) (Figure 1). Berry samples were collected at ripeness during the 2021 season, with three biological replicates per site. RNA was extracted from berries using a method from Villano et al. (2023), and concentrations measured with a NanoDrop ND-1000 spectrophotometer. To identify sncRNAs, 18 single-end small RNA libraries were sequenced with an Illumina TruSeq technology, data quality controlled by trimming reads shorter than 16 nucleotides using Trimmomatic v0.39. MicroRNAs and phased small interfering RNAs were identified using miR-PREFeR and ShortStack v3.8.5 (selection criteria: phase score ≥ 30). The PN40024 (v4) grapevine reference genome was employed for the alignments. Expression analysis excluded small RNAs with counts below 1 cpm or a coefficient of variation above 0.5, using the Trimmed Mean of M-values for normalization. Principal Component Analysis (PCA) confirmed the reproducibility of replicates and facilitated differential expression analysis across vineyards. Potential targets of differentially expressed RNAs were predicted using psRNATarget, with biological functions and pathways examined via Gene Ontology and KEGG. Small RNA data were correlated with already available environmental information (Ferlito et al., 2023) through Weighted Gene Co-Expression Network Analysis (WGCNA), linking RNA expression to climatic variables.

Results and discussion:

In a previous study, we evaluated the physiological and reproductive responses of Aglianico and Cabernet Sauvignon across the three environments to determine their influence on adaptations (Ferlito et al., 2023). Aglianico showed more variability in key physiological parameters such as leaf water potential and photosynthesis rates compared to Cabernet Sauvignon, which displayed more consistent responses, indicating lesser environmental sensitivity (Ferlito et al., 2023). Based on this evidence, we decided to study the role of small RNAs in influencing the phenotypic plasticity of grape berries grown in different environments. Across 18 samples, high-throughput sequencing generated a total of 228,740,031 raw reads, with an average of 12,707,779 reads per sample. A total of 736 small RNAs were predicted, including 568 miRNAs and 168 phasiRNAs. After filtering, 304 miRNAs did not meet the selection criteria due to low expression levels or high variability, leaving 264 miRNAs and 168 phasiRNAs in the final dataset – a total of 432 small RNAs.

Principal component analysis (PCA) and differential expression analysis demonstrated distinct influences of the growing environment on Aglianico and Cabernet Sauvignon. Specifically, the first principal component (PC1) differentiated the Aglianico samples from those of Cabernet Sauvignon, indicating unique small RNA expression patterns across the three environments (Figure 1). This is consistent with the findings from our differential expression analysis, which indicated that environmental variations induced a greater change in the expression of small RNAs in Aglianico than in Cabernet Sauvignon. Furthermore, while the Cabernet Sauvignon samples demonstrated tight clustering, with minimal separation of Campania replicates, indicating a relatively uniform expression patterns across different environments, the Sicilian Aglianico samples diverged noticeably from those of other regions. This result is consistent with differential expression analysis, where the Sicilian vineyard in Aglianico displayed the greatest number of differentially expressed small RNAs (127 between Sicily and Molise, 123 between Sicily and Campania). In contrast, Cabernet Sauvignon showed fewer differences in expression profiles, with Campania vineyard being the only one to exhibit differential expression of small RNAs (25 between Campania and Sicily, 49 between Campania and Molise). This suggests a higher degree of expression variability among the Aglianico samples, underscoring their greater sensitivity to environmental differences compared to the relatively stable expression observed in Cabernet Sauvignon.

In-silico prediction identified several target genes for the differentially expressed small RNAs, notably in pathways related to secondary metabolite biosynthesis, stress response, and regulation of gene expression. These findings suggest that small RNAs may play critical roles in accumulating secondary metabolites, enhancing stress tolerance, and regulating key transcription factors.

WGCNA clustered the small RNAs in 13 highly co-expressed modules (Figure 2). The correlation of these modules with climatic traits enabled the identification of hub small RNA groups whose expression is significantly influenced by environmental factors.

Conclusion:

In this research, we explored the small RNA transcriptomes of two grapevine varieties, Aglianico and Cabernet Sauvignon, in three different Southern Italian environments. Aglianico showed greater environmental sensitivity, displaying more variable small RNA expression patterns across regions compared to Cabernet Sauvignon. In-silico target prediction further demonstrated that these small RNAs are crucial in regulating pathways important for metabolite accumulation and stress responses. This highlights their potential role in adapting the grapevine's physiological traits to diverse environmental stresses, potentially affecting fruit quality and yield.

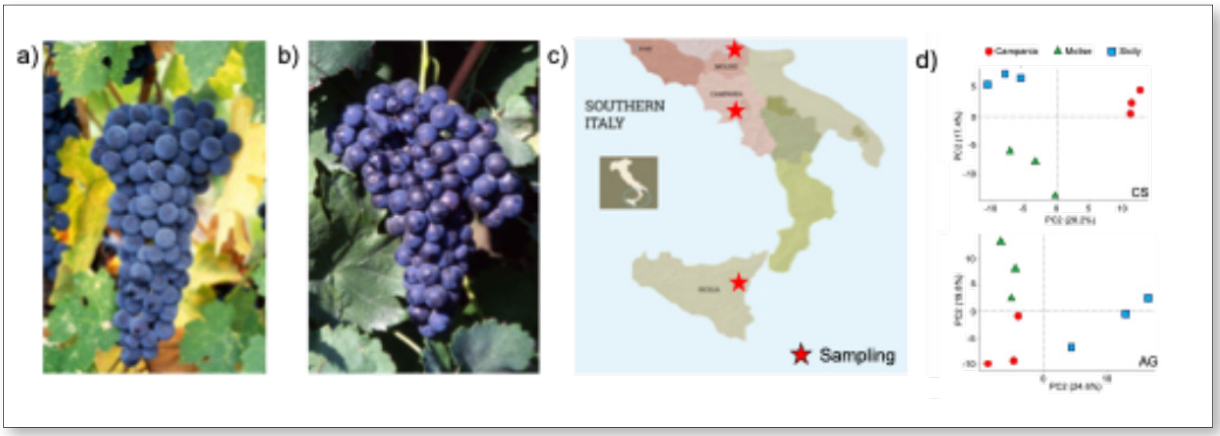

Figure 1. The genetic material used in this study and the PCA constructed using TMM values of small RNAs expression of the 18 replicates.

a) Cabernet Sauvignon, b) Aglianico, c) sampling areas, d) PCA where shapes represent different sites, whereas colours indicate the varieties (CS: Cabernet Sauvignon; AG: Aglianico).

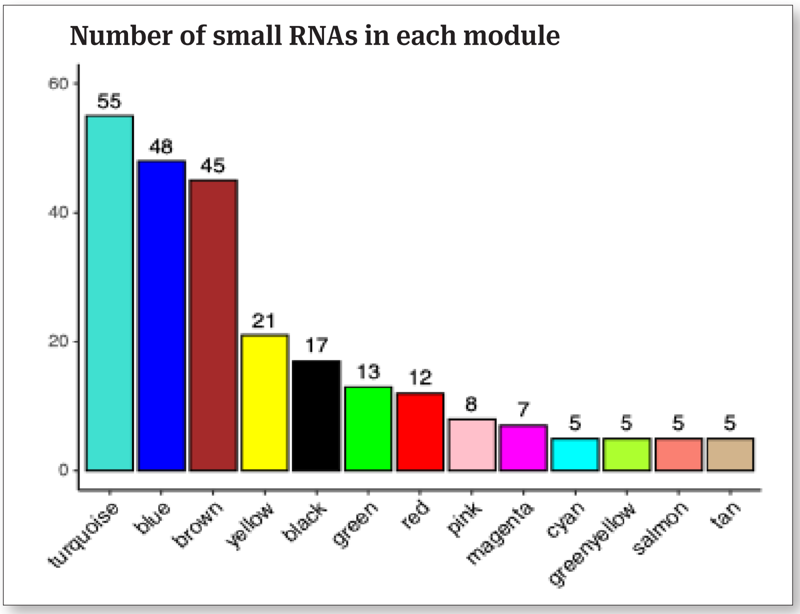

Figure 2. Barplot showing the number of co-expressed small RNAs in each module detected

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NOV 19, 2024 | 14.15 PM | SCIENTIFIC SESSION: **PLANT MATERIAL AND MANAGEMENT I - FLASH ORAL**

Telomere Length as a genomic biomarker of well-being in grapevines: proof of concept on Aglianico grapevine

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Keywords: **telomere length, qPCR, grapevine health status, epigenetic biomarker, aglianico.**

ABSTRACT

In recent years, molecular biomarkers have emerged as important tools in modern agriculture, facilitating the monitoring of plant health and providing objective assessments of resistance and susceptibility to environmental factors. Within the realm of grapevines *(Vitis vinifera L.)*, genomic biomarkers hold promise owing to their ability to integrate multifaceted, context-dependent information.

In this context, telomere length emerges as a promising, rapid, and cost-effective genomic biomarker, as observed in other species such as mammals and other plants. Telomeres, repetitive DNA sequences situated at chromosome ends, play a central role in safeguarding genetic material from damage and have been widely used in processes related to health, aging, and stress in mammalian models. While the telomere sequence (TTTAGGG) is evolutionarily conserved across species, the development of species-specific protocols and primer designs is imperative for accurate analysis. Currently, standardized protocols for measuring telomere length in grapevines are lacking. Therefore, our study attempts to establish a qPCR protocol for assessing telomere length in grapevines, serving as an epigenetic biomarker for their well-being.

Quantitative real-time PCR (qPCR) enables precise quantification of telomere length relative to an internal reference gene specific to grapevines, ensuring stable measurements across diverse environmental conditions. Implementation of this novel protocol will facilitate the evaluation of telomere length dynamics in grapevines under varying conditions, thereby providing a valuable tool for assessing the vine's health status.

This contribution presents the first results on the Aglianico vine subjected to different levels of water stress (irrigated and non-irrigated) under the same soil conditions in an area of southern Italy devoted to the production of high-quality wines (Taurasi DOCG area) in the Tenuta Donna Elvira winery (Montemiletto—AV).

NOV 19, 2024 | 14.20 PM | SCIENTIFIC SESSION: **PLANT MATERIAL AND MANAGEMENT I - SCIENTIFIC ORAL**

Rediscovering grapevine diversity in Argentina: a brief update

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Keywords: **genetic diversity, autochthonous varieties, *criollas*, Listan Prieto, genetic variability.**

ABSTRACT

The history of grapevine in South America dates from around 500 years. During that period, several varieties were originated from natural crossings between the varieties brought by Spaniards. Recent evidence brought to light that the existing diversity within the group of autochthonous cultivars from Argentina and other South American countries, is higher than previously thought. These varieties are commonly known as *criollas*. In this paper, we present a brief update of the results of more than 10 years of study in which we have prospected, rescued and identified grapevine phenotypes recovered in ancient vineyards in the western provinces of Argentina.

During this period, we have analyzed more than 200 samples in several locations. Their identity and pedigree were analyzed through nuclear simple sequence repeat (nSSR) markers. Our results show that the diversity within the Argentinian and South American cultivars is higher than previously thought. Our grapevine collection, one of the most important in the Southern Hemisphere, and ancient vineyards located in isolated valleys, are reservoirs of minor cultivars, and growers have played a key role in maintaining and conserving them. Significance of the Study: This genetic diversity constitutes a valuable tool to explore alternatives for diversification and adaptation to climate change.

Introduction

Currently, between 6000 and 10,000 cultivars of *Vitis vinifera L.* exist worldwide, which are cultivated for different purposes, wine production, table grapes, raisins, or juice (Lacombe et al., 2013). These existing cultivars have originated since grapevine cultivation and domestication commenced 11,000 years ago (Dong et al., 2023). While this considerable genetic diversity is mainly conserved in germplasm collections (This et al., 2006), the global wine market is limited to a small group of cultivars. The 13 most planted cultivars around the world, Kyoho, Cabernet

Sauvignon, Sultanina, Merlot, Tempranillo, Airen, Chardonnay, Syrah, Red Globe, Garnacha Tinta, Sauvignon Blanc, Pinot Noir, and Trebbiano Toscano, cover more than one-third of the total cultivated surface area. The 33 most planted cultivars cover more than 50% of the global cultivated area (OIV, 2017), which represents less than 1% of the total existing genetic diversity (Wolkovich et al., 2018). This global trend to cultivate some international cultivars has led to the disappearance of numerous minor and local genotypes. Furthermore, these 13 international cultivars cover more than 60% of the cultivated surface area of the main producer countries, and even more (up to 80%) in some countries, such as Australia, New Zealand, or Chile (Wolkovich et al., 2018). In Argentina the situation is somewhat different since the two more cultivated varieties (Malbec and Bonarda) are not within these 13 most important varieties, and almost 30% of the cultivated area corresponds to local cultivars or *criollas* (INV, 2020). The main cultivated *criollas* in our country are Cereza and Criolla Grande, two varieties widely spread during the 1960s and 1970s because of their high yield potential. Other *criollas* varieties widely cultivated are Pedro Giménez, Torrontés Riojano, and Moscatel Rosado and a large number of minority varieties spread over different regions.

The history of grapevine *(Vitis vinifera L.)* in America dates to the fifteenth century, when it was first introduced to the Antilles during the Spanish colonization where it did not prosper due to climatic conditions (Martínez et al., 2006). However, it was cultivated with success in Mexico a few years later, and then in Peru in the early sixteenth century (Martínez et al., 2006) expanding subsequently to the rest of the South American colonies (Milla Tapia et al., 2007). The introduction to Argentina would have been in 1557, when some plants were introduced to the North of Argentina from Chile. During these first steps of South American viticulture and for more than 300 years, the Spanish variety Listán Prieto was the predominant variety (Lacoste et al., 2010). Besides, Muscat of Alexandria was introduced from Spain to Mendoza by Jesuitic missionaries and it was one of the most cultivated white varieties until the end of the twentieth century. During the eighteenth century, the vast majority of the *criollas* varieties were originated. Several recent studies have demonstrated that the two most planted varieties at that time (Criolla Chica and Muscat of Alexandria) are the main progenitors of South American varieties, including the group of the Torrontés, Criolla Grande, Cereza, and Pedro Giménez, for instance (Agüero et al., 2003; Martínez et al., 2006; Milla-Tapia et al., 2007; Durán et al., 2011; Boursiquot et al., 2014). The most probable processes leading to the origin of these genotypes may probably be the unintentional sowing of raisin seeds which spontaneously generated from marcs that were mixed and incorporated as manure to fertilize the vineyards. However, until some years ago, the diversity about this group of varieties remained unknown. Here, we resume the works performed previously by our group (Aliquó et al. 2107; Torres et al. 2022) and some other in course where we have identified, rescued, conserved and characterized this family of varieties.

Materials and methods

During these last 10 years, we have analyzed more than 100 accessions. We first analyzed accessions conserved at the Grapevine Collection, located at the INTA EEA Mendoza experimental campus (lat. 33°S; long. 68°51'W), Argentina. Those accessions were collected by Gonzalez and Vega (1949) in ancient vineyards in the western provinces of the country. From that date, they were conserved in the collection without identification. We also collected samples found in ancient vineyards located in different provinces of Argentina (Torres et al., 2022). A first morphological analysis was performed in situ to determine the putative origin of specific plants identified within the vineyards. Then, a sample was extracted and a set of 19 microsatellites was analyzed (Aliquó et al., 2017) and the identity and parental analysis were performed with CERVUS v3.0.7. The genetic profiles obtained were compared with the Vitis International Variety Catalogue (VIVC, http://www.vivc.de/) to verify the identity and check for synonyms and homonyms. We also compared our results with the INRAe database, which comprises more than 4000 accessions genotyped (Lacombe et al., 2013).

Results and Discussion

Our results have revealed that (i) the diversity among *criollas* varieties is higher than previously supposed (Aliquó et al., 2017), and (ii) this diversity is conserved in ancient, isolated, small vineyards where growers have played a key role in conserving this genetic diversity (Torres et al., 2022). Summarizing, we have found 70 different varieties, including 21 European, 49 *criollas* of which 34 of them were previously unknown *criollas* (Aliquó et al., 2017; Torres et al., 2022). As expected, a big group corresponded to the progeny originated from Listan Prieto × Muscat of Alexandria (Fig. 1). Still, many other varieties have also participated as parents, such as Muscat a Petits Grains Blanc, Mollar Cano, and many backcrossing. Surprisingly, Malbec also participated in the origin of two red cultivars. This finding suggests that the process leading to the origin of *criollas* varieties continued after the introduction of French cultivars by Pouget in 1853.

Most of the prospected vineyards were trained in an overhead system (i.e., "parral"), a traditional training system in Argentina, that still represents around 50% of the cultivated surface (INV, 2019). These family vineyards, with less than 1 ha of surface, are mostly cultivated for local market and self-consumption. They are planted with the most cultivated *criollas* (e.g., Pedro Gimenez, Criolla Grande Sanjuanina, Cereza), but they present a high diversity of other varieties planted in the same block, many of them not still identified or confounded with others. The role played by growers in maintaining the vineyards has been crucial to avoid the genetic erosion of the species.

Conclusions

Grapevine genotypic diversity in Argentina, and probably also in South America, is higher than previously thought. The identification through molecular markers has allowed us to highlight this diversity. Small grapegrowers distributed in different locations in the western counties of Argentina and the Grapevine Collection at INTA (which conserves material brought to our country more than 100 years ago) has played a key role in conserving this diversity that otherwise would have been lost. This collection has now been enriched with a *criollas* section, including around 71 accessions of different autochthonous varieties and their related genotypes.

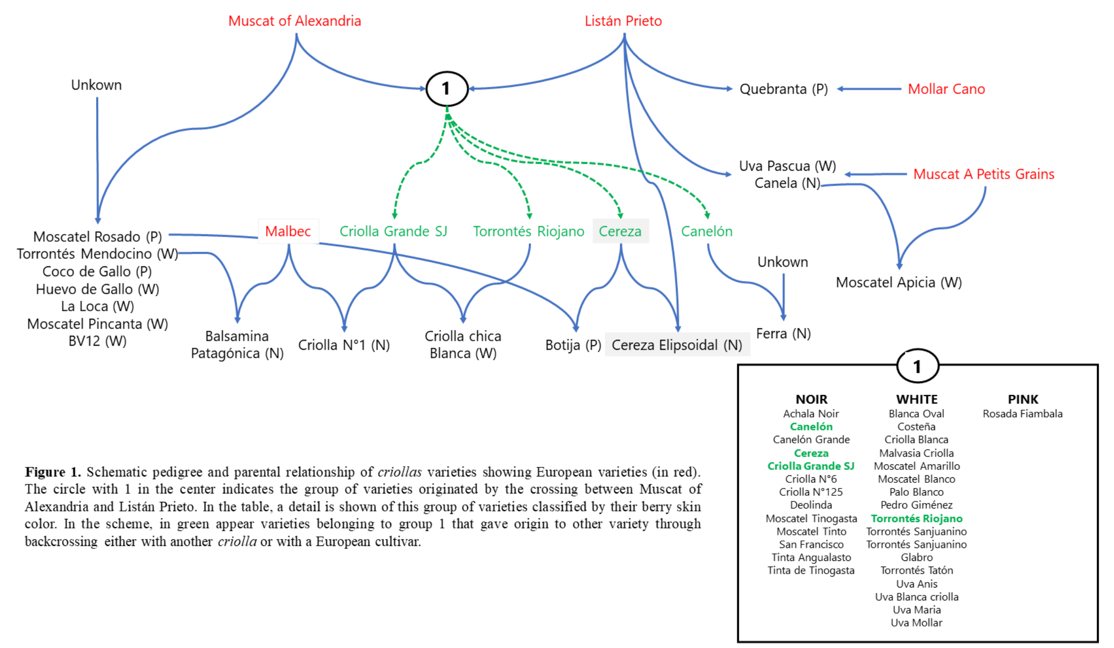

Figure 1. Schematic pedigree and parental relationship of *criollas* varieties showing European varieties (in red). The circle with 1 in the center indicates the group of varieties originated by the crossing between Muscat of Alexandria and Listán Prieto. In the table, a detail is shown of this group of varieties classified by their berry skin color. In the scheme, in green appear varieties belonging to group 1 that gave origin to other variety through backcrossing either with another *criolla* or with a European cultivar.

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NOV 19, 2024 | 14.35 PM | SCIENTIFIC SESSION: **PLANT MATERIAL AND MANAGEMENT I - FLASH ORAL**

Mapping Australia's grapevine diversity: The 1000 grapevine genomes project

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Keywords: **grapevine, germplasm, clonal identification, whole genome sequencing.**

ABSTRACT

Grapevine cultivars can be unequivocally typed by both physical differences (ampelography) and genetic tests. However due to their very similar characteristics, the identification of clones within a cultivar relies on the accurate tracing of supply records to the point of origin. Such records are not always available or reliable, particularly for older accessions. Whole genome sequencing (WGS) provides the most highly detailed methodology for defining grapevine cultivars and more importantly, this can be extended to differentiating clones within those cultivars.

The AWRI has developed a world-first clonal sequencing methodology that combines the latest next-generation genome sequencing technologies, high-performance computing and customised bioinformatics tools. This technique has been successfully used to define clonal variation across 1000 accessions of 20 different cultivars obtained from nurseries and vineyards throughout Australia.

To aid in the phylogenetic analysis and identification of intra-cultivar somatic mutations, long-read reference genomes were produced for several cultivars, including Shiraz, Grenache and Sauvignon Blanc. These reference genomes were also used to detect unique structural variations that may be important drivers of the phenotypic differences observed between these cultivars.

NOV 19, 2024 | 14.40 PM | SCIENTIFIC SESSION: **PLANT MATERIAL AND MANAGEMENT I - FLASH ORAL**

From rosé to red wines. The revival of the Grolleau N grape variety in Anjou (France) as an adaptation to climate change and market trends

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Keywords: **typicity, terroir, PDO, surveys, sensory analysis.**

ABSTRACT

The concept of typicity linked to a specific terroir is based on a range of knowledge held by different actors: the ability to establish product characteristics, to produce, to evaluate, and to appreciate (Casabianca et al., 2006). This type of production, generally promoted and protected within a Geographical Indication (GI), can contribute to the sustainable development of the region in which it is produced. In response to climate change, agro-ecological transition, and increasingly competitive markets, GI actors are part of new collective strategies (Ruggieri et al., 2023). We analysed these strategies, focusing on a case study in the Anjou PDO wine area (around 400 winegrowers produce this PDO), within the Loire Valley wine area (France). The Grolleau N grape variety, historically present in the region and mainly used for rosé wines, is attracting renewed interest for the production of red wines. A first step involved 3 interviews with the PDO managers and document analysis. In a second step, 10 semi-structured interviews were conducted and used to create a questionnaire to identify agronomic and sensory characteristics and winegrowers' mental representations; 52 winegrowers responded. Sensory analyses were carried out to evaluate the impact of Grolleau N on the sensory typicity of the Anjou PDO red wines. Our results provide new insights into the agronomic and sensory characteristics of Grolleau N. Interest in the Grolleau N variety was confirmed, but winegrowers do not want to make it compulsory in wine blends. More generally, our methodology can be used to study the influence of new grape varieties in a context of adaptation to climate change and to the market for GI wines.

NOV 19, 2024 | 14.45 PM | SCIENTIFIC SESSION: **PLANT MATERIAL AND MANAGEMENT I - FLASH ORAL**

Recovery, conservation, economic and touristic valorisation of autochthonous grapevine germplasm in the experience of Apulia Region (Italy)

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Keywords: **winegrape, local germplasm, *ex situ* conservation, valorisation, tourism.**

ABSTRACT

Apulia, a southern Italian region overlooking the Adriatic and Ionian seas with 865 km of coastline, stretching towards the Mediterranean, for geographical, climatic and historical reasons is particularly rich in germplasm, with a vast heritage of unique varieties for wine and table grapes. If the extensive clonal and sanitary selection programs, starting from the 1970s, made possible the valorisation of the main local varieties at the basis of regional denominations, the recent attention to the agrobiodiversity protection met the interest of consumer and markets for new products and wines by minor and neglected varieties. Since 2012, three successive integrated projects for the agrobiodiversity of the Mediterranean crops, funded by the Rural Development Plan of Apulia Region, enabled the research institutions to explore all the region, plant new collection fields, acquire new equipment and facilities for the conservation and the study of regional germplasm. The project "Recovery of Apulian grapevine germplasm" (ReGeViP) promoted the Apulian viticultural heritage through historical, sanitary, morphological, genetic, and technological studies/analyses aimed to identify, recover, characterize, and protect interspecific and intra-varietal biodiversity under genetic erosion, providing also sanitation and official registration to the National Catalogue of Vine Varieties. Within the germplasm conservation centre of Locorotondo, in the charming frame of Itria Valley, the ancient stone buildings, such as trulli, lamie and a snow house, have been restored and transformed in a "Widespread Museum of Biodiversity" aimed to attract and welcome visitors among ancient varieties, premultiplication, breeding and experimental fields, like in an open-air classroom; wine tasting and the storytelling about memories and traditions of regional germplasm and local communities, complete a full and unique enotouristic experience. In a multifunctional approach, the experience of Apulia demonstrates how the protection of viticultural biodiversity, through the exploitation of the minor genetic resources, could became a concrete opportunity of sustainable economic development.

NOV 19, 2024 | 14.50 PM | SCIENTIFIC SESSION: **PLANT MATERIAL AND MANAGEMENT I - FLASH ORAL**

New insights in the study of autochthonous minor grapevine cultivars as a tool for terroir preservation and adaptation to climate change.

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Keywords: **grapevine biodiversity, physiology, ampelography, grape must composition.**

ABSTRACT

One of the great challenges facing viticulture today is climate change impact. For this reason, the need has arisen to develop new strategies for vineyards to adapt to climate fluctuations. The effects associated with climate change jeopardize the preservation of the terroir characteristic of specific winegrowing regions where viticulture has been practiced for thousands of years, such as the Marco de Jerez (Spain). This region, the southernmost in Europe where vines are grown and wines of recognized prestige are obtained, works mainly with three white grape varieties: "Palomino Fino", "Pedro Ximénez" and "Moscatel de Alejandría". However, the number of cultivars allowed to produce these wines has been extended recently.

In this context, the main objective of this work is to study the physiological, ampelographic and enological behaviours of 6 traditional white grape cultivars from the Marco de Jerez, in order to determine their potential for adaptation to the new growing conditions and the demand for new types of wines, always preserving the expression of the terroir so characteristic of southern Spain. In addition, "Palomino Fino" has been used as a reference variety, which is characteristic and predominant in the region of Jerez.

The study of the different traditional white cultivars has made it possible to determine the viability of their cultivation in warm climate zones, and therefore their establishment as a tool for the preservation of the characteristic terroir of the Jerez. Therefore, its use can be established as a natural alternative for the production of white wines in a warm climate region, while contributing to the conservation of the genetic diversity of these varieties. However, to promote its cultivation throughout other wine regions with similar climates, it is necessary to continue with further studies, as well as to study its behaviour in other soil and climatic conditions.

NOV 19, 2024 | 15.30 PM | SCIENTIFIC SESSION: **PLANT MATERIAL AND MANAGEMENT II - SCIENTIFIC ORAL**

Water status assessment in grapevines using plant electrophysiology

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Keywords: **grapevines, drought, electrophysiology, plant electrical signals.**

ABSTRACT

Traditional methods for assessing vine water status, such as the Scholander pressure chamber, are time-consuming and labour intensive. The development of alternative methods which are accurate, reliable and can provide real-time water status is a necessity for farmers all over the world. Therefore, this study proposes the use of plant electrophysiology as a novel approach for real-time water status assessment in grapevines. The study conducted climate chamber experiments under different irrigation regimes, monitoring various morphological and physiological parameters in parallel with electrophysiological measurements. Machine learning techniques, including two models based on classification and regression, were employed to analyze the collected data and train prediction models. Results indicate significant differences in irrigation status between well-watered and water-deficit plants, with the latter showing reduced growth and physiological activity, confirming the water stress status of the plant. The developed models demonstrated promising results in differentiating between control and water stress groups. Additionally, the regression model showed better results on finding true stress and true control groups compared to the classification model. Further validation and optimization of the models are necessary, particularly under field conditions.

Introduction:
The ever-increasing risk of water deficit stress due to global warming exposes winegrowers to new challenges regarding water status assessment and implementation of adequate mitigation strategies such as irrigation and accurate vineyards management (Scholasch & Rienth, 2019). Water status of vines is commonly assessed by destructive batch measurements such as the Scholander pressure chamber which is time and labour intensive (Rienth & Scholasch, 2019). Reliable, automatized, and remote real-time water status assessment methods are still scarce. Plants respond to water deficit in different ways and many morphological and physiological aspects are affected by water limitation. Changes in morphology of root system and leaves,

photosynthesis rate, transpiration and stomatal conductance are a few examples of plants' adaptation to water stress. In the same way, endogenous ion transport mechanisms are part of plants' life cycle and play a crucial role in their homeostasis. These changes in ion distribution, measured as electrical potential variations, quickly reflect environmental alterations, and can be transmitted over long distances (Zhang et al., 2020). Plants facing different kinds of stressors trigger physiological changes to adapt to the new environmental conditions. This physiological response can generate an electrical potential difference which can be measured in real-time (Najdenovska et al., 2021). Together with the use of mathematical modelling and artificial intelligence, these biological signals have been used to assess plants water status in tomato, mulberry and Chinese violet cress (Najdenovska et al., 2021; Xing et al., 2019; Zhang et al., 2020). Grapevines have started to be explored, however no evaluation of water stress responses in grape vine using electrophysiology has been published yet. In this work, we adopt this new innovative method based on plant electrophysiology (Najdenovska et al., 2021; Tran et al., 2019) for the determination of vine water deficit stress. To build models for analysis of the correlation between electrophysiological signals and water status, different series of water stress experiments were conducted. Classical ecophysiology methods taken along with electrophysiology recordings were used to create accurate models to determine water deficit based on plants electrical potential.

Materials and methods:

Experimental design and drought assays

To generate dataset from plants experiencing different state of the water deficit, four series of two-weeks (trial 1 and 2), three-weeks (trial 3) and four-weeks (trial 4) climate chamber experiments (16 plants each), were conducted on *Cabernet Sauvignon* L. cuttings under different irrigation regimes. Plants were grown under 25 °C Day /15 °C night; 14/12 lighting hours and 55% of humidity. They were split into two groups of irrigation: well-watered (WW), where watering was managed to keep field capacity (FC) between 80-100% and water-deficit (WD) where irrigation was kept from 60% to 40% FC. The irrigation status of all plants was monitored three times a week by pot weighting in order to determine the soil water content (SWC). Predawn leaf water potential (Ψpd) was measured in all WW and WD plants using a pressure chamber (PMS Instrument, USA) every 5 days. Net photosynthesis, stomatal conductance, transpiration, water use efficiency, vapour-pressure deficit and chlorophyll fluorescence were measured three times a week using a portable photosynthesis system (CIRAS-3, PP systems, USA). Plant growth, stem diameter and leaf emergence rate were monitored every 7 days. At the end of each trial biomass accumulation and plant water content was also estimated taking into account fresh and dry mass. All plants were connected to the Vivent electrophysiological amplifier. To measure differential electrical potential from each plant, two silver electrodes were inserted in the plant trunk (reference electrode) and in the middle of the vegetative stem (active electrode). Each electrophysiology amplifier can record signals from up to 8 plants, therefore, two devices were used. Electrophysiological signals were recorded throughout the entire experiment and could be monitored in real-time on the Vivent online dashboard to evaluate signal quality and perform basic analysis. Vivent electrophysiological amplifiers have 200MOhm input impedance. Acquisition of 265 Hz frequency was used and recorded signals were subjected to analog notch filtering to remove 50 and 100 Hz mains noise.

Machine learning - interpreting electrophysiological signals in response to drought: dataset and training.

The dataset consists of univariate time series representing the electrophysiology recording of each plant during each trial. We segmented the data into consecutive rolling windows, each covering 24 hours. These windows were created to overlap, with a 6-hour shift between each successive window. Subsequently, we applied a Debauchies 11 discrete wavelet decomposition to each window, yielding wavelet coefficients at different levels of decomposition (Mallat et al., 1989). From these wavelet coefficients, we extracted a comprehensive set of features to capture relevant information. This included standard statistical measures such as minimum, maximum, and mean, computed for each level of decomposition. Additionally, we used Catch22 features (Lubba et al., 2019), a curated set of features designed for time series analysis. Next, the dataset was split into training and test sets, the former was used to train the model while the latter was kept aside and only used for performance evaluation. Moreover, the sets were split by plant to avoid information leakage (Kaufman et al., 2012). This meticulous approach safeguards against bias and ensures the robustness of our analysis. For training strategies, two different methodologies were used: 1) classification, where the model outputs the probability of a window being WD and 2) regression, where the model predicts the Ψpd value of a given window. In both cases, the extracted features were used as input to an extreme gradient-boosted tree algorithm (Chen & Guestrin, 2016). For the hyperparameter optimisation of the models, we used a leave-one-group-out strategy with groups consisting of the four separate experiments and made use of the Bayesian optimisation python library Optuna (Akiba et al., 2019).

Results and discussion:

To develop accurate models for drought prediction in grapevines based on electrophysiology, we conducted different series of drought experiments under controlled conditions to minimize other field aspects besides water deficit. The collected data was used to train the machine learning algorithms. In all trials, irrigation status (measured by SWC) was significantly different between groups. The WW plants were kept constantly at a minimum of 75% FC, while the WD group could reach less than 40% of FC when no more water was available. The water status was confirmed by the measurements of Ψpd. In all the assays, Ψpd values of WW plants remained around − 0.3 Mpa (Fig. 1A). For WD treatment values ranging from −0.6 to −2.5 Mpa (Fig. 1A) were observed after 7 or 10 days, depending on the assay.

A significant reduction of absolute growth and leaf emergence rate was observed on WD plants. Net photosynthesis (Fig. 1B), stomatal conductance, transpiration and water use efficiency was congruently reduced in WD plants. Significantly reduced biomass and plant water content were also demonstrated in response to water privation. A differential biomass allocation was not observed between groups. All the above-mentioned results are well-known ecophysiological responses to plants water deficit (Gambetta et al., 2020), confirming the stressed status of the evaluated grapevines.

The datasets obtained from real-time monitoring of electrical potential in both WW and WD groups were utilized to develop two distinct grapevine drought stress prediction models. For the classification model, evaluation of the test predictions yielded a precision score of 1.0 and a recall score of 0.42, as illustrated in Table 1. In contrast, the regression model aimed to predict the value of Ψpd. Unlike the classi-

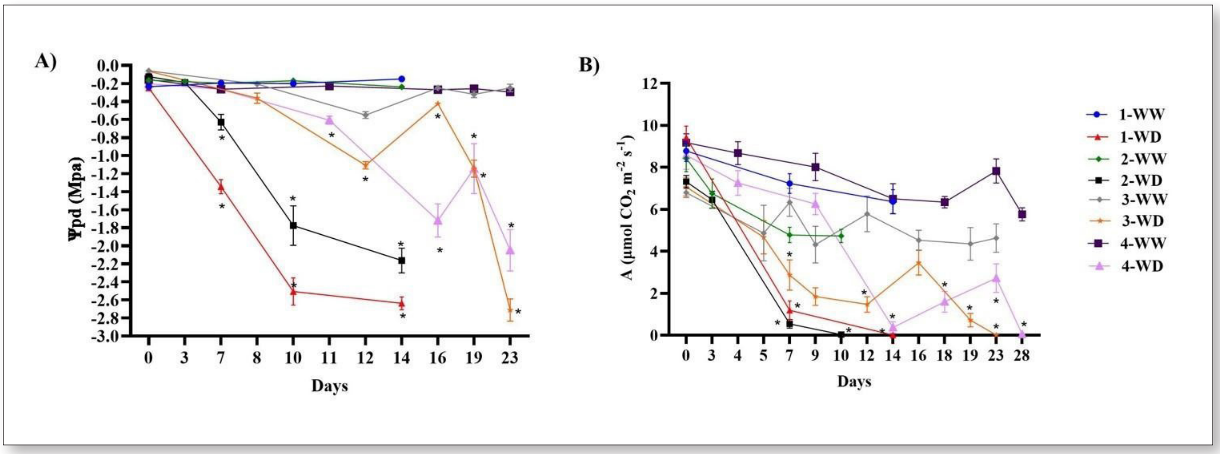

Figure 1. Physiological monitoring of grapevines under drought stress

(A) Predawn leaf water potential (Ψpd) was measured in all plants for the 4 trials using a pressure chamber approximately every 5 days. (B) In the same way, net photosynthesis was determined for the same plants using a portable photosynthesis system. WW: well-watered; WD: water-deficit; 1, 2, 3 or 4 indicates the trial number and the asterisks represent statistical differences between treatments in the same trial (t-test, $p<0.05$).

fication model, precision and recall scores are not applicable for regression tasks. To facilitate comparison with the classification model, we defined a threshold indicating plant entry into WD when Ψpd is lower than -0.9 MPa, as suggested by previous studies (Choné et al., 2001; Leeuwen et al., 2009; Lovisolo et al., 2010). Subsequently, we constructed a confusion matrix for the regression model (Table 1) and computed precision and recall scores of 0.46 and 0.55, respectively. This approach allows for a standardised comparison between the classification and regression models.

Table 1. Confusion matrix for the classification and regression model

	Classification		Regression	
	True Stress	True Control	True Stress	True Control
Predicted Stress	22	0	83	99
Predicted Control	30	74	89	181

Both models have low precision-recall average scores. However, it is important to note that these metrics focus on individual windows. In practical applications, the drought status of a field is often determined by aggregating data from multiple windows originating from various plants, thereby mitigating inter-plant variability. When employing this averaging technique, the test predictions reveal that the classification model has effectively learned to differentiate between windows from WW and WD conditions. Similarly, applying the averaging technique to the regression model also yields a notable differentiation between the two water regimes (Fig. 2B). The results indicate that the model predictions can discern between the two groups as early as 6 days into the experiments, just 3 days after the start of the watering restriction.

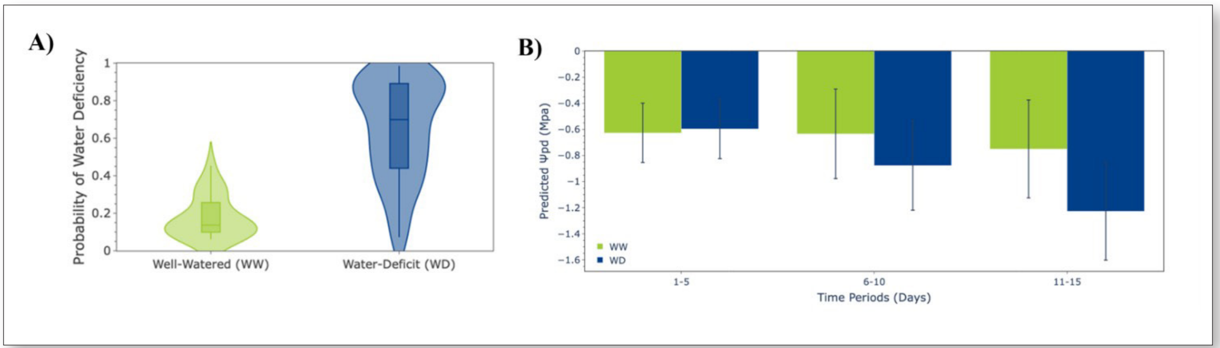

Figure 2. Water deficit prediction models for grapevines based on plant electrophysiology.
A) Box plot showing the median test predictions per label (WW and WD) for the classification model. The shaded area represents the rotated and vertically-mirrored kernel density plot of the predictions. (B) Average of test predictions per group with standard deviation approximating predawn leaf water potential (Ψpd), over three time periods for the regression model.

Conclusion:

Drawing upon the obtained results from climate chamber experiments, electrophysiology measurements provide a promising technology to continuously assess water status of vines in real-time. Nevertheless, in subsequent experiments, the obtained results need to be confirmed, models optimized, and their performance investigated under field conditions. Future experimentations with a focus on other biotic and abiotic stressors and respectively adapted models could make the use of electrophysiology a valuable tool for multi-stress prediction in vineyards.

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NOV 19, 2024 | 15.45 PM | SCIENTIFIC SESSION: **PLANT MATERIAL AND MANAGEMENT II - SCIENTIFIC ORAL**

Can silica application enhance vine performance, quality, and potentially mitigate climate change-induced stresses?

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Keywords: **berry sensory assessment, biodynamics, fruit quality, sustainability, vineyard management.**

ABSTRACT

Climate change can affect vineyards. Impacts include altering grape growth and harvest timing, leading to compressed harvests and changes in fruit quality. Biodynamic viticulture is gaining popularity, with both environmental and marketing benefits as drivers, and involves application of a series of nine preparations to soil and plants. Biodynamic preparation 501 is silica based and has minimum yearly use requirements for certified growers. There are conflicting reports of silicon-based foliar sprays eliciting favourable plant reactions, leading to enhancements in quality, yield, and resistance against pests and diseases. Here, vine growth, reproductive metrics, berry and wine composition analyses, and sensory evaluations were conducted over two years to compare the effects of biodynamic and commercial silica treatments against a water control on Semillon and Cabernet Sauvignon *(Vitis vinifera L.)*. Very few differences were observed in yield and vine growth parameters. Basic berry compositional attributes pH, TA, TSS, total anthocyanins and phenolics showed little to no differences. While berry and wine sensory descriptive analysis showed significant differences in skin and seed tannin related attributes suggesting that berry and wine sensory may be better able to capture small, but significant variations in the vineyard. The findings of this study might validate anecdotal reports of increased light interception and propose a direct association between silicon and polyphenols, potentially impacting sensory mouthfeel characteristics by modifying skin thickness. This study demonstrates the potential of silica applications to offer a positive contribution to climate change mitigation through enhanced vine resilience to environmental stresses.

Introduction:

Climate change is already placing greater pressure on vineyard infrastructure and management, impacting the grape and wine community, as evidenced by changes in grape phenology and harvest dates, which has led to compressed harvests and changes in fruit quality (van Leeuwen et al., 2024). The susceptibility to climate change impacts differs throughout the value chain, with the vineyard exhibiting the highest level of vulnerability. Possible adaptation strategies that can be implemented in vineyards include improved irrigation efficiency, modified irrigation practices to combat frost and heatwaves, retaining soil moisture via vineyard floor management practices, alternative varieties and/or rootstocks, and modified management practices (van Leeuwen et al., 2019). At the same time, there has been an increased exploration into methods of farming that reduce the need for synthetic fertilisers and chemicals, and strive to be more environmentally friendly and sustainable including organic and biodynamic farming practices (Döring et al. 2019). One component of biodynamic practice is the application of atmospheric silica sprays and anecdotal evidence suggests that silica sprays may "strengthen" the plant through the thickening of cell walls and enhanced light assimilation of the plant, leading to better fruit and seed development with improved flavour, aroma, colour, and nutritional quality. Foliar sprays containing silicon have demonstrated the ability to enhance plant responses, including improved quality, yield, and resistance to pests and diseases (Laane 2017). Silica has been linked with increased cell wall thickness and in turn an increase in grapevine disease resistance (Döring et al. 2019). Foliar application has been observed to increase the total silicon concentrations in leaves and fruit, and the wine produced from the silica-treated grapes were ranked better in sensory evaluations (Schabl et al., 2020). However, to date, there is no definitive link established between silica use and improved grape and wine quality. This project sought to explore how applying foliar silica, including both biodynamic preparation 501 and a commercial equivalent (potassium silicate), affects grapevines and influences the quality of their fruit and resultant wine as a potential tool to mitigate climate change stresses.

Materials and methods: Experimental design, vine management and treatment application

The experimental trial was carried out in the Coombe Vineyard at the Waite Campus of The University of Adelaide, South Australia during the 2011/2012 and 2014/2015 growing seasons. Semillon (clone SA32) and Cabernet Sauvignon (clone 125) vines were planted in 1992 with 3 m row and 1.8 m vine spacing. Vines are grown on own roots, trained to a bilateral cordon, with vertical shoot positioning (VSP) and hand pruned to approximately 30–40 nodes per vine. A randomised design of three treatments including a control with six vines per treatment replicate was used. These were grouped into panels, with buffer panels between each treatment to prevent cross-contamination due to spray drift. Control vines received a foliar application of rainwater, biodynamic vines were sprayed with horn silica '501' (Biodynamic Agriculture Australia) and a commercially available potassium silicate solution (OF-30, Ferbon, Australia) was applied to foliage of the commercial treatment vines. The biodynamic preparation consisted of 1 g of preparation 501 (Biodynamic Australia Pty Ltd, Australia) diluted in 17 L of rainwater (1.2 μM). The potassium silicate (Ferbon, OP-30, Australia) solution was a 1 in 300 dilution in rainwater (18 μM) as per the manufacturer's instructions. Grapevine growth stages (Coombe 1995) and the lunar-sidereal calendar (Keats 2011/12 and 2014/15) were used to determine timing of treatments. Application of treatments in the first season were on October 25th 2011, at the modified E-L stage 19 (beginning of flowering) and December 16th 2011 at E-L

Stage 31 (berries pea-size). In the second season application occurred on the 4th of November 2014, E-L Stage 25 (80% flowering), and the 11th of December 2014, being E-L Stage 31 (berries pea size). Both these dates were during spray periods for silica according to the lunar calendar (Brian Keats, Australia).

Vine growth, reproductive performance and chemical analysis

Five inflorescences per vine were randomly selected and enclosed within a mesh bag prior to flowering (E-L19). At the completion of flowering, mesh bags were collected, and the number of flower caps counted to give an average number of flower caps per inflorescence. Percentage fruit set was evaluated as the ratio of berries per bunch to flowers per inflorescence, as described by Collins and Dry (2009). Bunch yield components were assessed on five randomly selected bunches per vine. Total bunch number and total yield per vine were measured at harvest for each treatment. The weight of canes removed from each vine at pruning was recorded, and the ratio of fruit weight to pruning weight calculated to give an indication of vine balance (Smart & Robinson 1991). Stomatal density was determined on 10 leaves per vine for each treatment, with leaf samples collected at harvest using methods described by Rogiers et al. (2011). Petioles were collected at E-L 25 (80% flowering) for elemental analysis using an inductively coupled plasma optical emission spectrometer (ICP-OES) and the concentration of nitrogen was determined by the combustion technique (Waite Analytical Services, Adelaide). Silica concentration was determined through the colourimetric determination of autoclave-induced digestion of the ground petiole sample, as described by Elliot and Snyder (1991). The same process was used to assess the elemental concentration of juice samples. Berry samples were collected at harvest from each vine replicate of each treatment strategy for both Semillon and Cabernet Sauvignon. From each sample, a randomised selection of fifty berries was taken and crushed. The juice collected was used for berry compositional analysis. TSS was measured as degrees Brix (°Brix) using a DMA 35N Density Meter (Anton Paar GmbH, Austria). pH and TA were measured by titration to pH 8.2 (Iland et al. 2004) using a Crison Compact Titrator 08328 Alella (Crison, Spain). A modified spectrophotometry method described by Iland et al. (2004) was used to obtain total anthocyanin and phenolic levels. The same analyses plus alcohol measures were performed on wines made in 2015 only.

Berry and wine sensory analysis

Grape berry and wine sensory evaluation was performed to examine the sensory differences arising from the application of BD 501 and potassium silicate compared to control treatments and to relate sensory attributes to berry composition. Before sensory evaluation, randomly selected bunches from each vine replicate were stored frozen at -20 °C and defrosted for 24 h at 4 °C, panellists received 5 berries per treatment replicate in duplicate for tasting. Wines were also made in 2015 from 50 kg ferments taken at harvest. Panels consisted of 8-10 members (21 to 40 years old) all with previous formal sensory evaluation and descriptive analysis experience. The panel underwent sample specific training in berry and wine assessment and performance evaluation in three, 2 h sessions and participated in two, 2 h formal evaluation sessions. A round table discussion with panellists was conducted to generate sensory descriptors and line scales based on the methods of Lohitnavy et al., (2010).

Data analysis

Measures were analysed using analysis of variance (ANOVA) in the statistical software XLSTAT (Addinsoft, XLSTAT, Version 2015.4.01.21576). Multiple comparisons were used incorporating the Tukey (HSD) and Fisher (LSD) post hoc tests with the F probability (P-value) set at <0.05 for statistical significance. Principle component analysis (PCA) was also used in XLSTAT to display statistically significant attributes.

Results and discussion:
Vegetative and Reproductive Growth

Silica concentration in petiole tissues were significantly greater when a foliar application of potassium silicate was applied (Figure 1). Very few differences in vegetative and reproductive growth measures were found between treatments (data not shown). However, greater yield was observed when silica was applied with a greater response from potassium silicate application to vines in season 2 for Semillon and in both seasons for Cabernet Sauvignon (Figure 2).

Numerous differences in berry sensory assessment of Semillon and Cabernet Sauvignon grapes were observed over the two seasons of application (Figure 2). Many of the attributes that differed between treatments were associated with mouthfeel characteristics. For example, skin and seed astringency as well as tannin intensity and grain size were found to be significantly greater when both silica applications were applied. Skin disintegration was also observed to be harder for potassium silicate treated fruit and could be related to an increase in skin thickness and the mechanical strength provided by silica (Epstein 1994). Several changes in flavour were observed with the application of silica. Skin citrus flavour was higher for potassium silicate and lower for biodynamic silica compared with the control in Semillon, skin flavour intensity was higher for potassium silicate and biodynamic silica when compared with the control in Semillon, pulp and skin ripe dark fruit flavour was higher for potassium silicate compared with biodynamic silica and the control in Cabernet Sauvignon, seed flavour was shown to be altered with the application of silica compared with the control. Silica application has been shown to improve the taste of tomatoes as well as increase the quality of apples, tobacco and rice (Wang et al. 2001). No research has been conducted into silica and flavour molecule synthesis in grapevines, however, increases in flavour are positively correlated to wine quality and highlight a benefit of silica application. Wine assessments were also made but data is not shown.

Berry sensory evaluation highlighted numerous discernible differences in mouthfeel characteristics. Seed tannin size appeared finer in biodynamic silica compared to potassium silicate and the control. Longer re-salivation times for potassium silicate and biodynamic silica indicated higher astringency. In Cabernet Sauvignon, seed astringency was higher for biodynamic silica, while tannin grain size was lower for potassium silicate. While no significant difference was observed for total phenolics or epicatechin concentration, the sensory panel was able to discern numerous sensory differences. This could suggest that silica is influencing the type of tannin present in the grapes, however, no research into silica and tannin and phenolic synthesis and accumulation has been conducted. To determine the cause of sensory differences observed in skin and seed tannin attributes, the phenolic composition of berries should be examined further, as a difference in tannin type or structure could be the cause of sensory differences. The form of tannin and phenolic compounds can alter sensory perception and will be the emphasis of future work. Silica has also been linked to the development of peristomatal protuberances and foliar application of

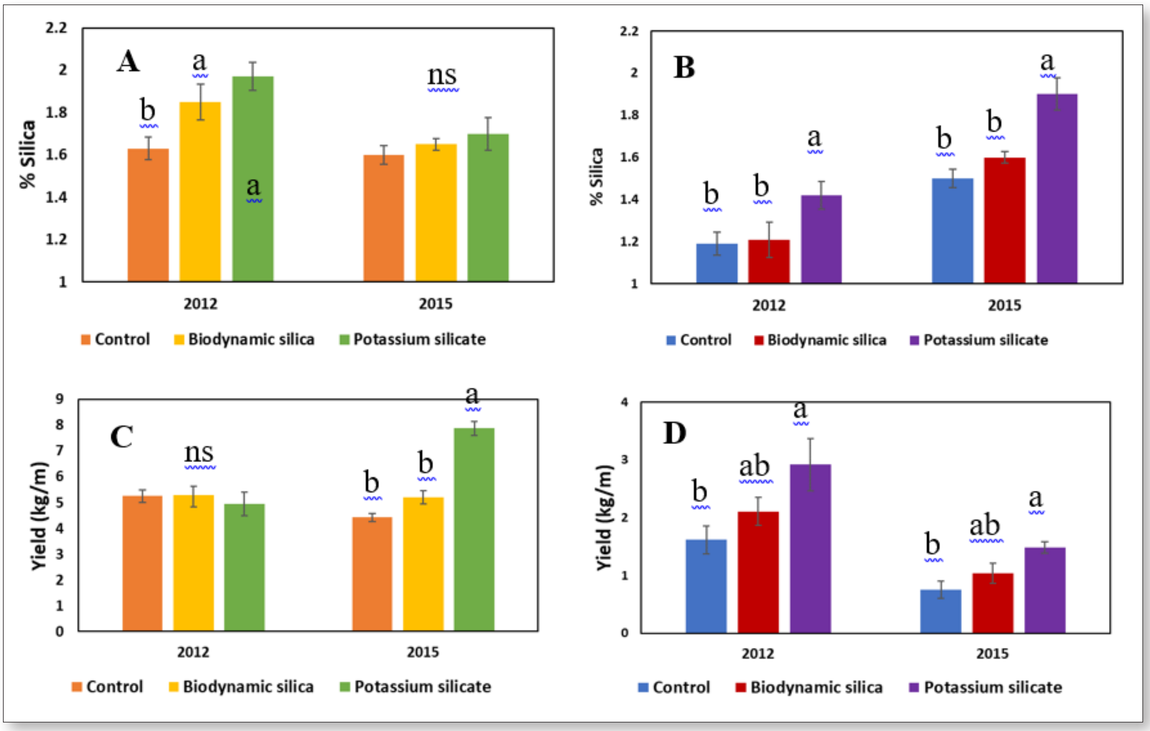

Figure 1. Percentage silica in petiole tissues and yield (kg/m of cordon) of Semillon (A +C) and Cabernet Sauvignon (B + D) in the 2011/12 and 2014/15 growing seasons, Coombe vineyard, Adelaide, Australia.

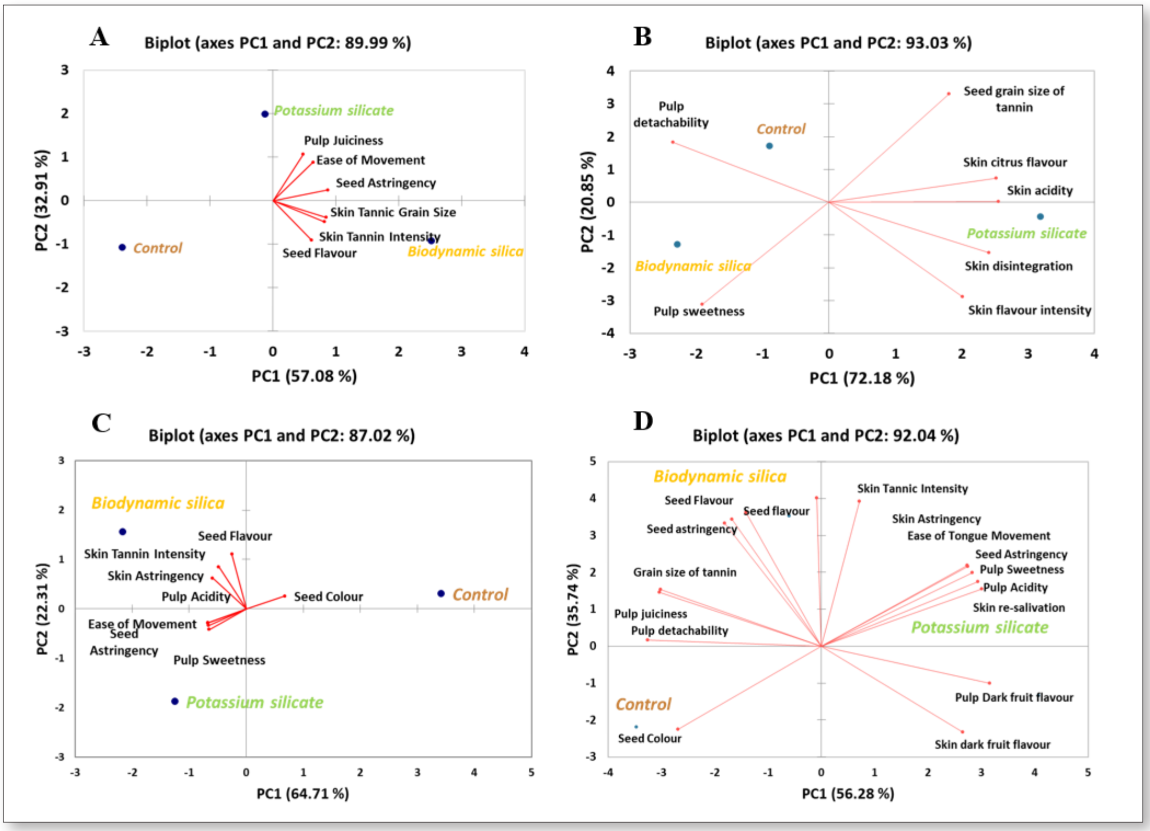

Figure 2. Principal component analysis of significantly different berry sensory attributes for Semillon and Cabernet Sauvignon from Control, Commercial potassium silicate and Biodynamic silica treatments.

A = Semillon 2011/12 season, B = Semillon 2014/2015 season, C = Cabernet Sauvignon 2011/12 season, D = Cabernet Sauvignon 2014/15 season.

silica may affect their development and the subsequent preferential accumulation of phenolic compounds in later stages of berry maturation (Blanke et al. 1999).

Conclusion:

The application of silica increased flavour intensity, altered mouthfeel attributes in grapes and increased aroma and flavour in Cabernet Sauvignon wines (data not shown). Vegetative growth and yield increased with silica application and this experiment highlighted that a larger portion of the beneficial results were observed for potassium silicate, which could be due to the lower silica concentration in the biodynamic application. Increases in perceived astringency observed may be attributable to changes in tannin type and structure, and further research will help to elucidate this effect and substantiate this in the context of grower's claims of increased light interception or a direct binding of silicon with polyphenols. Since grape composition is directly related to wine quality, quantification of the links between grape and wine sensory attributes will aid in determining whether these skin and seed attributes are positive or not and hence help to confirm anecdotal evidence of improved fruit quality through silica application in vineyards. This study demonstrates how silica applications have the potential to positively contribute to mitigating climate change by enhancing vine resilience to environmental stresses and improving fruit quality.

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NOV 19, 2024 | 16 PM | SCIENTIFIC SESSION: **PLANT MATERIAL AND MANAGEMENT II - SCIENTIFIC ORAL**

Agronomical and oenological characterization of grapes and wines elaborated from five red fungal resistant Italian varieties at Serra Gaúcha, Southern Brazil

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Keywords: **Fungal disease, resistant wine grape, phenolic composition, UPLC-MS, Sustainability.**

ABSTRACT

Serra Gaúcha is the main wine producing region of Brazil. Around 80% of total wines are elaborated, in the region, with *Vitis labrusca* grape varieties, while 20% from *Vitis viniefera L.* The climate condition is humid temperate, requiring new grape varieties, adapted and more resistant to pathogens. Therefore, the objective of the study was to evaluate the agronomical and oenological characteristics of grapes and wines from five red Italian varieties considered resistant to downy mildew. The experiment was performed in a randomized trial with two blocks, consisting of 12 plants each, with vine spacing of 1.15m between plants and 2.30m between rows. The red varieties tested were Merlot Kanthus, Cabernet Volos, Julius, Merlot Khorus and Cabernet Eidos, in the 2021 vintage. Disease susceptibility, cycle duration, yield, and oenological parameters of grapes and wines were evaluated. All varieties were resistant for downy mildew, and cycle duration varied between 160 to 183 days. Julius presented the highest yield, while Carbenet Eidos presented the lowest. No differences were observed for total soluble sugars, while total acidity and pH varied according to the grape variety. Phenolic compounds were strongly influenced by grape varieties, and differences were observed for skin+pulp and seeds extracts of grapes and wines. Cabernet Eidos presented the highest amounts of total anthocyanins in skin+pulp, while Merlot Khorus the lowest concentrations. In seed extracts, Cabernet Volos and Cabernet Eidos presented the highest concentrations of total flavanols, while Julius, Merlot Kanthus and Merlot Khorus presented the lowest values. In wines, Julius presented the highest concentrations of total flavanols, while Cabernet Eidos the lowest amounts. Merlot Khorus presented the highest concentrations of total anthocyanins, while Cabernet Eidos the lowest amounts. Ex-

cept Cabernet Eidos, all other varieties may have good adaptability to the region and could be commercially used by wineries in the future for winemaking.

Introduction:

Rio Grande do Sul is the main wine grape-producing state in Brazil, responsible for 62.72% of national winegrowing area, and 90% of the national production of grapes and wines (Mello and Machado, 2020). In 2019, 332.6 million liters of wine were consumed in Brazil, and Serra Gaúcha was the main wine grape-producing region. Brazilian wines are composed of 80% from *Vitis labrusca* grape varieties, and 20% from *Vitis vinifera L.* (Mello and Machado, 2020; Pereira et al., 2020; Pereira, 2020). The region is located in a humid temperate climate, with high rainfall period during grape maturation. From December to March is the period of maturation and harvesting of wine grapes in the region, and total rainfall accumulated was 606 mm. In January, there was high rainfall (226 mm) and in February, the number of rainy days decreased and was 139 mm. In March, rainfall was 147 mm. The use of varieties tolerant/resistant to pathogenic fungal diseases, in order to reduce and/or avoid risks of losses in productivity or oenological quality caused by pathogen attacks, for wineries, improving the quality of their wine. Resistant varieties could also reduce phytosanitary treatments and production costs, thinking in a sustainable viticulture at Serra Gaúcha. New varieties were developed through backcrossing to obtain resistance genes. Among them, Merlot and Cabernet Sauvignon were crossed with varieties recognized for their resistance to fungal pathogens, such as the Bianca, Regent and Konza 20-3 varieties. These new varieties have a high percentage of *Vitis vinifera L.* in their pedigree (≥85%) (Etienne et al., 2016; Casanova-Gascón et al., 2019). They are internationally known as PIWI, an abbreviation of the German word *Pilzwiderständsfhige* (resistant to fungal diseases) (Souza et al., 2019; Zanghelini et al., 2019).

In this context, the objective of the study was to evaluate the agronomical and oenological responses of five red Italian varieties considered resistant to downy mildew, recently introduced in the region.

Materials and methods:

The study was developed in an experimental vineyard located at Embrapa Grape and Wine, in Bento Gonçalves city, Rio Grande do Sul state. The experimental design was installed in 2016 in randomized blocks, with two plots, of 12 plants per replicate, totaling 24 plants per variety, spaced 1.15m between vines and 2.30m between rows. The varieties were Merlot Kanthus, Cabernet Volos, Julius, Merlot Khorus and Cabernet Eidos, grafted onto the Paulsen 1103 rootstock. Vines were trained in vertical shoot positioning-VSP, pruned in a bilateral spur-pruned cordon. Agronomical characterization was carried out by determining the cycle duration (days after pruning until the harvest-DAP), susceptibility to downy mildew disease (by checking disease symptoms in the field), and yield (kg/plant) and (kg/ha). At harvest, decided according to grape sanity and climatic conditions of the region, 100 berries were collected per plot, of which 40 berries were used for physical-chemical analyses, namely total soluble solids (°Brix), total acidity (g L-1 of tartaric acid) and pH (AOAC, 2002). The remaining 60 berries were used to characterize individual and total phenolic compounds by UPLC-MS, by extracting with ethanol skin+pulp and seeds separately, in triplicate (20 berries each) (Pereira et al., 2021). Wines were elaborated using 20 kg of grapes from each plot, following standard protocols for reds, controlling alcoholic and malolactic fermentations (25±2ºC and 18±2ºC, respectively) (Peynaud, 1997). After cold stabilization, wines were bottled and analyzed according to the following physicochemical analyzes: density, alcoholic content, total acidity, pH (AOAC) and phenolics coumpounds by UPLC-MS according to Canedo-Reis et al. (2020) methodology. Results of harvest, 2021 vintage, were subjected to analysis of variance (ANOVA) and comparison of means using Tukey test at 5% probability level, using the Action stat statistical program.

Results and discussion:

Significant differences were observed for agronomical and oenological parameters. The five varieties were resistant to downy mildew in the 2021 vintage, no spraying was applied, and no symptoms were observed. Vintage 2021 was characterized and influenced by La Niña, considered a dry season as compared to other vintages. In 2021, the rainfall was 606 mm between December to February (Ripening period), while the normal is 550 mm. The cycle duration, between pruning to harvest, varied between 160 to 183 days (Table 1).

The yield was strongly influenced by variety. Julius presented the highest yield (3.0 Kg/plant), followed by Merlot Khorus (2.7 Kg/plant), Cabernet Volos (2.3 Kg/plant), Merlot Kanthus (2.3 Kg/plant), and Cabernet Eidos (0.6 Kg/plant). The average production per plant ranged from 2,226.5 to 11,245.5 Kg ha-1. The productivity (Kg ha-1) and weight per plant obtained in this study were lower than those found by Testolin et al. (2020), with the exception for Julius variety, which showed higher productivity.

There were statistical differences were observed for total soluble sugars (ranging from 19.5 to 22.5 ºBrix), and these results were lower than those observed by Testolin et al. (2020). Total acidity and pH varied according to the grape variety (Table 1). Cabernet Volos, Merlot Khorus and Merlot Kanthus grapes presented the highest total acidity value (6.7 g L^{-1} and 5.3 g L^{-1}), while Julius and Cabernet Eidos presented the lowest values (5.2 g L^{-1}). Concerning pH, it ranged from 3.40 (Julius) to 3.79 (Cabernet Eidos). Grapes of Cabernet Eidos and Merlot Khorus presented higher values of pH, while Cabernet Volos and Julius presented lower values than those described by Testolin et al. (2020).

In skin+pulp extracts of the grapes, higher values of flavonols + stilbenes were observed for Cabernet Volos, Julius, Cabernet Eidos and Merlot Kanthus (14.47 mg kg^{-1}, 13.42, 12.69 and 9.08 mg kg^{-1}, respectively), and lower concentrations for Merlot Khorus (7.18 mg kg^{-1}) (Table 2). Individual phenolic compounds were characterized. The major compound identified was isoquercitin, varying from 5.72 mg kg^{-1} (Merlot Khorus) to 11.74 mg kg^{-1} (Cabernet Volos) (data not shown). The highest concentration of total flavanols was observed in Merlot Khorus and Cabernet Volos grapes (789.75 and 782.85 mg kg^{-1}), while Cabernet Eidos and Merlot Kanthus presented the lowest values (250.82 and 265.81 mg Kg^{-1}). The major compound was epicatechin gallate, ranging from 187.52 mg Kg^{-1} (Cabernet Eidos) to 701.08 mg Kg^{-1} (Cabernet Volos) (data not shown). The concentration of total anthocyanins varied from 57.06 mg Kg^{-1} (Merlot Khorus) to 125.76 mg Kg^{-1} (Cabernet Eidos), which concentrations were lower than those determined in the study of Susin et al (2022), in Merlot grapes at Serra Gaúcha. The major compound of total anthocyanins was malvidin-3-glucoside, whose concentrations ranged from 26.07 mg Kg^{-1} (Merlot Khorus) to 98.04 mg Kg^{-1} (Cabernet Eidos) (data not shown). Merlot Kanthus, Cabernet Volos and Julius presented the highest concentrations of caftaric acid (18.59, 16.56 and 13.26 mg Kg^{-1}, respectively), while Merlot Khorus and Cabernet Eidos presented the lowest concentration (2.71

and 5.35 mg Kg^{-1}, respectively). These variations may be due to the climate conditions in the vintage for different regions at the harvest date, and the protocols of winemaking (Peynaud, 1997).

In seed extracts, a higher total content of flavonols + stilbenes were observed for Cabernet Eidos (11.98 mg kg^{-1}) and Merlot Khorus (10.80 mg kg^{-1}), and lower for Julius, Merlot Kanthus and Cabernet Volos (5.05, 5.39 and 6.02 mg kg^{-1}, respectively). The major compound of total flavonols+stilbenes was isoquercitin, which ranged from 1.48 mg kg^{-1} (Merlot Kanthus) to 9.21 mg kg^{-1} (Cabernet Eidos) (data not shown). Different concentrations of total flavanols were found in seed extracts, ranging from 3,006.0 mg kg^{-1} in Julius to 4,777.64 mg kg^{-1} for Cabernet Volos. The major individual compound of total flavanols was epicatechin gallate, ranging from 644.47 mg kg^{-1} (Merlot Khorus) to 1,796.06 mg kg^{-1} (Cabernet Volos) (data not shown).

These results were higher than those shown by Hornedo-Ortega (2020), from Cabernet Sauvignon, Merlot and others varieties. Merlot Khorus, Cabernet Eidos and Julius presented the highest concentrations of caftaric acid in seed extracts, while Cabernet Volos and Merlot Kanthus had the lowest concentrations (Table 2). Differences between the five varieties are due to genetic factor, and adaptation to the *Terroir* of Serra Gaúcha. That could be explained by, soil type, climate conditions, vine management, harvest date, and enological protocols (Van Leeuwen et al., 2004).

All wines were considered dry, according to the density, and had different values (Table 2). Alcoholic degree ranged from 10.22 % for Cabernet Eidos, to 13.28 % for Merlot Khorus, harvested in the same DAP (183 days). Total acidity varied from 6.4 g L^{-1} (Cabernet Eidos) to 9.4 g L^{-1} (Merlot Khorus), and pH presented differences. For wine phenolic compounds determined by UPLC-MS, Julius presented the highest concentrations of total flavonols + stilbenes and total flavanols (84.96 and 566.14 mg L^{-1}, respectively), while Cabernet Eidos presented the lowest amounts (12.91 and 266.92 mg L^{-1}, respectively). For total anthocyanins, the values ranged from 596.33 mg L^{-1} (Merlot Khorus) to 133.07 mg Kg^{-1} (Carbenet Eidos). Julius presented the highest concentration of caftaric acid (113.67 mg L^{-1}), while Cabernet Eidos had the lowest amount (38.12 mg L^{-1}). The variations of wine composition were due to genetic factor of each cultivar, which can be considered well adapted to the pedoclimatic conditions at Serra Gaúcha, except for Cabernet Eidos which presented very low yield, considering it to be explained by the low adaptation of the variety to the climatic conditions of the region or management adopted

Conclusion:

In 2021 vintage, Cabernet Eidos presented very low productivity and, this variety is not recommended for commercial use in the region. Other varieties showed very good yields and could be used by wineries. Differences were observed in the cycle duration, TSS, TTA and pH at harvest date, which suggest many possibilities for winemaking. Physico-chemical composition of skin+pulp and seed extracts, and wines, allowed us to determine the different oenological potential of the grapes and wines, in terms of flavanols, flavonols and anthocyanins. It is possible to recommend varieties to elaborate different kind of wines, for example, among young or aging wines. However, more study and harvests are needed to further validate the adaptation of these varieties in the Serra Gaúcha region.

Table 1. Agronomical and oenological characterization of red Italian varieties in 2021 vintage.

Varieties	Weight per plant (Kg)	Yield (Kg ha-1)	Cycle duration (DAP)	Total soluble sugars-TSS (°Brix)	Total acidity (g L^{-1} tartaric acid)	pH
Merlot Kanthus	2.3^{ab}±0.1	8,505.0^{ab}±315.0	160	19.6^{a}±0.2	5.3^{ab}±0.2	3.52^{ab}±0.02
Cabernet Volos	2.3^{ab}±0.1	8,548.0^{ab}±1,847.0	160	19.5^{a} ±0.4	6.7^{a}±0.1	3.31^{b}±0.04
Julius	3.0^{a}±0.4	11,245.5^{a}±1,06.5	168	22.5^{a} ±0.5	5.2^{b}±0.0	3.40^{ab}±0.03
Merlot Khorus	2.7^{a}±0.2	10,080.0^{a}±630.0	183	20.4^{a} ±2.6	6.7^{a}±0.0	3.71^{ab}±0.08
Cabernet Eidos	0.6^{b}±0.0	2,226.5^{c}±179.0	183	21.1^{a} ±2.7	5.2^{b}±0.0	3.79^{a}±0.16

*Averages followed by the same lowercase letter in the line do not differ by the Tukey test at the 5% probability level. DAP: days after pruning.

Table 2. Characterization of total and individual phenolic compounds from skin+pulp, seeds and wines extracts by UPLC/MS of Italian red varieties resistant, 2021 vintage.

Parameters*	Merlot Kanthus	Cabernet Volos	Julius	Merlot Khorus	Cabernet Eidos
Skin+pulp**					
Total flavonols + stilbenes	9.08^{ab}±1.54	14.47^{a}±2.27	13.42^{a}±1.25	7.18^{b}±1.40	12.69^{ab}±1.91
Total flavanols	265.81^{c}±30.42	782.85^{a}±33.27	503.47^{b}±58.36	789.75^{a}±233.86	250.82^{c}±34.47
Total anthocyanins	87.25^{b}±13.23	99.37^{ab}±8.27	83.58^{b}±11.00	57.06^{c}±2.47	125.76^{a}±13.94
Caftaric acid	18.59^{a}±2.26	16.56^{a}±2.77	13.26^{ab}±0.76	2.71^{c}±0.43	5.35^{c}±1.09
Seeds**					
Total flavonols + stilbenes	5.39^{c}±1.23	6.02^{c}±0.68	5.05^{c}±1.15	10.80^{ab}±4.22	11.98^{a}±1.40
Total flavanols	3390.56^{bc}±171.38	4777.63^{a}±208.64	3006.00^{c}±567.85	3732.62^{bc}±180.25	4159.15^{ab}±176.36
Caftaric acid	4.22^{b}±0.62	4.04^{b}±0.65	5.52^{ab}±1.31	9.25^{a}±2.02	6.96^{sb}±0.40
Wines**					
Density (20°C)	0.9974b±0,0002	0.9993a±0.0000	0.9958d±0.0002	0.9960c±0.0000	0.9974b±0.0008
Alcoholic Content (%)	11.41c±0.01	10.96d±0.01	12.86b±0.00	13.28a±0.02	10.22e±0.02
pH	3.54b±0.01	3.59b±0.01	3.73a±0.05	3.27c±0.01	3.83a±0.01
Total acidity (g L-1)	7.5c±0.0	7.8b±0.0	7.0d±0.0	9.4a±0.0	6.4e±0.1
Total flavonols + stilbenes	55.74c±2.24	45.40d±1.20	84.96a±0.93	68.86b±0.91	12.91e±0.98
Total flavanols	342.28c±6.50	377.99bc±2.61	566.13a±6.99	401.96b±0.04	266.92d±19.54
Total anthocyanins	340.33b±3.48	339.61b±4.99	329.79b±1.36	596.33a±0.15	133.07c±0.83
Caftaric acid	64.37c±0.27	67.62bc±1.28	113.67a±3.00	74.67b±1.60	38.12d±0.30

*Averages followed by the same lowercase letter in the line do not differ by the Tukey test at the 5% probability level. ** For skin+pulp and seeds, results are expressed in mg Kg^{-1} of grapes, while for wines, in mg L^{-1}; flavanols and stilbenes (expressed in mg Kg^{-1} of quercetin-3-O-glucoside) and total flavanols (expressed in mg Kg^{-1} of epicatechin).

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NOV 19, 2024 | 16.15 PM | SCIENTIFIC SESSION: **PLANT MATERIAL AND MANAGEMENT II - FLASH ORAL**

Unveiling the impact of rootstock mediation on Syrah physiology and wine quality under soil salinity and water deficit: a climate change scenario

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Keywords: **volatile, organic compounds, combined stress, rootstock, salinity, water deficit.**

ABSTRACT

Water scarcity and salinity pose growing challenges to the viticulture and wine industry. Understanding how grapevine physiology and wine quality adapt to these environmental hazards is crucial for developing mitigation strategies. Here, we investigated the mediatory potential of two rootstocks grafted with *cv.* Syrah scion. Syrah grafts on 1103 Paulsen (PL1103) and SO4 rootstocks were tested under sets of combinations of salinity (0.5 and 2.5 dS m-1) and different irrigation levels during the entire development season (66%, 100% and 133% of the local recommended irrigation amount) in an experimental five-year-old vineyard located on Sde Boker, Israel at 30°51'22.37" N and 34°46'52.98" E. Syrah grafts on SO4 generally produced higher yield than PL1103 grafts, while accumulating more Cl- ions in leaves. Lower physiological activity including chlorophyll fluorescence and photosystem efficiency under stress treatments were recorded in PL1103 vines than SO4. Spectrophotometric readings showed that salinity with deficit irrigation increased tannins and reduced carotenoid content in berries. Furthermore, PL1103 rootstock accumulated more chloride in wine than SO4 under salt stress. Rootstocks also influenced color and tannins. Using gas chromatography-mass spectrometry coupled with solid-phase microextraction (GC-MS-SPME), out of 84 volatile metabolites we profiled in Syrah wine, 31 of them showed significant differences between control and stressed vines. Among identified volatiles' groups, the esters decreased under stressed treatments, while volatile acids, ethers, and ketones increased specifically under salt stress. Salinity increased alcohols and ethers, regardless of rootstock. Root-

stock-dependent analysis revealed stronger positive correlations between volatile compounds of SO4 than PL1103 grafts. Principal component analysis clearly separated saline-treated and control samples, with key volatile compounds like ethane, 1-ethoxy-1-methoxy, 3-methylbutyl ester, ethyl ester and acetaldehyde (fruity), Butanal (nutty), 1-Propanol and 2-methyl-2 (solvent-like flavors) being the most discriminant. Altogether, our results show multi-level differences in Syrah wine quality, volatiles, and vine physiology and the involvement of rootstocks in the response of grapevine to salinity and water deficit.

NOV 19, 2024 | 16.20 PM | SCIENTIFIC SESSION: **PLANT MATERIAL AND MANAGEMENT II - FLASH ORAL**

Trunk ring-width and wood anatomy modifications through grapevine growth in response to contrasting wind exposure: a comparative analysis of two cultivars

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Keywords: **environmental factors; mechanically-induced stress; phenotypic plasticity; terroir; Argentine Patagonia.**

ABSTRACT

The Argentine Patagonia is the southernmost wine-growing region in the world and is characterized by a high frequency of mid and strong winds. This meteorological factor can induce mechanical stress (MIS), impacting grapevine physiology, but its effects remain understudied. Malbec (Mb), the most widely cultivated red variety in Argentina, and Cabernet Sauvignon (CS), a globally recognized cultivar, exhibit contrasting phenotypic plasticity, that is, capacity to express different phenotypes under changing environments. A field experiment was conducted with Mb and CS in the windy locality of Casa de Piedra, La Pampa (Argentina), selecting plants near a poplar windbreak (wind-protected) or farther away (wind-exposed). During the dormancy, wood cores samples of the main trunk were collected and used to evaluate annual ring width and xylem structure (WinCell software). These variables were correlated with meteorological data registered during the whole plant life (2011-2021). Additionally, multifactorial ANOVA for different growing seasons, wind exposures, and cultivars were done. Results indicate that grapevine xylem structure varied in response to seasonal environmental conditions, and depending on cultivar. Seasons with more extreme conditions (higher winds, temperatures, and lower precipitation), correlate with reduced annual ring width. Further analysis that is in process will elucidate xylem anatomy modifications to acclimate against extreme environmental conditions in windy regions.

NOV 19, 2024 | 16.25 PM | SCIENTIFIC SESSION: **PLANT MATERIAL AND MANAGEMENT II - FLASH ORAL**

Prediction of yield spatial variability within vineyard based on DIGIVIT mobile app

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Keywords: **precision viticulture, bunch segmentation, image analysis, Sentinel-2, yield map.**

ABSTRACT

In viticulture, forecasting yield at the vineyard scale a few weeks before harvest is crucial for the planning of vineyard operations, investment, and even marketing and sales strategies. Vine fields present a high yield variance due to within-field variability mostly explained by spatial variation of environmental factors. Traditional ground-based approaches are accurate, but the small number of observations and the choice of sampling areas not representative of the variability result in high errors in yield estimation (5 to 30%). Research in the field of precision viticulture, described many solutions based on leveraging technologies like GPS, remote sensing, and artificial intelligence, offers efficient support in sampling area localization or non-destructive monitoring tools. This study aims to develop and test a technological workflow using the mobile app Digivit, integrated with the AgroSat platform, to estimate yield variability in vineyards. The workflow was performed during the 2023 growing season in a series of vineyards (Italy) and involved two main steps: spatial variability characterization using AgroSat and yield estimation using the mobile Digivit app. AgroSat processed Sentinel-2 NDVI data to identify homogeneous zones, while Digivit used smartphone images of grape clusters to estimate yields. The field campaign, performed three weeks before harvest, involved monitoring representative vines within identified zones and uploading georeferenced images for cluster segmentation analysis. Yield estimates were validated against measured weights, showing a strong linear correlation (R^2=0.85, RMSE=43.74g). Excluding one outlier improved correlation to R^2=0.95, RMSE=14.58g. Vineyard-level yield predictions were compared with harvest data, achieving an overall error of 7%, in agreement with literature (Font et al., 2015; Aquino et al., 2018; Di Gennaro et al. 2019). The study demonstrates that Digivit app provides accurate, timely yield prediction, supporting farmers in harvest planning and winemaking management. The user-friendly mobile approach facilitates a broader adoption of precision viticulture technologies among farmers, overcoming barriers related to technical expertise.

NOV 19, 2024 | 16.30 PM | SCIENTIFIC SESSION: **PLANT MATERIAL AND MANAGEMENT II - FLASH ORAL**

Grape berry growth modeling for a wide range of *Vitis vinifera* cultivars

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Keywords: **vine, berry growth, yield, climate change, modeling.**

ABSTRACT

In order to study the impact of climate change on Bordeaux grape varieties, and to assess the behaviour of other grape varieties potentially better adapted to future climatic conditions, an experimental vineyard composed of 52 grape varieties was planted in 2009 at INRAE in Bordeaux Aquitaine France. Among many parameters studied since 2012, berry weight for each variety was measured weekly from mid-veraison to maturity, with four independent replicates.

An analysis with ten years of data enabled the classification of varieties according to their berry weight, which ranged from 1 to 3 grams per berry, on average. The year effect was also evaluated. Both variety and year were found to have a significant impact on berry weight. Using annual climatic parameters, it was also shown that both temperature and rainfall from flowering to veraison have a significant impact on berry weight. During the ripening period, both temperature and water status (as measured by δ13C in berry juice) had a significant impact on berry weight. Finally, seed number also has a significant impact on berry weight. This study provides a better understanding and characterisation of the environmental and genetic factors that govern berry weight across a wide range of grape varieties.

NOV 20, 2024 | 9 AM | SCIENTIFIC SESSION: PLANT MATERIAL AND MANAGEMENT III - CONFERENCE (KEYNOTE SPEAKER)

Turning water into wine: the water footprint of winegrape production

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Keywords: **grapevine, water status, climate change, adaptations, water footprint, water balance modelling.**

ABSTRACT

Water status profoundly affects the physiology of the grapevine and particularly its reproductive development and grape composition at harvest. Mild water deficits improve the qualitative potential of the grapes, while severe water deficit can impair quality parameters and yield. With climate change, the frequency and severity of drought events is increasing in most winegrowing regions and this trend is expected to continue over the next decades. Grapevines have been cultivated since millennia in warm and dry areas, in particular around the Mediterranean basin. In this region, growers have selected drought resistant genotypes and developed adapted training systems. Grapevines can be dry-farmed or irrigated. Traditionally, dry farming is the rule in Europe, while irrigation is predominant in winegrowing regions in other continents. Since the end of the 20th century, irrigation is gaining importance in Europe. This trend raises questions about sustainability, because of increased competition for limited freshwater resources. The amount of water required to produce a quantity of wine, or the water footprint, is a relatively recent concept, for which no consensus calculation method for vineyards has emerged yet. The development of a methodology for water footprint calculations could be a tool to assess the sustainability of water use in wine grape production. Such a method should be easy-to-implement and produce meaningful results for stakeholders and policymakers in both dry-farmed and irrigated vineyards.

Impacts of water status on vine physiology:
Water is essential for the vegetative and reproductive development of the grapevine. Water deficits develop frequently during the growing season, due to low rainfall, high evapotranspiration and/or low soil water holding capacity. These water deficits profoundly affect the physiology of the grapevine. One of the first visible symptoms of water deficit is a reduction

in shoot growth, in particular for secondary shoots (Pellegrino et al., 2006). When water availability becomes more limiting, stomatal closure reduces transpiration, which results in a decline of photosynthetic activity (Flexas et al., 1998). This response is triggered both by hydraulic (Charrier et al., 2018) and hormonal (Tardieu and Simonneau, 1998) signals. Stomatal closure appears when approximately 60% of the total transpirable soil water (TTSW) is consumed (e.g., 120 mm for a soil with a TTSW of 200 mm) and intensifies progressively as the remaining soil water is depleted (Lebon et al., 2003). The grapevine has a comfortable hydraulic safety margin, meaning that grapevines rarely die from hydraulic failure under severe drought, even when 100% of the TTSW is consumed (Charrier et al., 2018). However, vines operate with a lower hydraulic safety margin when exposed to multiple dry years (Tombesi et al., 2018). Perennial plants can also decline and eventually die when repeated restricted photosynthesis in a series of dry seasons lead to carbon starvation (McDowell et al., 2008).

Water deficits also affect reproductive development. Early water deficits (in May, or early June on the Northern Hemisphere, November, or early December on the Southern Hemisphere) can impair the initiation of inflorescences in the latent buds, leading to lower yields in the next season (Guilpart et al., 2014). All other yield components of a given vintage are impacted by water deficits during the same year, in particular berry weight. Pre-veraison water deficit results in a greater reduction of berry weight compared to post-veraison water deficit (Ojeda et al., 2001).

Regarding grape composition at harvest, berry sugar *content* is restricted under water deficit. This effect does not necessarily result in lower sugar *concentration*, because drought reduces berry weight in a similar magnitude. Mild water deficits accelerate grape ripening, due to the combined effect of limited competition for carbohydrates with growing shoots and smaller berries (van Leeuwen et al., 2023). Grape ripening can be impaired under severe water deficits when photosynthesis is too much restricted (growers refer to this phenomenon as “stuck maturation”), but this remains relatively rare (van Leeuwen et al., 2023). Water deficit increases the concentration of polyphenols in berry skins, and in particular of anthocyanins in red grape varieties (Ojeda et al., 2002; Koundouras et al., 2002). This effect is not only linked to a reduction in berry size (and the subsequent increase of skin to flesh ratio), but also due to a direct triggering of the enzymes involved in the synthesis of phenolic compounds (Castellarin et al., 2007, Triolo et al., 2019). Vine water deficit modifies aromas in grapes and wines. Green aromas like 2-methoxy-3-isobutylpyrazine (IBMP) are decreased under water deficit (Roujou de Boubée et al., 2000), while red wines produced from water deficit exposed vines develop a more complex bouquet after bottle ageing (Picard et al., 2017). Savoi et al. (2020) showed that mild water deficits also improve aromatic expression in white wines, although severe water deficits may reduce aromas of the volatile thiol family (Peyrot des Gachons et al., 2005) and trigger accelerated and atypical ageing, due to the development of o-aminoacetophenone (AAP; Hühn et al., 1999). Koundouras et al. (2006) investigated the effect of vine water status in Peloponnese, Greece on the red grape variety Ageorgitiko. These authors showed that water deficit improved aroma expression and overall wine quality. Hence, water deficit can be considered as an important factor in the production of high quality wine.

Wine production in a changing climate: Most viticultural areas are located around the globe between the 30th and 50th parallel latitude (Puga et al., 2022). Average Growing Season Temperatures from April through September (AvGST; Jones 2006; Jones et al., 2018) are between 9.9 and 30°C (Puga et al., 2022). Surprisingly, grapes used for wine production are grown in very dry to very wet areas, with annual rainfall ranging from 7 to 1836 mm/year (Puga et al, 2022). Average annual rainfall for a selection of wine grape producing regions is presented in table 1 (note that extreme areas were wine production is confidential have been discarded). However, most regions renowned for their high quality wines are rather dry.

Table 1. Precipitation average from 1989 to 2018 in some major winegrowing areas around the world. Data from Puga et al. (2022) who extracted the TerraClimate database at the location of a major city (name given between brackets in the table below) located within or near each wine region. Areas in pink have such low rainfall that irrigation of vineyards in mandatory for commercial viable viticulture.

Data: Puga et al, 2022 (exept Cariñena and Pinhão)		Precipitation [mm] Annual	Growing season April-Oct NH Oct-Avril SH	Vegetative rest Nov-March NH March-Nov SH
Atacama (Copiapó)	Chile	7	0	7
Mendoza (Junín)	Argentina	216	185	31
Central Valley (Fresno)	USA	272	60	212
Murray Darling (Mildura)	Australia	276	156	120
Maipo (Santiago)	Chile	335	47	288
Cariñena	Spain	358	225	133
La Rioja (Logrono)	Spain	440	256	184
Barossa Valley (Nuriootpa)	Australia	591	218	373
Rheingau (Geisenheim)	Germany	598	371	227
Piemonte (Asti)	Italy	620	394	226
Champagne (Reims)	France	631	380	251
Stellenbosch (Stellenbosch)	South Africa	709	215	494
Tuscany (Siena)	Italy	737	375	362
Loire (Angers)	France	751	391	361
Southern Rhône Valley (Nîmes)	France	755	443	311
Douro (Pinhão)	Portugal	761	355	406
Burgundy (Dijon)	France	778	477	302
Marlborough (Blenheim)	New Zealand	793	433	360
Cognac (Angoulême)	France	843	444	399
Bordeaux (Merignac Airport)	France	889	450	439
Napa (St Helena)	USA	892	145	747
Yarra Valley (Healesville)	Australia	1014	531	484
Margaret River (Margaret River)	Australia	1043	229	814
Willamette Valley (McMinnville)	USA	1155	313	842
Vale dos vinhedos (Bento Gonçalves)	Brazil	1836	1101	736

With climate change, rainfall patterns and evapotranspiration rates are changing, impacting the intensity of drought experienced by grapevines. For instance in Europe, drought is expected to increase at lower latitudes (in particular around the Mediterranean basin), while it is expected to decrease at higher latitudes (Figure 1; van Leeuwen et al., 2024). Predictions on the trend of drought experienced by grapevines are, however, complex, because they depend on:
1) the amount and timing of rainfall (variable according to location),
2) reference evapotranspiration or ET0 (increasing in most areas, as a result of higher temperatures) and
3) the length of the cycle from budburst to harvest (which reduces when temperatures increase, and when variety, soil water holding capacity and training system remain unchanged).

The impact of these three factors can be assessed by water balance modelling. When vine water status during the ripening period is modelled with a fixed end date (e.g. 30 September), water deficits are generally increasing over time as a result of increasing ET0 (as for example for Bordeaux: van Leeuwen and Darriet, 2016). However, when harvest dates are modelled, accounting for a shorter cycle when temperatures are higher, this trend is much less obvious (see for Bordeaux: van Leeuwen and Simonneau, 2024). Unfortunately, few trends are published with vine water status *measured* over longer periods.

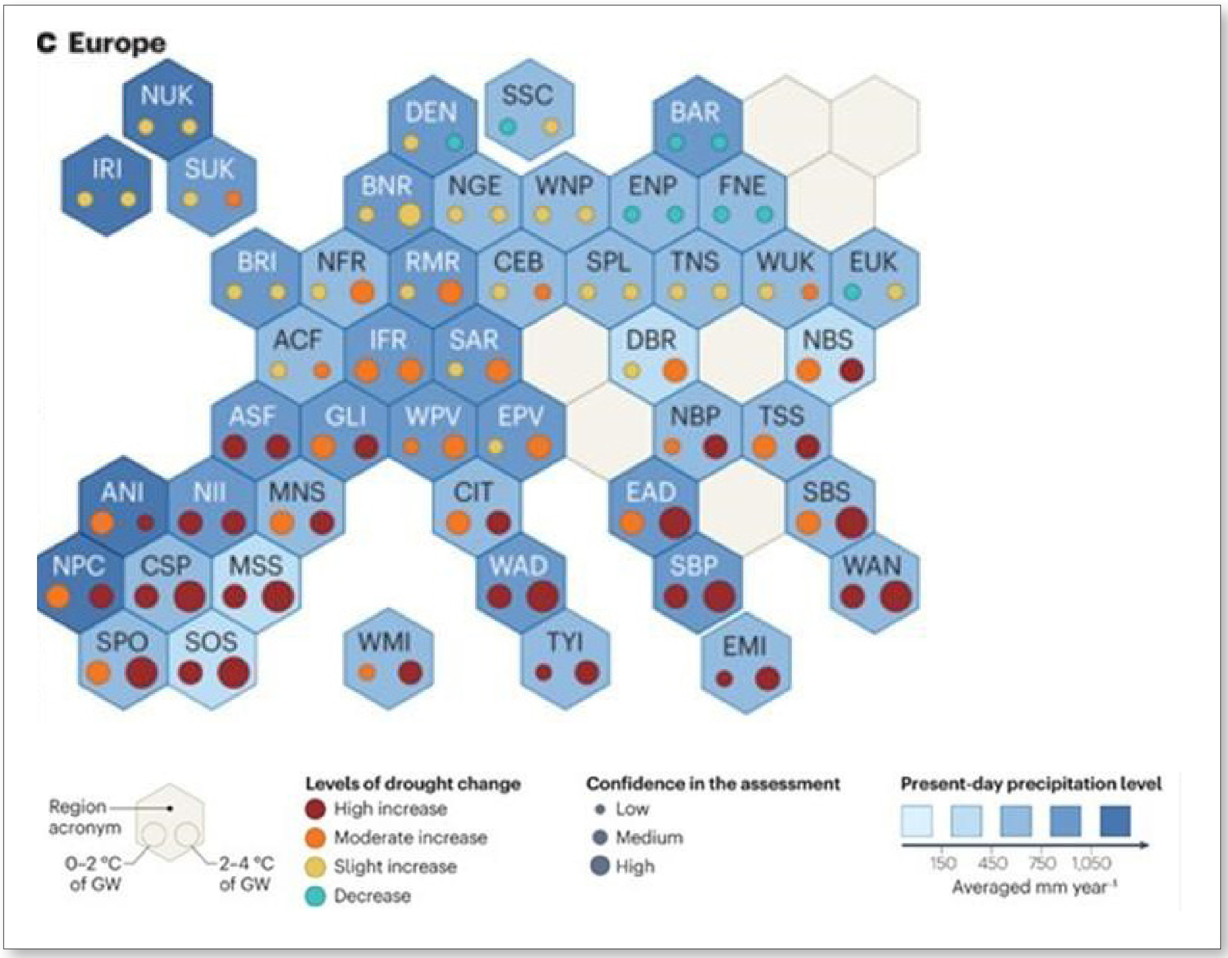

Figure 1. Expected levels of drought change in Europe, for 2 scenarios of climate change (0-2°C warming and 2-4°C warming compared to the preindustrial reference). Adapted from van Leeuwen et al., 2024.

Adaptations to drought:

The use of drought resistant plant material is a sustainable and cost-effective way to deal with drought. In the Mediterranean basin, growers have selected drought resistant varieties, like Grenache, Carignan and Cinsaut (Champagnol, 1984). The mechanisms driving genotypic differences in drought resistance are complex and involve, among others, the reactivity of stomatal closure to drought signals (Plantevin et al., 2022) and multiple hydraulic traits (Dayer et al., 2023). In dry environments, the use of drought resistant rootstocks is a major lever for adaptation. Rootstocks control the transpiration of the scion (Marguerit 2012), but all the multiple mechanisms involved in rootstock drought resistance have not yet been unravelled. Ollat et al. (2016) provides an empirical classification of drought resistance in rootstocks.

Another lever for adaptation to drought is the design of the training system. Reduced density (i.e., the number of vines per hectare) limits vine transpiration when expressed per surface area (van Leeuwen et al., 2019). The Mediterranean goblet bush vine is the ultimate drought resistant training system (Salvi et al., 2017). Unfortunately, vineyards planted with this training system are increasingly ripped-up, because of the constraint that no specific mechanical harvester has been designed.

The total amount of soil water available to vines, or TTSW, increases with rooting depth. Deep soil preparation promotes deep rooting (van Zyl and Hoffman, 2019), as does the use of vigorous rootstocks (Ollat et al., 2016). Moreover, dry-farmed vines seem to implement long-term adaptation strategies to low TTSW, although those mechanisms are not fully understood (Pagay et al., 2022).

When several adaptations to drought are combined (e.g., drought resistant grape variety, drought resistant rootstock, adapted training system), vines can be cultivated without supplementary irrigation in very dry environments. In Cariñena (Aragón, Spain), annual rainfall is as low as 360 mm. In these conditions, Grenache grafted on 110R and trained as goblet bush vines, produce high quality wines without any visual drought stress damage on the vines in most years (Figure 2A). In the same environment, Tempranillo vines trained as VSP (vertical shoot positioning) and cordon pruned, suffer excessively from drought stress and may require supplementary irrigation (Figure 2B).

Figure 2. A - Goblet trained Grenache in Cariñena (Aragón, Spain) on September 2, 2019.
B - Vertical shoot positioned (VSP), cordon pruned Tempranillo on September 3, 2019.

Photo credit: Laure de Rességuier.

This observation raises a question about when supplementary irrigation is required in vineyards. Drought stress can easily be relieved with irrigation and yields can be secured or even increased when compared to those obtained in dry-farmed vineyards (Intriglio et al., 2008). The example in Figure 2A shows, however, that excessive water deficit stress can also be avoided by the use of adapted plant material and training systems. The implementation of irrigation has multiple impacts on vine physiology, on the economics of wine production and on its water footprint.

Different techniques for irrigation:
Vineyards can be irrigated by flooding, sprinklers or drip systems (van Zyl and Huyssteen, 1988). Drip and sprinkler systems are more efficient in terms of water consumption (van Zyl and Huyssteen, 1988). Because sprinkler irrigation promotes diseases like downy mildew (Smart et al., 1974), drip irrigation has become the reference technique for vineyard irrigation, although precise statistics on the percentage of each approach are not easily accessible. Most drip systems are above-the-surface, although buried systems are currently developing because they limit water losses through direct evaporation (Noltz et al., 2016). Several techniques for deficit irrigation have been developed, including partial root zone drying (PRD; Stoll et al., 2000; Scholasch and Rienth, 2019) and regulated deficit irrigation (RDI; Santesteban et al., 2011; Scholasch and Rienth, 2019). Water for irrigation can be sourced from shallow groundwater, aquifers, rivers, natural lakes or artificial water reservoirs. The latter can be rain fed, or filled with water pumped from aquifers.

Implications of irrigation:
Many studies attest to the efficiency of supplementary irrigation in increasing vineyard yields, in particular when irrigation is applied early in the season (among many references on the topic see Intriglio et al., 2008; Muniz et al., 2020 and references cited herein). Full irrigation decreases wine quality (in particular for red wine), because it induces an increase in berry size and reduction in grape and wine anthocyanins concentration due to a lower skin-to-pulp ratio (Ojeda et al., 2001; 2002). The impact of deficit irrigation on wine quality varies depending on the local context (soil, climate, cultivar) and the amount and timing of irrigation water applied. RDI and PRD allow for increased yield with minimal (or no) quality losses. Drip irrigation restricts root growth to the drip-zone (Araujo et al., 1995), while promoting vigour (Intriglio et al., 2008), possibly leading to a disbalance between aboveground and belowground development. Such vines, with excessively vigorous canopies, developed on a shallow and restricted root system, increase the chances of hydraulic failure in the vine under heatwaves when atmospheric demand is very high (Scholasch and Rienth, 2019). This disbalance is reduced by increasing irrigation intervals (compared to high-frequency irrigation; Scholash et al., 2018).

Depending on the soil and source water, irrigation in dry climates has the potential to increase salinity in the vine root zone, possibly leading to salt stress (Qadir et al., 2014). This is particularly the case when accumulated salts in the vine root zone are not leached by excess irrigation or high rainfall (Minhas et al., 2020). Salt accumulation in soils negatively impacts soil structure (Laurenson et al., 2011) and soil microbiome (Rietz and Haynes, 2003; Egamberdieva et al., 2010). When irrigation water is sourced from treated wastewater or salty aquifers this process is accelerated (Hoogendijk et al., 2024), leading to yield reductions in food crop production (Gao et al., 2021), including vineyards (Laurenson et al., 2011). The grapevine is a salt-stress sensitive species, although some rootstocks like Ramsey are more tolerant than others (May, 1994).

The water footprint of winegrape production:

Fresh water is a limited resource while global demand is ever increasing, in particular in agriculture (Rosa et al., 2020). Physical water scarcity refers to the situation where demand exceeds the amount of available water. Economic water scarcity occurs when there is inadequate investment in water distribution infrastructure providing access to fresh water resources (White, 2014). The concept of the Water Footprint of goods and services was introduced by Hoekstra from the University of Twente (The Netherlands) and resulted in the foundation of the Water Footprint Network (WFN; Hoekstra, 2017). Water Footprint is defined as the volume of water used per unit of product (Hoekstra and Chapagain, 2007). Mekkonen and Hoekstra (2011) defined several types of water according to their origin and identified them by a colour code:

- the Blue Water Footprint refers to the volume of surface and groundwater consumed (evaporated) as a result of the production of a good, in general through the implementation of supplementary irrigation;
- the Green Water Footprint refers to the rain-water consumed; applied to plants it refers to the water consumed from the rootzone, originating from local rainfall;
- the Grey Water Footprint of a product refers to the volume of freshwater that is required to assimilate the load of pollutants based on existing ambient water quality standards.

The colour code is now widely accepted, although the precise definitions for each type of water are not consensual and other researcher prefer separating water footprint from water consumption (see next paragraph). The calculation of water *footprint* in crop production is important, because water consumption can only be efficiently reduced when relevant metrics are available

Methodologies for water footprint calculations:
Water Footprint Network and Life Cycle Assessment approaches

There is no consensus on how water footprints should be calculated, and alternative methods for water footprint accounting can yield highly divergent results. The water that is used in the production process of an agricultural (or industrial) product is called the 'virtual water' contained in the product (Hoekstra, 2003). According to the WFN, Water Footprint should be accounted at a global scale, because water can be virtually traded between countries (Hoekstra, 2003). This assumption leads to the calculation of Water Footprints in which green and blue water are more or less equivalent. Life Cycle Assessment (LCA) aims at assessing the environmental footprint of a product from the cradle to the grave, *i.e.*, from raw material acquisition, via production and use phases, to waste management (Finnveden et al., 2009), including water footprint calculations. LCA assesses the local environmental impact of the production of commodities and proposes the calculation of a water scarcity weighted footprint (Liu et al., 2017), together with a method called “assessing impacts on water consumption based on Available WAter REmaining” (AWARE, Boulay et al., 2018). The subsequent approaches of water footprint calculations of the WFN and LCA communities have given rise to a fierce controversy in the scientific literature (Hoekstra, 2016; Pfister et al., 2017).

The WFN approach, considering green and blue water as more or less equivalent, does not seem appropriate for Water Footprint calculations in wine grape production. It considers water intensive goods should be produced in areas where water is not scarce, which is not compatible with the strong regional identity of wine production. The LCA approach is not easily applicable either, because calculations are complex, and the result depends on other water usages in the same catchment area.

Hydrological method

An alternative method, using water balance modelling, was proposed by Deurer at al. (2011) on kiwifruit in New Zealand and was applied to winegrape production by Herath et al. (2013). This method is based on a "hydrological" approach, considering hydrological inflows, outflows and storage changes. It can be implemented by means of water balance modelling and has been updated by Johnson and Mehrvar (2021). It has the advantage that it is applicable to both irrigated and dry-farmed vineyards. The hydrological approach distinguishes between blue and green water "footprint" (where inflow, outflow and storage changes are considered simultaneously), and blue and green water "consumption" (where only the outflow is considered). These are referred to respectively as Green and Blue Water Footprints (GWF and BWF) and Consumptive Green and Blue Water Footprints (CGWF and CBWF). Water footprints and consumption are expressed relative to yield (L/kg, which is comparable in magnitude to L/0.75L bottle of wine). Blue water consumption is a highly theoretical concept, because in irrigated vineyards the relative part of water consumed from rainfall and irrigation cannot be easily distinguished and will not further addressed in this article. Grey Water Footprint depends considerably on local water standards and is out of the scope of this article, as is the water footprint of the transformation of grapes to wine (small compared to the water footprint of the production of grapes).

According to Herath et al. (2013) and Johnson and Mervar (2021), **Green Water Footprint (L/kg)** represents the water balance of a dry-farmed vineyard and can be expressed as:

$$GWF = \frac{10\left((T_r + E_r + D_r + R_r) - (P - P_i)\right)}{Y_r}$$

(eq. 2)

Where :

- 10 is for unit conversion
- T_r represents vine and cover crop transpiration (mm/year)
- E_r represents evaporation from the soil surface (mm/year)
- D_r represents drainage from the rootzone in rainfed conditions (mm/year)
- R_r represents surface runoff (mm/year)
- P represents precipitation (mm/year)
- P_i represents precipitation intercepted by the canopy (mm/year)
- Y_r represents yield in rainfed conditions (T/ha/year)
- r refers to rainfed conditions

In this approach, the inflow of the GWF is rainfall and the outflow is transpiration, evaporation, drainage and runoff. As a result, the GWF represents changes in soil water storage in the rootzone. In most situations, the GWF equals zero on an annual basis, because the water consumed by the vines and cover crop from the soil during the vegetative season is generally refilled by autumn and winter rains. In a particular year it can, however, be negative when the soil available water is depleted during the summer and rainfall is low at the end of the year.

Precipitation intercepted by the canopy (P_i) corresponds to rain that hits the canopy and which is evaporated from the leaves before it reaches the ground. In climates with multiple small rainfall events in the summer, this can represent a substantial part of the total precipitation, but the precise amount is not easy to estimate.

Consumptive Green Water Footprint (L/kg) represents evapotranspiration from a dry-farmed vineyard relative to yield and can be expressed as (Herath et al., 2013; Johnson and Mehrvar, 2021):

$$CGWF = \frac{10(T_r + E_r)}{Y_r} \qquad \text{(eq. 1)}$$

Where:
- 10 is for unit conversion
- T_r represents vine and cover crop transpiration (mm/year)
- E_r represents evaporation from the soil surface (mm/year)
- Y_r represents yield (T/ha/year)
- r refers to rainfed conditions

CGWF only considers consumptive use from the vineyard (i.e., transpiration and evaporation). To understand the relevance of calculating CGWF of viticulture in a particular location, it may be appropriate to also consider the CGWF of the ground cover that would otherwise occupy that location for comparison.

Blue Water Footprint represents the net usage of ground and surface water and can be expressed as (Herath et al., 2013):

$$BWF = \frac{10(I-(D_i+R_i))}{Y_i} \qquad \text{(eq. 4)}$$

Where :
- 10 is for unit conversion
- I represents the amount of irrigation applied (mm/year)
- D_i represents drainage from the rootzone (mm/year)
- R_i represents surface runoff (mm/year)
- Y_i represents yield under irrigated conditions (Tonnes/ha/year)
- i refers to irrigated conditions

Note that if drainage and/or runoff occur, D_i and/or R_i result both from irrigation water and rainfall.

BWF calculations are particularly relevant to be considered in irrigated vineyards. A negative BWF calculated on an annual basis indicates a net backflow to the aquifer and/or surface water bodies (the sum of rainfall and irrigation is greater than evapotranspiration), meaning that irrigation in the given vineyard and year is sustainable. Conversely, a positive BWF indicates that more water is taken from the environment compared to the return flow, which in the long term is not sustainable. In dry-farmed vineyards, BWF is always negative or zéro, because no water is taken from aquifers or surface water bodies.

These equations can be simplified by considering that P_i, R_r and R_i are most often negligible. These assumptions are not always met for R_r in regions with heavy rainfall and/or in sloping vineyards and for Ri when flood irrigation is applied. These terms are, however, always very difficult to estimate.

To assess the applicability of the hydrological water footprint calculation, a preliminary test was conducted for rainfed and irrigated vineyards. These tests were performed using climate data from Bordeaux (Merignac Météo France weather station) and Roussillon (Sencrop private weather station, location 42,7109 latitude; 2,9695 longitude) as inputs of the grapevine soil water balance model from Lebon et al. (2003).

Applications of the hydrological method for water footprint calculations to a rainfed vineyard.

Bordeaux (France) served as an example of a rainfed vineyard for which a hypothetical analysis was performed using the vineyard water balance model of Lebon et al., 2003. Annual Green Water Footprint (GWF, Figure 3A), Annual Consumptive Green Water Footprint (CGWF, Figure 3B) and annual Blue Water Footprint (BWF, Figure 3C) were calculated for 24 years (2000-2023) with climate data of the Bordeaux-Mérignac weather station. Simulations were run for three levels of TTSW (100 mm, 200 mm and 300 mm) and three row spacings (Wide Spacing = 3 m ; Medium Spacing = 2 m ; High Density = 1 m). Yield was set to 6,000 kg/ha.

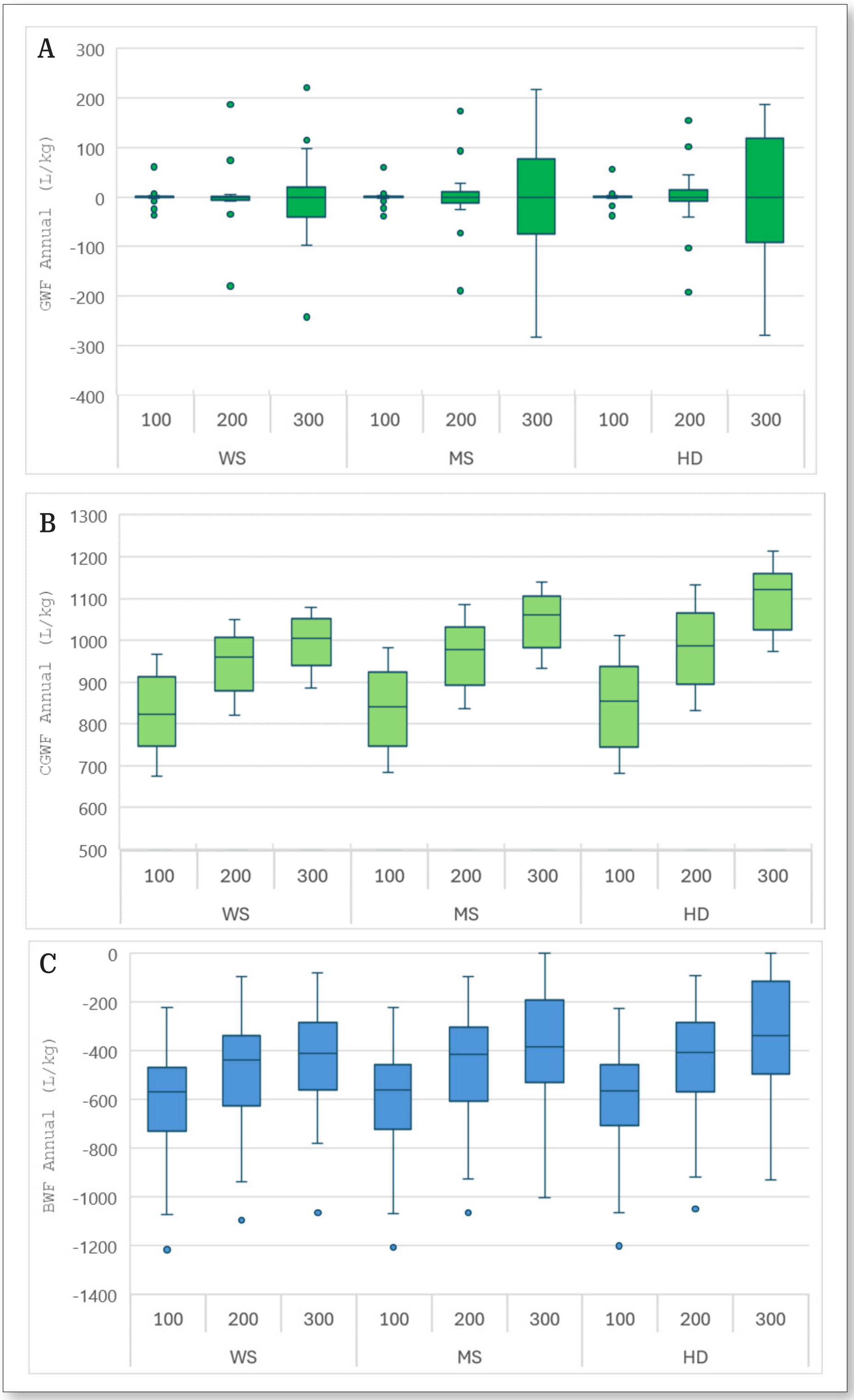

Figure 3. Annual Green Water footprint (A), annual Consumptive Green Water Footprint (B) and annual Blue Water Footprint (C) calculated with the hydrological water footprint method based on Herath et al., 2013 for Bordeaux from 2000-2023. Three levels of TTSW were considered (100, 200 and 300 mm). WS = wide spacing (3 m between the rows); MS = medium spacing (2 m); HD = high density (1 m). Yield was set at 6,000 kg/ha.

Although variable from year-to-year, average Green Water Footprint over multiple years is zero, because the water depleted from the soil during the growing season is refilled with winter rain (Figure 3A). Consumptive Green Water Footprint ranges from 676 L/kg (year = 2010, WS, TTWS = 100 mm) to 1213 L/kg (year = 2000, HD, TTSW = 300 mm), depending on the year, TTSW and row spacing (Figure 3B). Blue Water Footprint is zero or negative in all combinations of year, TTSW and row spacing. In a dry-farmed vineyard, the Blue Water Footprint represents drainage, ranging in these simulations from 0 L/kg (2017, MS and HD, TTSW = 300) to -1217 L/kg (2000, WS, TTSW = 100 mm).

Applications of the hydrological method for water footprint calculations to an irrigated vineyard.

A real irrigated vineyard located in the Roussillon region (France) served as an example for GWF, CGWF and BWF calculations. Because only three years of data were available, the results are presented as a table (Table 2).

Table 2. Annual Green Water Footprint (GWF), annual Consumptive Green Water Footprint (CGWF) and annual Blue Water Footprint (BWF) calculated with the hydrological water footprint method based on Herath et al., 2013 and Johnson and Mehrvar, 2021, for a vineyard in Roussillon (France) from 2021-2023. Row spacing = 2.5 m, TTSW = 105 mm. Yield = 5.6, 7.5 and 4.1 Tons/ha in 2021, 2022 and 2023, respectively.

Year	Rainfall (mm)	Irrigation (mm)	GWF (L/kg)	CGWF (L/kg)	BWF (L/kg)
2021	466	67	16	563	-37
2022	362	57	171	497	-108
2023	309	35	2	483	61
Average	379	53	**63**	**514**	**-28**

In this situation, average Green Water Footprint is not zero, because during dry winters TTSW is not always refilled. Consumptive Green Water Footprint ranges from 483 to 563 L/kg, according to the climatic conditions and yield of each year. Blue Water Footprint is sometimes negative (2021, 2022) and sometimes positive (2023). Negative BWF means outflows are superior to inflows resulting in net drainage when considered over the whole year. In the very dry year 2023, the inflow of blue water (irrigation) was higher than the outflow, so no drainage occurred.

Considerations about the application of water footprint calculations:

Although grapevines are a drought resistant crop species, their water footprint can be highly variable, depending on environmental conditions (rainfall, ET_0, TTSW), plant material (grape variety and rootstock) and management techniques (training system, vineyard floor management, irrigation or dry-farming). For sustainable wine production it is important to assess its water footprint with an easy-to-apply, universally accepted methodology, producing meaningful results in both dry-farmed and irrigated conditions This seems to be the case for the hydrological method with a limited number of input variables (daily climate data, TTSW, training system and canopy dimensions, irrigations schedule, yield). However, some potential issues still need to be resolved. The hydrological method can be applied at the plot level and considers that water is sourced locally, which is not always the case in irrigated areas. If water is taken from surface water bodies located at higher elevation, these can be unsustainably depleted, while aquifers and rivers in the irrigated agricultural areas can be replenished. Runoff from the soil surface is difficult to estimate but can be substantial in (1) flood irrigation, (2) climates with heavy rainfall events and (3) in sloping vineyards. Rainfall intercepted by the canopy was not considered here, but may not be negligible in regions with frequent, but small rainfall events. The grey water footprint cannot be easily taken into account in an internationally accepted water footprint calculation, because it depends on local water quality standards.

Conclusions:

Water is a major resource in wine grape production. Water scarcity impacts both yield and grape composition at harvest. Yield decreases with increasing water deficit, while grape quality potential increases, before decreasing when water deficit turns into severe stress. Global freshwater resources are increasingly limited in most winegrowing regions due to climate change. Hence, adequate management of vine water status is of utmost importance to reach yield and quality objectives in wine production, while minimizing impacts on water resources. Plant material (varieties and rootstocks) needs to be chosen in relation to local water availability. The training system is also an important consideration in adaptation to drought. Irrigation can then be considered when these other adaptations are not sufficient to produce high quality wines with economically sustainable yields, which is particularly the case when annual rainfall is below 350 mm. In irrigated vineyards, irrigation techniques and scheduling should be managed to reduce freshwater consumption as much as possible. Water footprint calculations produce metrics to assess and improve the efficiency of water management for sustainable wine grape production. No internationally accepted standard exists yet for water footprint calculations, but the hydrological method shows promise for application in both dry-farmed and irrigated vineyards with the aim of better assessing sustainable water use in wine grape production.

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NOV 20, 2024 | 9.30 AM | SCIENTIFIC SESSION: **PLANT MATERIAL AND MANAGEMENT III - SCIENTIFIC ORAL**

Drivers of grape berry sugar accumulation in field conditions at local scale

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Keywords: **grapevine, grape ripening, temperature, berry development, *Vitis vinifera L.* cv. Merlot, climate change, water status.**

ABSTRACT

The final sugar concentration in grapes is an important parameter for winegrowers as it determines the alcohol content by volume of the final wine, allowing to optimize the timing of harvest. In this research, a comprehensive dataset spanning seven years and 18 sites located in Saint-Emilion, Pomerol and satellite appellations (Bordeaux, France) was used to assess how growth and developmental factors (berry weight and mid-veraison date, respectively) and environmental factors (vine water status, nitrogen status, and mean air temperature) influence the dynamics of sugar accumulation.

The results of this study highlighted the strong influence of mean temperature on the timing of maximum sugar accumulation, the duration of sugar accumulation and maximum sugar concentration in grape berries. Berry weight and the rate of sugar accumulation also appeared to be significant drivers of final sugar concentration. Fast ripening and increased berry weight were associated with lower sugar concentrations. Sites were clustered according to parameters driving sugar accumulation dynamics and mapped at the scale of the study area, in order to link these findings to terroir expression. In this study, vine nitrogen status did not emerge as a significant explanatory variable in any of the models developed to analyse sugar accumulation dynamics and berry weight, and a small but significant effect of vine water status on the precocity of the plateau and on berry weight was found.

These results provide a better understanding of the factors that affect the dynamics of sugar accumulation in grape berries, which can help vine growers to adapt to climate change. For example, by promoting practices to delay the onset of ripening to shift to a cooler period of ripening through the choice of plant material or management practices. Alternatively, this can be done through an increase in berry weight, which lowers grape sugar and therefore wine alcohol concentration, taking care not to alter the skin-pulp ratio excessively to avoid reducing secondary metabolites.

NOV 20, 2024 | 9.45 AM | SCIENTIFIC SESSION: **PLANT MATERIAL AND MANAGEMENT III - SCIENTIFIC ORAL**

Exploring grapevine canopy management: insights from a six-year field trial in Switzerland

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Keywords: **pre-flowering defoliation, intensity, 3-mercaptohexanol, wine aroma**

ABSTRACT

A six-year field trial studied the physiological response of the Swiss white cultivar *Vitis vinifera* Arvine, rich in varietal thiols and precursors, to canopy management, i.e. removing either main leaves or lateral shoots or both from the cluster area. Four treatments were set up in a randomized block design to assess the impacts of removing either 1) only laterals, 2) laterals + 50% main leaves, 3) laterals + 100% main leaves, or 4) only main leaves from the cluster area. All lateral and leaf removals were performed at pre-flowering stage.

Intensive pre-flowering LR of both lateral shoots + 100% main leaves from the cluster area severely reduced the yield potential (−47% on average) and tended to reduce the concentration of 3-mercaptohexanol precursors (3MH-Cys) in the must (−21%; p-value < 0.10). The impact of LR was modulated by removing less main leaves. When compared one-to-one with removing only the lateral shoots, removing only main leaves induced the growth of a larger leaf area (+13 %) due to the development of lateral shoots; it also induced a lower chlorophyll index, a lower number of berries per cluster (−11 %) and a lower yield potential (−12 %); in the must at harvest, there were higher concentrations of soluble sugars, malic acid (+12 %), yeast-assimilable nitrogen and glutathione (+8 %), without affecting the concentrations of 3MH-Cys; in terms of wine tasting, removing main leaves induced negligible differences in terms of color intensity and vegetal aromas.

Observing the long-term impact of each LR treatment separately provided insights into the physiological mechanisms influencing fruit development and aroma formation, pointing out the interests and risks of pre-flowering LR. This trial is part of an extended project on grapevine canopy management and its impact on grape composition in temperate Swiss climatic conditions.

Introduction:

Leaf removal (LR) is a common practice in viticulture to limit fungal attacks and improve grape maturation. The impact of LR is a combination of effects associated with both the loss of important source leaves proximal to the clusters and the modification of the microclimate in the cluster area (Martin et al. 2016). When applied before flowering, LR impacts the berry set and strongly affects the yield at harvest (VanderWeide et al. 2020). It may also affect grape composition and wine sensory in terms of soluble sugars, acids and polyphenols (Poni et al. 2009). Previous researches have shown the importance of LR timing, which is related to regional climatic conditions and should depend on the objective of the viticulturist (Alem et al. 2018). Moreover, lateral shoots do not always grow sufficiently before flowering to be removed easily. In practice, this would mean several passes in the case of pre-flowering LR, unless removal of the main leaves is considered sufficient. A six-year field trial studied the physiological response of the Swiss white cultivar *Vitis vinifera* Arvine, rich in varietal thiols and precursors, to canopy management, i.e. removing either main leaves or laterals or both from the cluster area.

Materials and methods:
The trial was carried on in the experimental vineyards of Agroscope in Leytron, Switzerland, from 2016 to 2021. The cultivar Arvine was grafted onto rootstock 3309C, planted in 2011 at a density of 6180 vines/ha and pruned in a single Guyot system. The canopy was trimmed to 110 cm in height. Four treatments of 18 plants each were replicated four times in a randomized block design to assess the impacts of removing either A) only laterals, B) laterals + 50% main leaves, C) laterals + 100% main leaves, or D) only main leaves from the cluster area. All lateral and leaf removals were carried out at the 'separated floral buds' phenological stage (BBCH 57, Lancashire et al., 1991) and consisted of manual removal of either the first six main leaves, laterals or both (depending on the treatment) from the base of each shoot.

Field measurements were made per replicate, except for leaf mineral composition which was assessed once per treatment. Bud fertility was estimated (average number of clusters per shoot). Potential yield was estimated in July (before cluster thinning). Cluster thinning was carried out per treatment to achieve 11 t/ha at harvest, in line with regional practice. Average berry weight was determined from 100 berries collected one week before harvest. Cluster weight was estimated from the yield per vine divided by the average number of grapes previously assessed. Pruning weight, an indicator of plant vigour, was assessed in winter by removing 10 shoots from the penultimate position on the cane; the shoots were then equalised to one metre in length and weighed. Leaf mineral composition (N, P, K, Ca and Mg) was assessed at veraison. Must composition was assessed at harvest: total soluble sugars (TSS), titratable acidity, tartaric and malic acids and pH. Further analyses were performed once per treatment: total phenolic concentration (Folin index), ammonium and free alpha amino acids, total glutathione concentration. Wines were made per treatment and were analysed to assess the concentrations of glycerol, proline and succinic acid. The chromatic characteristics of the wines were described according to the CIELab method. A sensory analysis was carried out each year.

The data were statistically described as a randomised complete block design, with leaf removal treatment (four levels) as a fixed factor and year (five levels) and replicate (four levels) as random factors. Tukey's post hoc test was used for multiple comparisons.

Results and discussion:
Table 1 summarizes the observations and analyses performed on grapevines, musts and wines as a function of the canopy removal treatments.

1. About the intensity of pre-flowering LR (comparison treatments A, B and C)
Pre-flowering LR had a huge impact on the agronomic performance of the vines and essentially affected the berry set and the yield: compared to the removal of only laterals (A), which is the standard in the region, the removal of laterals + 100% leaves (C) in the cluster area resulted in an average yield loss of 37% over the period 2017-2021 (Figure 1). Treatment C resulted in a lower leaf chlorophyll index and a higher leaf to fruit ratio. It had an overall negligible effect on must composition, in particular +8% in tartaric acid, and no effect on grape nitrogen content in comparison to treatment A. No consistent effects on wines were observed, except for a slight increase in Folin index and colour intensity. Treatment C tended to reduce aroma precursors (3MH-Cys) from 21.0 to 16.6 µg/L (not significant), with no effect on wine aromas, in comparison with treatment A. Reducing LR intensity (treatment B, 50% main leaves) allowed to modulate the effect on yield, in line with the results of Verdenal et al. (2019) on five other cultivars in Switzerland. While pre-flowering LR represents an interesting tool to regulate the yield, the interaction of the climate in Switzerland may also affect the berry set and make it difficult to predict both the yield at harvest and the effect on grape composition. The 82% yield loss in 2016 was extremely high due to the exceptionally cold and cloudy conditions during flowering that year, which induced poor conditions for berry set (data not shown). Thus, in view of both the risk of not reaching the production target and the limited impact on white wine composition, we don't recommend a too intensive LR (i.e. more than 50% LR in the cluster area) due to its unpredictable berry-set rate related to the climate condition at flowering in the same year.

2. About removing either main leaves or laterals from the cluster area (comparison treatments A and D)
Compared to the removal of only the lateral shoots (A), the removal of the main leaves only (D) resulted in a larger leaf exposed area (+15%), a lower chlorophyll index (-3%) and a lower yield potential (-14%), mainly due to fewer berries per bunch (-11%); the musts were more acidic, mainly due to more malic acid (+14%), and contained more yeast-assimilable nitrogen (+10%) and glutathione (+11%). There was no trend for soluble sugars, 3MH-Cys or Folin index. The differences in wine composition were negligible: treatment D resulted in slightly more colour intensity and less vegetable aromas than in treatment A. There was no fungal attack during the six years on the trial. In this context, removing only the main leaves seems to be an interesting low-risk practice with a moderate effect on both the yield potential and the grape composition.

Conclusion:
The trial confirmed the strong impact of pre-flowering LR of the cluster area on the berry-set rate and the yield at harvest. Intensive LR is not recommended due to its negligible impact on wine composition and its unpredictable impact of berry set related to the climate condition at flowering in the same year. Observing the separated effects of removing the main leaves or lateral shoots over six years is an essential stepping stone to unravelling the physiological mechanisms that influence fruit development and aroma formation. Removing only the main leaves seems to be an interesting practice with a moderate effect on both the yield potential and the grape composition. This trial is part of an extended project on grapevine canopy management and its impact on grape composition in temperate Swiss climatic conditions.

Table 1. Vineyard observation, grape must analyses and wine analyses, per year and per canopy removal treatment. Cultivar Arvine, Leytron, Switzerland. Numbers with different letters are statistically different (Tukey's test, p < 0.05).
***** p < 0.001; ** p < 0.01; * p < 0.05; · p < 0.10; n.s., non-significant.**

	Observations	Canopy removal treatment in the cluster area: A. Only laterals	B. laterals + 50% leaves	C. laterals + 100% leaves	D. Only 100% leaves	*p*-value	Interaction year × canopy treatment
Vineyard observations	Bud fruitfulness (clusters per shoot)	1.7	1.7	1.7	1.7	n.s.	n.s.
	Leaf nitrogen (% dry mass)	2.5	2.5	2.6	2.5	n.s.	—
	Leaf phosphorus (% dry mass)	0.2	0.2	0.2	0.2	n.s.	—
	Leaf potassium (% dry mass)	1.6	1.4	1.6	1.7	·	—
	Leaf calcium (% dry mass)	3.4	3.2	3.3	3.1	n.s.	—
	Leaf magnesium (% dry mass)	0.3	0.3	0.3	0.3	n.s.	—
	Chlorophyll index mid-June	495 a	486 a	461 b	463 b	***	*
	Chlorophyll index mid-July	531 a	525 ab	516 bc	513 c	***	n.s.
	Chlorophyll index mid-August	534 a	532 ab	528 ab	516 b	*	n.s.
	Chlorophyll index mid-September	525	533	522	514	n.s.	n.s.
	Light-exposed leaf area (m^2/m^2 of ground)	1.2 b	1.2 b	1.1 c	1.3 a	***	***
	Early estimated yield (kg/m^2)	1.7 a	1.3 b	0.9 c	1.5 b	***	*
	Cluster thinning (number removed per vine)	3.3 a	1.7 b	0.3 c	2.3 b	***	***
	Berry weight at harvest (g)	1.2 ab	1.1 c	1.1 bc	1.2 a	**	**
	Number of berries par cluster	228 a	205 a	160 b	203 a	***	n.s.
	Cluster weight at harvest (g)	221 a	184 b	155 c	200 ab	***	***
	Yield at harvest (kg/m^2)	1.1	1.0	0.9	1.0	n.s.	***
	Leaf-to-fruit ratio (m^2/kg)	1.2	1.4	1.9	1.5	·	**
	Pruning weight (g/m)	48	45	44	45	n.s.	n.s.
Grape must analyses	Total soluble sugars (Brix)	23.8 ab	23.6 ab	23.5 b	24.1 a	*	n.s.
	pH	3.03	3.03	3.01	3.03	·	n.s.
	Titratable acidity (g tartrate/L)	10.9 b	11.1 ab	11.1 ab	11.3 a	*	n.s.
	Tartaric acid (g/L)	9.1 b	9.3 b	9.7 a	8.8 c	***	***
	Malic acid (g/L)	4.2 b	4.2 b	4.0 b	4.7 a	***	n.s.
	Ammonium (mg/L)	156	152	151	155	n.s.	—
	Alpha amino N (mg N/L)	96 ab	93 b	99 ab	107 a	*	—
	Yeast assimilable nitrogen (mg N/L)	224 ab	218 b	223 ab	235 a	**	—
	Folin index must	11.5 ab	12.0 ab	12.7 a	11.0 b	*	—
	Total glutathione (mg/L)	53 b	52 b	51 b	59 a	***	—
	3MH-Cys (µg/L)	21.0	19.7	16.6	21.7	n.s.	—
Wine analyses	Glycérol (g/L)	8.4	8.6	8.7	8.5	n.s.	—
	Succinic acid (g/L)	0.7	0.8	0.8	0.7	·	—
	Proline (mg/L)	108 ab	104 ab	94 b	115 a	*	—
	Folin index wine	6.2 ab	6.5 a	6.6 a	5.9 b	*	—
	Lighness L	99	99	99	99	n.s.	—
	Color a (red/green)	-0.9	-0.9	-0.9	-0.9	n.s.	—
	Color b (yellow/blue)	4.8 a	5.2 a	5.2 a	4.8 a	*	—
	Color intensity	4.0 b	4.1 a	4.1 ab	4.1 ab	*	—
	Fruitiness	4.4	4.4	4.3	4.4	n.s.	—
	Floral	2.6	2.7	2.7	2.7	n.s.	—
	Herbaceous	1.8	1.7	1.7	1.6	n.s.	—
	Lactic	1.2	1.2	1.2	1.2	n.s.	—
	Global nose impression	4.3	4.3	4.3	4.4	n.s.	—
	Volume	4.6	4.5	4.4	4.6	n.s.	—
	Acidity	4.5	4.6	4.6	4.5	n.s.	—
	Bitterness	2.4	2.5	2.5	2.2	n.s.	—
	General impression	4.2	4.2	4.1	4.3	n.s.	—

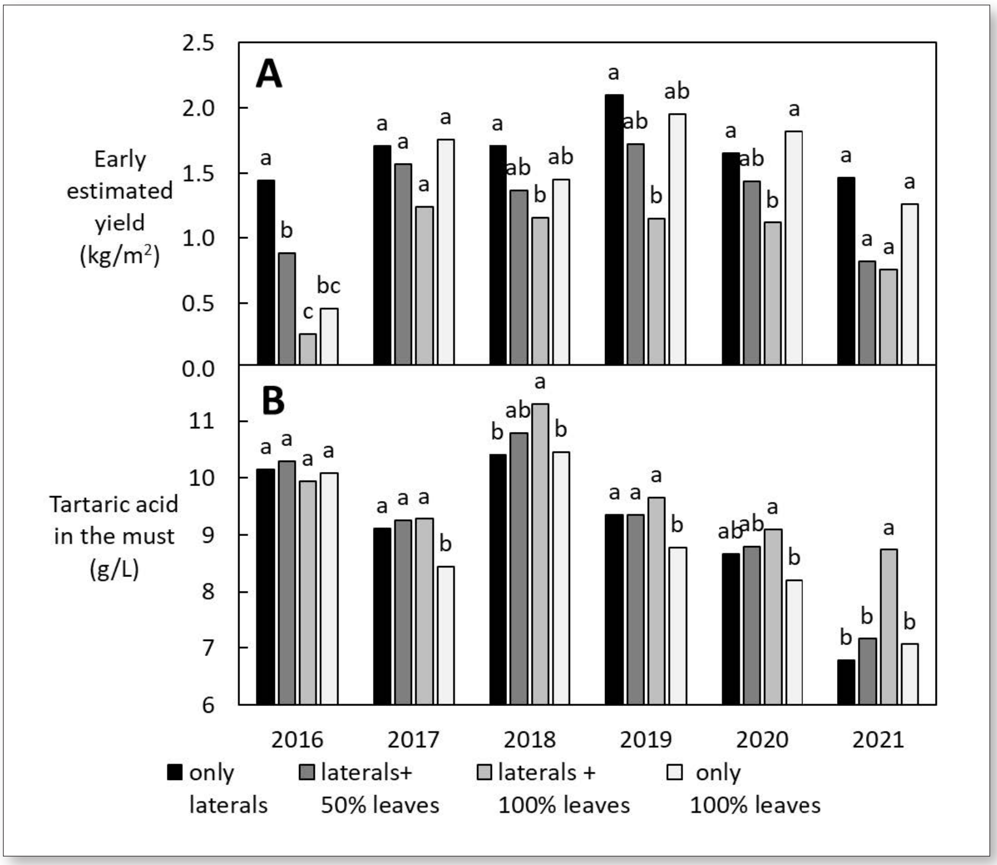

Figure 1. Estimated yield before cluster closure (A) and tartaric acid in the must at harvest (B) as a function of canopy removal treatment. Cultivar Arvine, Leytron, Switzerland.

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NOV 20, 2024 | 10 AM | SCIENTIFIC SESSION: **PLANT MATERIAL AND MANAGEMENT III - FLASH ORAL**

How Geographical Indications and clones shift the phenolic and sensory profiles of Cabernet Sauvignon wines from Mendoza? A three year inspection

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Keywords: **descriptive sensory analysis, geographical origin, polyphenols, terroir, *Vitis vinifera L.***

ABSTRACT

The phenolic composition and sensory characteristics of Cabernet Sauvignon wines from two clones and four geographical indications (GI) of Mendoza, Argentina were evaluated during three vintages. The vines were clones of Mount Eden and Clone 7 planted in Agrelo, Pampa El Cepillo, Altamira and Gualtallary, in an altitudinal range of 950 to 1,500 m asl. The wines were made under standardized winemaking conditions during the 2018, 2019 and 2022 vintages.

The evaluated climate characteristics for each season were associated with the chemical/sensory parameters, i.e. altitude was an influencing factor associated with higher phenolic contents. Chemometric tools and integrative analysis allowed the discrimination of wines according to different GIs and seasons. Certain phenolic compounds were associated with years, GIs and/or clones (with significant interactions). Astilbin and (-)-epigallocatechin gallate (tannin monomer) were associated with Agrelo, while p-coumaric acid and caffeic acid increased in Pampa El Cepillo and Altamira. Dihydroxylated anthocyanins, quercetin, and trans-resveratrol, all linked to increased antioxidant capacity, were associated with Gualtallary.

The sensory descriptors also discriminated by GIs, with Agrelo wines being associated with astringency and those from Gualtallary with chocolate and sweet profile on the palate.

The clones had a lower degree of significance compared to that of the GIs, however certain interactions were ob served between some clones and GIs in particular. The vintage influenced both, the phenolic and sensory profiles of wines, allowing their classification and highlighting the characteristics of the terroir and year of production.

These results allow individualization throughout the three harvests, contributing to better communication with consumers and the positioning of Argentinean wines, in close relationship with the characteristics of the terroir of the wines.

NOV 20, 2024 | 10.05 AM | SCIENTIFIC SESSION: PLANT MATERIAL AND MANAGEMENT III - FLASH ORAL

Fungicide resistance, vineyards, and indigenous yeast: revisiting a core concept with a fresh perspective

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Keywords: **fungicide resistance, yeast, disease management, vineyard.**

ABSTRACT

Vineyard disease management is a critical viticultural practice that protects both grape yield and quality. However, the repeated use of fungicides has led to the emergence of resistance in pathogenic fungi, the main target of these treatments. This approach has also unintentionally affected beneficial yeast and fungi in vineyards, compromising their health and the overall vineyard ecosystem. As some of these beneficial organisms play a role in biocontrol and have other beneficial characteristics for winemaking, it's important to understand their resistance to fungicides when developing disease management strategies. Our hypothesis was that fungal isolates from vineyards would exhibit greater resistance to fungicides regularly used in those vineyards. Specifically, we expected that fungi from grapes treated with synthetic fungicides would be more resistant to synthetic fungicides than those from organic grapes and vice versa.

To investigate how commercial fungicides affect autochthonous fungi including non-*Saccharomyces* yeast 65 isolates were recovered from 'biodynamically' and 'conventionally' sprayed grapes and their uninoculated fermentations. These 65 isolates and 5 commercial reference strains were tested against a range of 'organic' (copper sulfate, copper oxychloride + sulfur, sulfur) and 'conventional' (spiroxamine and penconazole) fungicides to investigate if isolates exhibited greater resistance to the fungicides associated with the management practices from which they were isolated. Results showed that copper sulfate and copper oxychloride + sulfur had the most detrimental effects on yeast and fungal survival, showing no significant differences in resistance between isolates from 'biodynamic' and 'conventional' practices. These findings emphasise the importance of holistic vineyard management that considers the diverse microbial communities within the vineyard ecosystem.

NOV 20, 2024 | 11 AM | SCIENTIFIC SESSION: **PLANT MATERIAL AND MANAGEMENT IV - SCIENTIFIC ORAL**

Physiological and biochemical responses of grapevine varieties to Mediterranean summer stress: basis for sustainable long-term adaptation measures

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Keywords: ***Vitis vinifera;*** **photosynthesis; photosynthetic pigments; antioxidants; summer stress.**

ABSTRACT

In regions prone to climate change, such as those with a Mediterranean climate, viticulture's suitability for high-quality wine production is expected to decline. Assessing the different varieties' adaptability in specific terroirs offers valuable insights for informed decisions in variety selection and vineyard management. This study aimed to evaluate the physiological and biochemical traits of typical Douro Region grapevine varieties —Aragonez (AR), Touriga Nacional (TN), and the less-used Tinto Cão (TC)—and understand how these traits can contribute to their resilience to Mediterranean conditions. The experiment was conducted in the Portuguese Demarcated Douro Region. The plants were studied during the veraison and maturation stages. The grapevine varieties exhibited distinct strategies. AR displayed a superior ability to maintain stomata open, efficient photosynthetic responses, and high photosynthetic pigment concentration. TC and TN had similar photosynthetic rates, but TC displayed decreased photochemical efficiency, potentially attributed to its lower investment in photosynthetic pigments as a defence against excessive sunlight. Despite this, TC exhibited superior stem water potential, soluble sugars accumulation in leaves and greater antioxidant responses during veraison. Thus, the overlooked TC variety holds promise as a viable option for viticulture in environments increasingly impacted by climate change.

Introduction:
Grapevine (*Vitis vinifera* L.) is a typical crop of the Mediterranean region, and specifically of Portugal, where has a great socioeconomic and cultural relevance. The Douro Demarcated Region (DDR), located in the northeast of Portugal and recognized in 2001 by UNESCO as World Heritage, is one of the most iconic wine regions in the world. High temperatures, irradiances and water scarcity are well-known stress factors that severely limit grapevine

productivity in Douro, a Region highly susceptible to climate change (IPCC, 2023). At a physiological level, those stressful conditions can impose negative impacts on grapevine behaviour, such as reduced growth and leaf area, modifications in water status, declines in photosynthetic activity due to stomatal and non-stomatal limitations and changes in the source-to-sink relationships and oxidative stress (Moutinho-Pereira et al., 2007; Dinis et al., 2014; Zamorano et al., 2021).

Grapevine varieties have adapted over time to survive and thrive in the specific climates where they originated. This adaptation involves the development of protective mechanisms tailored to the environmental conditions of their native habitats. By studying the intrinsic traits of grapevine varieties, such as their physiological characteristics, researchers can gain insights into their resilience to various environmental stresses. This comprehensive understanding allows for the identification of lesser-known grape varieties that possess unique adaptations and may exhibit remarkable resilience to current and future climatic challenges (Bota et al., 2016; Florez-Sarasa et al., 2020; Mendoza et al., 2022). By cultivating and promoting these varieties, farmers can diversify their crop portfolios and reduce the vineyards' vulnerability to extreme weather events or shifting climatic patterns, contribute to the preservation of biodiversity in vineyard ecosystems and support the long-term sustainability of the wine industry.

The DDR embraces a great diversity of grapevine varieties, recognized for their viticultural and oenological qualities (IVV, 2022). Aragonez (AR, syn. Tinta Roriz, Tempranillo) and Touriga Nacional (TN) are among the most representative varieties, with AR constituting around 16.4% of the vines and TN about 10.6% (IVV, 2022). However, lesser-known varieties can show impressive resilience to the region's typical climate conditions. Tinto-Cão (TC) is a prime example, despite its smaller expression (<1%) (IVV, 2022). Known for its ability to withstand harsh environmental factors such as intense sunlight, high temperatures, and water scarcity, TC also thrives in infertile soils. Its berries, with thick skins, yield high-quality wines with distinct characteristics, making it particularly suitable for Port Wine production. However, TC can have more variable yields than the most representative varieties (Moutinho-Pereira et al., 2007; Magalhães, 2015).

The objective of this study was to assess the plant physiological and biochemical traits associated with grapevine varieties, particularly AR, TN, and TC, and understand how these traits can contribute to their resilience to Mediterranean conditions. Specifically, we aimed to investigate whether and how these varieties exhibit adaptations that enable them to thrive in environments characterized by high temperatures, irradiances, and water scarcity. We also aim to determine if the lesser-used variety Tinto Cão holds promise as a viable option for viticulture in environments increasingly affected by climate change.

Materials and methods:

The research was carried out in 2019, in Peso da Régua (41°10'35.80''N; 7°47'48.00''W), Baixo Corgo sub-region of DDR, Portugal. The climate is typically Mediterranean with mild rainy winters and long, hot and dry summers. Three *Vitis vinifera* L. varieties, grafted onto the 1103P rootstock, were studied: Touriga-Nacional (TN), Aragonez (AR) and Tinto-Cão (TC). At the beginning of the experiment, from 20 twelve-year-old plants per variety were marked three groups, each containing 5 uniform plants, distributed along the row to perform the analysis. All the different measurements were performed on two different days, at veraison (E-L36) and maturation (E-L38) stages, according to the modified Eichhorn-Lorenz (E-L) system (Coombe, 2004). The experimental and growth conditions can be seen in more detail in Brito et al. (2024).

Stem water potential (Ψ_{stem}) was determined with a pressure chamber (Model 1000, PMS Instrument Company, Albany, USA) after the selected leaves were placed inside reflective and airtight bags for 1:30 hours, to promote stomatal closure and establish equilibrium between the leaf and the stem water potential. Modulated Chlorophyll *a* fluorescence and leaf gas exchange were obtained *in situ* at midday (14:00–15:30 h, local time). For modulated Chlorophyll *a* fluorescence evaluation was used a Pulse Amplitude Modulation Fluorometer (mini-PAM, Photosynthesis Yield Analyzer; Walz, Effeltrich, Germany). The parameters effective quantum efficiency of PSII ($\Phi_{PSII}= \Delta F/F'_m= (F'_m - F_s)/F'_m$ and non-photochemical quenching ($NPQ = (F_m - F'_m)/F'_m$) were determined. The leaf gas exchange was measured with an infrared gas analyser (*LC pro+*, *ADC Bioscientific Ltd*., UK), operating in the open mode. The parameters net CO_2 assimilation rate (A) and stomatal conductance (g_s) were then calculated. These three methodologies are fully described in Brito et al. (2024).

The leaf photosynthetic pigments, total chlorophyll (Chl) and carotenoids were extracted with 80% acetone, the extracts were analysed by a spectrophotometer and determined according to the formulas of Šesták et al. (1971) and Lichtenthaler (1987), respectively. Soluble sugars were extracted by heating leaf samples in 80% ethanol and quantified according to the Anthrone method of Irigoyen et al. (1992) and expressed as mg of glucose g^{-1} of dry weight (DW). Total phenolic compounds concentration and total antioxidant activity were obtained using leaf extracts in 70% methanol. Total phenols were determined according to the Folin-Ciocalteu's procedure (Singleton and Rossi, 1965) and expressed as mg gallic acid equivalents per gram of extract (mg GAE g^{-1} DW). The antioxidant activity was evaluated by the radical scavenging activity on ABTS radical and expressed as mg of Trolox equivalents per gram of extract (mg TE g^{-1} DW) (Rodrigues et al., 2015).

Statistical analysis was performed using the IBM® SPSS® Statistics program (v. 26). After testing for ANOVA assumptions (homogeneity of variances with the Levene's mean test, and normality with the Kolmogorov-Smirnov test), data were submitted to one-way analysis of variance (ANOVA). Means were separated with the Tukey's post-hoc test at 5 % level.

Results and discussion:

Among the varieties studied, TC exhibited the highest Ψ_{stem}, although this was only statistically significant compared to TN (Figure 1). Additionally, while AR displayed higher g_s, leading to increased water loss, TN and TC exhibited similar g_s values (Figure 2), indicating that TC prioritizes a water conservation strategy during dry periods. Consistent with the lower g_s, both TN and TC showed lower A compared to AR (Figure 2), suggesting that stomatal limitations are influencing their photosynthetic responses. As the stress conditions intensified during the maturation stage, non-stomatal limitations also contributed to the reduced A in both TC and TN. However, these non-stomatal limitations were more pronounced in TC than in TN, as evidenced by the reduced ΦPSII and the increased NPQ (Figure 2), indicating superior photoprotection through thermal dissipation (Baker et al., 2008).

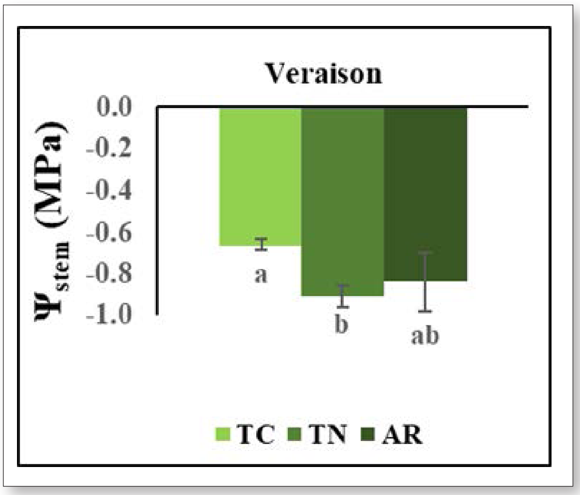

Figure 1. Stem water potential (Ψstem) in Tinto-Cão (TC), Touriga-Nacional (TN) and Aragonez (AR) grapevine varieties at veraison. Means ± S.D. followed by the same letter are not statistically different.

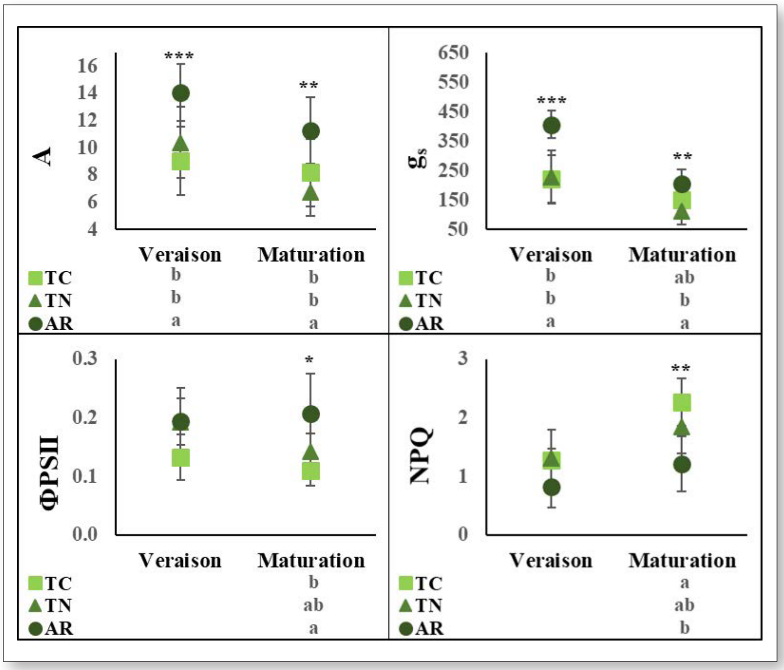

Figure 2. Net CO_2 assimilation rate (A, µmol m^{-2} s^{-1}) stomatal conductance (gs, mmol m-2 s-1), effective quantum efficiency of photosystem II (ΦPSII) and non-photochemical fluorescence quenching (NPQ) in Tinto-Cão (TC), Touriga-Nacional (TN) and Aragonez (AR) grapevine varieties at veraison and maturation. Means ± S.D. followed by the same letter are not statistically different.

Photosynthetic pigments play a crucial role as physiological indicators of grapevine photosynthesis and photoprotection. Consistent with its superior photosynthetic performance, the AR variety consistently exhibited the highest levels of total chlorophyll and carotenoid contents (Table 1). Chlorophylls are primarily involved in light harvesting, while carotenoids, besides their role in energy dissipation, can also serve as accessory pigments, absorbing light in different spectral regions and transferring excitation energy to chlorophyll molecules to enhance photosynthesis (Taiz and Zeiger, 2006). In contrast, the TC variety appeared to adopt a different strategy, with leaves exhibiting lower levels of photosynthetic pigments, resulting in a lighter green colouration and consequently higher light reflectance capacity (Moutinho-Pereira et al., 2007). Despite this, TC maintained similar photosynthetic rates to TN. This reduction in photosynthetic pigment concentrations in grapevine leaves under drought, heat, and high irradiance conditions is a common adaptive response to mitigate excessive sunlight absorption and minimise the generation of reactive oxygen species (Moutinho-Pereira et al., 2007; Dinis et al., 2014). This adaptive strategy is particularly important in sun-exposed environments and under other adverse stressful conditions.

Table 1. Leaf chlorophyll (Chl), carotenoid, soluble sugars and total phenols contents (mg g^{-1} DW) and antioxidant activity (mg g^{-1} DW) of Tinto Cão (TC), Touriga Nacional (TN) and Aragonez (AR) varieties in Veraison and Maturation.

Means ± S.D. followed by the same letter are not statistically different.

	Chl *total*	Carotenoids	Soluble Sugars	Total phenols	Antioxidant activity
Veraison					
TC	2.21 ± 0.121 c	0.589 ± 0.960 b	39.2 ± 3.83 a	36.9 ± 1.41 a	37.8 ± 0.46 a
TN	2.86 ± 0.386 b	0.647 ± 0.060 b	17.3 ± 1.65 c	27.9 ± 2.37 c	35.0 ± 1.41 b
AR	3.63 ± 0.339 a	0.821 ± 0.077a	28.9 ± 1.78 b	30.8 ± 1.25 b	35.7 ± 0.71 ab
Maturation					
TC	2.17 ± 0.224 c	0.445 ± 0.058 b	23.0 ± 1.81	22.4 ± 1.34 c	29.0 ± 1.49 b
TN	2.68 ± 0.202 b	0.662 ± 0.056 a	20.6 ± 2.20	25.9 ± 1.78 b	35.0 ± 0.50 a
AR	3.33 ± 0.399 a	0.809 ± 0.116 a	22.9 ± 2.19	31.8 ± 2.48 a	35.1 ± 1.33 a

Despite the reduced photosynthetic rate of TC, this variety exhibited significantly higher sugar accumulation in leaves at veraison (Table 1), suggesting that TC prioritizes carbohydrate storage up to that stage. This accumulation may repress photosynthesis through feedback regulation to optimise the plant's carbon-to-nitrogen balance (Paul and Foyer, 2001). This response is also a defensive mechanism in the TC variety, aimed at maintaining leaf turgor under challenging environmental conditions (Boussadia et al., 2013; Gerson et al., 2020). In contrast, TN and AR varieties displayed different behaviour, exhibiting lower soluble sugar levels until veraison. Although TC and TN displayed comparable rates of photosynthesis, TN appeared to prioritize sugar transport to sink organs, such as berries, potentially compromising sugar retention within leaves during veraison. Environmental stresses can induce variable effects on the production of phenolic compounds within cells. These compounds boost multifaceted properties, including the neutralization of reactive oxygen species, formation of bonds with metallic elements, and augmentation of oxidative enzyme activity (Elavarthi and Martin, 2010). Notably, the TC variety displayed elevated levels of leaf phenolic compounds compared to the other varieties at veraison (Table 1), suggesting an adaptive response to unfavourable environmental conditions. Alongside, secondary metabolic products act as antioxidants, with TC leaves also showing higher antioxidant activity during this stage (Table 1). However, the necessity to export photoassimilates to sink organs during the maturation stage likely compromises the TC investment in accumulating leaf phenolic compounds at that stage.

Conclusion:

Distinct strategies were adopted by the different grapevine varieties in response to the Mediterranean summer adverse conditions. AR stood out for its ability to keep stomata open and maintain efficient photosynthesis during harsh summer conditions. This can be due partly to its higher concentration of photosynthetic pigments and superior antioxidant response during maturation. TC and TN had similar photosynthetic rates, but TC displayed a tendency towards reduced photochemical efficiency. TC invested less in photosynthetic pigments, possibly as a defence against excessive sunlight, yet exhibited superior water status and mechanisms to maintain cell turgor. TC also showed superior antioxidant responses during veraison. The overlooked TC variety holds promise as a viable option for viticulture in environments increasingly impacted by climate change. Assessing these varieties' adaptability in specific terroirs like Baixo-Corgo in the DDR provides valuable insights for vine growers and winemakers, aiding informed decisions in variety selection and vineyard management.

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NOV 20, 2024 | 11.30 AM | SCIENTIFIC SESSION: **PLANT MATERIAL AND MANAGEMENT IV - SCIENTIFIC ORAL**

Assessment of different formulations of Kaolin+Silicon foliar application in *Vitis vinifera* under summer stress

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Keywords: **climate change, short-term strategies, physiology, biochemistry, fruit quality.**

ABSTRACT

Viticulture and winemaking offer numerous social, economic, and environmental benefits, such as boosting rural incomes, creating jobs, and promoting tourism. However, sustainable grape production is vital, yet threatened by climate change. Temperatures above 35°C during growth can harm leaf photosynthesis, berry metabolism, and wine quality. Such effects are exacerbated when coupled with water deficits. Kaolin, an inert white clay mineral composed of $Al_2Si_2O_5(OH)_4$ possesses the ability to reflect harmful ultraviolet and infrared radiation to a greater extent than photosynthetically active radiation. Furthermore, silicon can be applied as a protective measure for leaves, either as a biofilm, nutrient supplement, or biostimulant. This approach aids plants in maintaining equilibrium, promoting growth, and fostering development even in the face of (a)biotic stressors. The present study, carried out in 2023 in the Douro Region, investigates the principal effects of different combinations of kaolin particle film (Kl at 2%) and silicon (Si at 2, 4 and 6%) (MiKS) on red 'Touriga Franca cv., namely on some physiological parameters and fruit quality attributes. Effectively, MiKS 2 increased water use efficiency and leaf phenols content and MiKS 3 increase the content of leaf flavonoids, *ortho*-diphenols, and sugars in the veraison stage. Regarding to fruit attributes, MiKS 3 increase the phenols, flavonoids, *ortho*-diphenols and tannins and MiKS 1 the total anthocyanins. This preliminary study indicates that the application of MiKS in early summer can be an operational tool to improve water use efficiency and increase some protector metabolites in leaf tissue that improve some grape composition parameters.

Introduction:
It is known that warmer and dryer climate conditions will challenge Portuguese viti-

culture, negatively impacting the economy, particularly for renowned winemaking regions such as the Douro Demarcated Region (Fraga et al., 2014). A reshaping of the main Portuguese winemaking regions is likely to occur in the upcoming decades. Therefore, it is essential to emphasize the need for the appropriate cultural practices to adapt to climate changes to maintain the typicity and wine styles. Several of our studies revealed that grapevine physiological, agronomic and genetic attributes were modified by particular microclimate conditions (Carvalho et al., 2018; Dinis et al., 2018), primarily by low water availability and high light/temperature levels. Severe summer stress negatively affects the vineyards due to the impacts on phenology, physiology, and cellular and molecular biology. Summer abiotic stresses provoke a significant decline in photosynthetic productivity (Dinis et al., 2018), leading to yield and quality changes in sugar levels and low aroma components, resulting in high alcohol content and low acidity wines (Dinis et al., 2020). Is essential a deepened knowledge of the physiological/biochemical/molecular nature of responses to drought in combination with other abiotic stresses to make possible and effective the treatment with natural exogenous compounds without resorting to genetic manipulation, avoiding the introduction of generally engineered plants.

It is crucial to develop adaption alternatives, not only in economic terms but also in terms of grape quality and environmental sustainability. Our research group has continuously studied the complex physiology and biochemistry responses of leaves and berries during ripening and how it is impacted under field conditions (Dinis et al., 2016; Bernardo et al., 2017). Our background knowledge acquired on the exogenous kaolin (Kl) application is pivotally essential for the current project approach. The silicon (Si) role in plants is not restricted to forming a physical/mechanical barrier in cell walls. Si modulates plants' metabolism and alters physiological activities, particularly in plants subjected to abiotic stress conditions. Indeed, Si improves water status and enhances chlorophyll content and photosynthetic activity (Moussa et al., 2006). Under water-stress conditions, the presence of Si may result in a better supply of K^+ (Kaya et al., 2006). From a technological perspective, this effect can influence the pH of musts and wines, thereby their chemical and microbiological stability and improving the perception of wine flavour (Mpelasoka et al., 2008). Knowing that after foliar application the Kl adhesion must be improved, a new compound will be formed by mixing the Kl with the Si, expecting the physiological grapevine improvement, namely the water use efficiency, which will impact the fruit quality. These preliminary results suggest that treating crops with protective compounds should not be ruled out as a drought mitigation strategy but rather regarded as an economical and easy way to ease plant growth and productivity in the increasingly rough environmental conditions. Combining these outcomes with the experience/skills of the team, this project will provide much helpful information on grapevine-drought interaction, with solid scientific impact, and on the efficiency of the new formulation strategy resulting in a positive effect on regional, national and global wine industry.

The main objective of this work is to evaluate the effects of three formulations, mixing Kl (2%) with 3 concentrations of Si (2, 4 and 6%) in the grapevine performance and yield quality.

Materials and methods:

The experiment was done in the Douro Region, in the sub-Region Cima-Corgo, in the commercial vineyard *Quinta de Ventozelo* with "Touriga Franca" (TF) variety. For the experimental work, three random blocks were selected with 4 rows each block, with 10 vines each. Each row corresponds to one of the treatments carried out, making a total of 120 vines under study. In this trial, four treatments were defined, with the following formulations: I) Control, without kaolin or silicon; II) MiKS 1, with 2% kaolin and 2% silicon; III) MiKS 2, with 2% kaolin and 4% silicon; IV) MiKS 3, with 2% kaolin and 6% silicon. Predawn water potential (Ψb) was determined according to Scholander et al. (1965). Gas exchange parameters and Chlorophyll a fluorescence measurement was done according to Dinis et al. (2020). Proline was quantified according to Bates et al. (1973), and phenolic compounds according to Dinis et al. (2020). Photosynthetic pigments and soluble sugars were obtained according to Dinis et al. (2018).

Results and discussion:
Throughout the maturation period, an increase in water deficit was observed in all treatments (Fig.1). According to the scale proposed by Deloire et al. (2005), on veraison, the values (-0.35 MPa) were between mild and moderate water stress. In the maturation stage, all treatments exhibited high stress (<-0.6 MPa), being MiKS 3 the most efficient treatment with low predawn water potential.

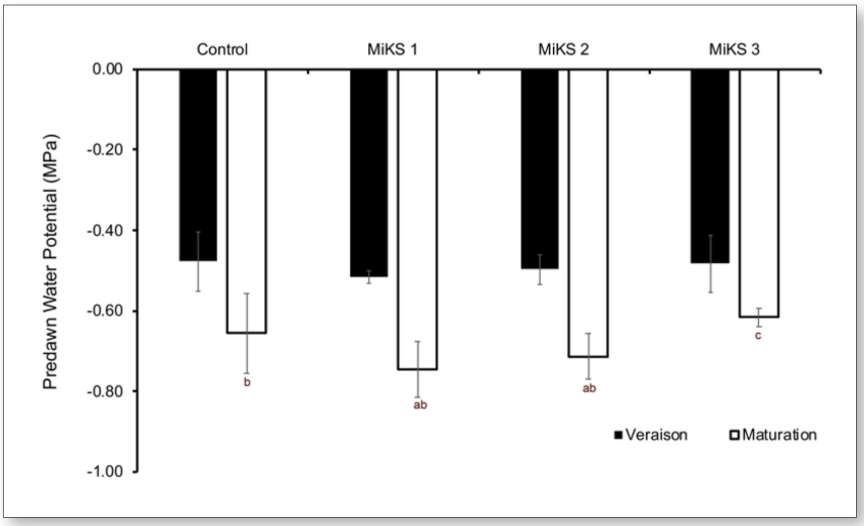

Figure 1. Predawn water potential of vines under 3 different concentrations of Kaolin (Kl) and Silicon (Si), (MiKS 1, Kl 2%+Si2%; MiKS 2, Kl 2%+Si4%; MiKS 3, Kl 2%+Si6%), in veraison and maturation stages.

Different lower-case letters represent significant differences between treatments within the same stage of the vegetative cycle ($p < 0.05$).

Regarding gas exchange parameters (Table 1), no differences were found in the veraison stage, however the MiKS 2 results showed to be more efficient in the maturation stage, in the morning period, presenting highest A and A/gs values. In the midday period the MiKS 2 also showed the highest values of A, as well as the control, but both MiKS 2 and MiKS 3 has the better water use efficiency. As the kaolin concentration is the same in all the mixtures, this difference in A/gs could be provoked by the silicon effect as it was also demonstrated in other study (Farahani et al., 2020).

Table 1. Effects of leaf application of different concentrations of Kaolin (Kl) and Silicon (Si) (MiKS 1, Kl 2%+Si2%; MiKS 2, Kl 2%+Si4%; MiKS 3, Kl 2%+Si6%) in net CO2 assimilation (A), intrinsic water- use efficiency (A/gs), and maximum quantum efficiency (Fv/Fm), in veraison and maturation stages.

Stage	Period	Treatment	A ($\mu molm^{-2}s^{-1}$)	A/gs ($\mu molmol^{-1}$)	Fv/Fm	Stage	Period	Treatment	A ($\mu molm^{-2}s^{-1}$)	A/gs ($\mu molmol^{-1}$)	Fv/Fm
Veraison	Morning	Control	12.0 ± 3.58	75.6 ± 10.7	0.800 ± 0.039	Maturation	Morning	Control	3.34 ± 2.49 ab	59.8 ± 26.0 a	0.737 ± 0.028
		MiKS 1	9.43 ± 2.37	90.3 ± 12.4	0.841 ± 0.041			MiKS 1	1.91 ± 0.801 ab	87.8 ± 12.1 b	0.723 ± 0.065
		MiKS 2	12.4 ± 3.42	83.0 ± 13.1	0.812 ± 0.075			MiKS 2	4.16 ± 1.51 b	97.6 ± 6.79 b	0.744 ± 0.053
		MiKS 3	9.50 ± 2.84	80.5 ± 17.0	0.839 ± 0.052			MiKS 3	1.49 ± 0.782 a	78.8 ± 14.6 ab	0.705 ± 0.105
		P value	0.221	0.319	0.487			*P* value	0.026	0.005	0.763
	Midday	Control	10.6 ± 4.33	81.3 ± 6.50	0.800 ± 0.046		Midday	Control	3.45 ± 1.98 b	109.4 ± 15.9b	0.736 ± 0.099
		MiKS 1	5.55 ± 1.33	87.7 ± 6.95	0.828 ± 0.025			MiKS 1	1.09 ± 0.442 a	86.6 ± 17.9a	0.667 ± 0.111
		MiKS 2	9.51 ± 2.85	87.4 ± 9.60	0.802 ± 0.041			MiKS 2	2.47 ± 1.67 ab	120.6 ± 20.3c	0.777 ± 0.074
		MiKS 3	9.36 ± 3.60	85.8 ± 4.75	0.831 ± 0.042			MiKS 3	1.12 ± 0.390 a	127.9 ± 23.6c	0.743 ± 0.119
		P value	0.060	0.408	0.393			*P* value	0.015	0.179	0.330

Different lower-case letters represent significant differences between treatments within the same stage of the vegetative cycle ($p < 0.05$).

In general, the MiKS 2 showed the highest leaf phenols, but the MiKS 3 has the highest content of leaf flavonoids, *ortho*-diphenols (Table 2), and in the veraison stage the highest sugar concentration. These metabolites act as a defence mechanism against UV radiation or pathogenic attack, reducing the oxidative stress of reactive oxygen species and damage caused by reactive nitrogen species (Mao et al., 2017).

Table 2. . Effects of leaf application of different concentrations of Kaolin (Kl) and Silicon (Si) (MiKS 1, Kl 2%+Si2%; MiKS 2, Kl 2%+Si4%; MiKS 3, Kl 2%+Si6%) on leaf *ortho*-difenols, flavonoids, phenols, sugars, proline total chlorophylls and carotenoids (mg g^{-1} DW), in veraison and maturation stages.

Stage	Treatment	*Ortho*-diphenols	Flavonoids	Phenols	Protein	Sugars	Proline	Total Chlorophyll	Carotenoids
Veraison	Control	30.8 ± 1.40 a	3.55 ± 0.759 a	17.5 ± 0.539 a	0.514 ± 0.085	53.8 ± 0.726 a	0.731 ± 0.098 a	3.79 ± 0.096 c	0.648 ± 0.037 c
	MiKS 1	35.8 ± 2.50 ab	3.66 ± 1.63 a	18.9 ± 1.10 ab	0.418 ± 0.173	54.2 ± 0.595 a	2.69 ± 0.735 a	2.67 ± 0.113 a	0.279 ± 0.017 a
	MiKS 2	41.0 ± 2.53 b	5.63 ± 1.60 ab	21.2 ± 2.10 b	0.691 ± 0.370	60.9 ± 1.44 b	36.2 ± 3.75 b	3.34 ± 0.117 b	0.501 ± 0.035 b
	MiKS 3	38.8 ± 1.84 b	8.10 ± 1.19 b	19.4 ± 0.983 ab	0.469 ± 0.368	68.8 ± 1.11 c	4.93 ± 0.795 a	3.40 ± 0.031 b	0.465 ± 0.022 b
	P value	0.002	0.010	0.050	0.656	<0.001	<0.001	<0.001	<0.001
Maturation	Control	33.2 ± 1.92 ab	7.21 ± 3.65 b	17.5 ± 0.642	4.30 ± 1.12 b	58.9 ± 0.168 c	42.8 ± 2.66 c	3.20 ± 0.192 b	0.387 ± 0.027 bc
	MiKS 1	33.4 ± 2.48 ab	3.89 ± 0.314 ab	18.9 ± 0.782	3.73 ± 0.511 ab	53.7 ± 1.36 b	0.336 ± 0.182 a	2.55 ± 0.079 a	0.298 ± 0.024 a
	MiKS 2	28.9 ± 2.59 a	1.66 ± 0.029 a	17.7 ± 1.61	3.35 ± 0.020 ab	58.4 ± 1.30 c	4.09 ± 0.832 b	3.07 ± 0.065 b	0.426 ± 0.022 c
	MiKS 3	36.8 ± 2.01 b	6.24 ± 1.30 ab	19.1 ± 2.76	2.20 ± 0.047 a	41.6 ± 2.02 a	5.37 ± 0.057 b	3.04 ± 0.083 b	0.343 ± 0.020 ab
	P value	0.019	0.032	0.550	0.017	<0.001	<0.001	<0.001	<0.001

Different lower-case letters represent significant differences between treatments within the same stage of the vegetative cycle ($p < 0.05$).

These preliminary results showed that MiKS 3 leads to an increase of the concentrations of phenols, flavonoids, *ortho*-diphenols, and tannins, and MiKS 1 increase the anthocyanins fruit content (Figure 2). Regarding quality, these compounds are appreciated, so the MiKS 3 seems to be efficient in improve the grape quality.

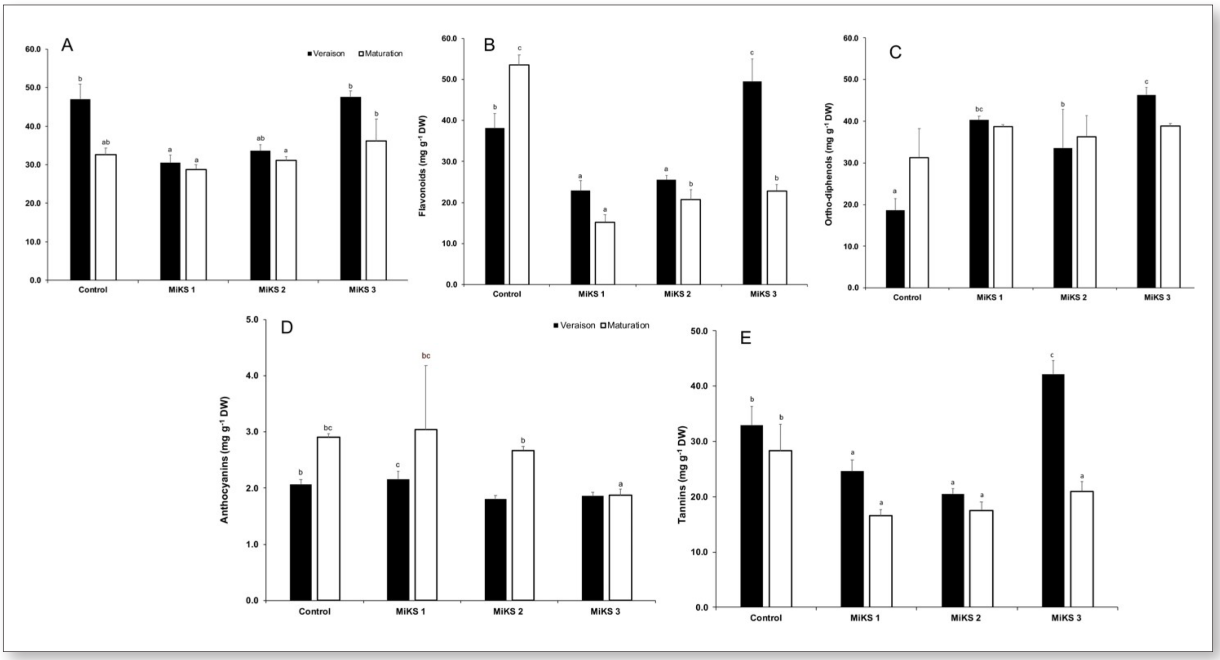

Figure 2. Content of leaf phenols (A), flavonoids (B), *ortho*-diphenols (C), Anthocyanins (D) and tannins (E) under 3 different concentrations of Kaolin (Kl) and Silicon (Si), (MiKS 1, Kl 2%+Si2%; MiKS 2, Kl 2%+Si4%; MiKS 3, Kl 2%+Si6%), in veraison and maturation stages.

Different lower-case letters represent significant differences between treatments within the same stage of the vegetative cycle ($p < 0.05$)

Regarding to the productivity (3A), the Control and MiKS 1 have similar productivity, around 2.5 kg per plant, with no significant difference between them. The MiKS 2 treatment shows a slight increase in productivity (approximately 3 kg per plant) compared to Control and MiKS 1, but not significantly different. The MiKS 3 treatment showed the highest productivity, about 3.5 kg per plant, and is significantly different from the Control and MiKS 1 treatments. This could suggest that the dosage of MiKS 3 are more suitable for enhancing productivity. However, no differences in the number of bunches per plant (3B) between treatments.

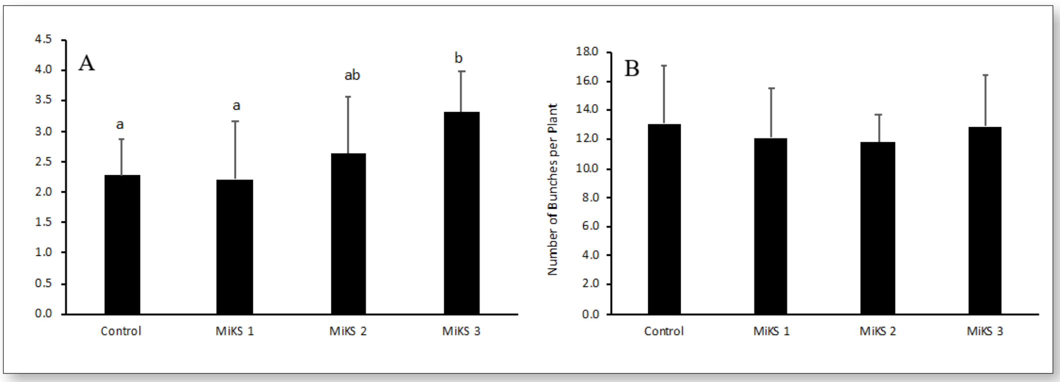

Figure 3. Productivity (A), and number of bunches per plant (B), of the 4 treatments under study: control without treatment and 3 different concentrations of Kaolin (Kl) and Silicon (Si), (MiKS 1, Kl 2%+Si2%; MiKS 2, Kl 2%+Si4%; MiKS 3, Kl 2%+Si6%)..

Different lower-case letters represent significant differences between treatments ($p < 0.05$).

Conclusion:

It is crucial to emphasize that these results were from experiments conducted within a single season and these are the preliminary results. However, looking to the overall results the MiKS 2 and MiKS 3 seems to improve the water use efficiency and phenolic leaf compounds. Focusing to the fruit quality the MiKS 3 stand out with high phenolic compounds and tannins as well as high productivity. All the formulations lead to a reduction in proline content at maturation stage, which indicates greater plant comfort.

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Funding: Vine and Wine Portugal - Driving Sustainable Growth Through Smart Innovation. Entidade Promotora: GRAN CRUZ PORTO-SOCIEDADE COMERCIAL DE VINHOS LDA. Sub-Projeto: Kaolin and silicon particle film mixture: a new formulation for *Vitis vinifera* under severe water stress [MiKS4Vine]

NOV 20, 2024 | 11.30 AM | SCIENTIFIC SESSION: **PLANT MATERIAL AND MANAGEMENT IV - SCIENTIFIC ORAL**

Impact of training system, soil management and soil water holding capacity on vine water status in a changing climate over 60 years in the Cognac production area

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Keywords: **grapevine, water status, modelling, sensitivity analysis, FTSW, climate change.**

ABSTRACT

This study investigates the impact of vine training systems on water deficits in the Cognac region (France), through the application of a vine water balance model, taking into account different soil water holding capacities (SWHC) and soil management strategies, including grass cover. Using climate data from the SAFRAN gridded database, over 2 million simulations were performed for the period 1962 to 2021 to quantify the response of grapevine water status under varying training systems and environmental conditions. Three indices based on simulated relative stomatal conductance were developed to characterize the intensity of grapevine water deficit during the critical flowering-to-maturity period.

Results show a significant trend of increasing water deficit between 1962 and 2021, particularly in the north-western part of the region, affecting 23% of the Cognac production area. Sensitivity analysis of the water balance model indicates that SWHC is the predominant factor influencing grapevine water status, explaining nearly 80% of the variance in water deficit days. The simulations further suggest that adjustments in canopy width and grass cover have a significant effect on the duration and severity of water deficit.

The methodology developed in this research allows quantifying the relative importance of major drivers of vine water deficits: SWHC, training system parameters and vineyard floor management, under different climatic conditions. By doing so, it offers easy-to-implement strategies for vineyard management, in order to mitigate the impacts of climate change in viticulture. It was applied to the Cognac region, but the workflow developed is applicable to any grape growing region in the world.

NOV 20, 2024 | 11.45 AM | SCIENTIFIC SESSION: **PLANT MATERIAL AND MANAGEMENT IV - FLASH ORAL**

The importance of rural extension and advisory services to achieve a sustainable viticulture in a climate change scenario

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Keywords: **extension service, climate change, viticulture practices.**

ABSTRACT

A healthy and dynamic agricultural sector is an important foundation of rural development, generating strong bonds to other economic sectors. The success of sustainable rural development depends on developing and implementing comprehensive strategies for dealing with climate change, drought, territorial desertification and natural disasters. Improving access to information, education, extension services and learning resources, will lead to a strong and more resilient rural community. Climate change is one of the main challenges of the viticulture sector. The European Green Deal and "Farm to Fork Strategy" are ambitious and innovative by demanding a decreasing of 50% on the use of conventional active substances by 2030. This could be considered an opportunity but is also a very demanding challenge for farmers. The rural extension and advisory services play a huge role in supporting farmers to achieve all the demands. Through a face-to-face presence in the field, but also with the help of digitalization, precision farming, AI and data analyses, it's possible to create methodologies enabling farmers to deal with the new demands. In Portugal, and in the Peninsula de Setubal's region, the viticulture sector is characterized by farmers with more than 60 years old, small to medium areas and a low educational degree. This situation leads to more difficulties in the implementation of an effective consultancy. So, to have a higher impact, the solution was the creation of living-labs/ demo-farms. It's considered crucial to enable farmers to see *"in loco"* the implementation of new technologies and practices.

NOV 20, 2024 | 11.50 AM | SCIENTIFIC SESSION: **PLANT MATERIAL AND MANAGEMENT IV - FLASH ORAL**

Temperature and solar radiation affect grape composition in vineyards located in the Saint-Emilion and Pomerol winegrowing area

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Keywords: **Merlot, climate change, solar radiation, primary metabolites, anthocyanins.**

ABSTRACT

Expected modifications of climate in the near future, could significantly modify the composition of berries at harvest, and thus wine typicity. Elevated temperatures increase sugar accumulation in grapes and reduce significantly anthocyanin accumulation for Merlot, leading to the imbalance between anthocyanins and sugars. High temperatures also modify the amino acid content and finally affect aromas or aroma precursors. However, several other environmental factors also contribute to the overall variability in berry composition between nearby vineyards, making it difficult to identify the impact of each individual factor. In this context, the objective of our study was to clarify the effect of temperature variability across a network of vineyards from the Saint-Emilion and Pomerol wine producing areas. We selected eight Merlot plots characterized by similar soils, vine age and management system with significant temperature differences during the ripening period (about 2°C between the coldest and warmest sites). Samplings of 20 to 50 berries were carried out at different stages (pea-size, veraison and harvest) in 2019 and 2020. In order to evaluate the putative impact of cluster exposure to solar radiation, berry composition of clusters from each side of various oriented rows (E/W or N/S) was separately determined. Biochemical analyses were combined with RNA-seq technology to screen differentially expressed genes at transcriptome level.

Temperature and exposure to solar radiation had a more specific impact on the amino acids composition of the pulp and the anthocyanin content of the skins. The differential expression of genes associated with the secondary metabolism, especially those related with flavonoids and phenolic compounds was more important in berry samples with a West (W) orientation compared to those with an East (E) orientation. In addition, the accumulation of malvidin forms was favored by high temperatures while cyanidin and peonidin forms were more accumulated in east- and west-facing berries.

NOV 20, 2024 | 11.55 AM | SCIENTIFIC SESSION: **PLANT MATERIAL AND MANAGEMENT IV - FLASH ORAL**

Terroir and biodiversity: evaluating native bee abundance in vineyards of the Uco Valley, Mendoza

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Keywords: **landscape, edge effects, flower resources, nesting sites, conservation.**

ABSTRACT

The latest definition of "terroir" approved by the OIV includes landscape and vineyard biodiversity as distinctive characteristics of winegrowing products. Many vineyards in the Uco Valley, Mendoza, are located within a landscape matrix dominated by native vegetation, imparting unique biodiversity features. It is expected that areas of native vegetation will exhibit a higher diversity of native bees compared to vineyards. However, the edges between these environments are zones of high insect activity due to the greater availability of complementary resources, such as floral resources and nesting sites.

In this context, we aimed to assess changes in the abundance of native bees at varying distances from the edge between a vineyard and an extensive area of native vegetation. During December 2023, we conducted sampling using pan traps at the edge, and at 50 and 150 meters within each environment. Additionally, traps were placed on the first internal road of the vineyard, which runs parallel to the edge at 200 meters.

Consistent with our hypothesis, the highest abundance of native bees was found at the boundary between the two environments, significantly decreasing towards the interior of the vineyard. However, high and similar abundance values to those at the edge were recorded on the internal road of the vineyard. This suggests that these sites, often overlooked due to their sparse vegetation cover, may provide key resources for bees, either through plant communities or nesting sites.

Further investigation is necessary to analyze the species composition of native bees at each site, particularly on the internal roads, to better understand their role in biodiversity conservation.

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SCIENTIFIC SESSION: **PLANT MATERIAL AND MANAGEMENT - POSTER**

Exploring the intra-varietal phenotypic diversity in traditional grapevine varieties of La Rioja (Spain) to cope with new viticulture conditions

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Keywords: **clonal diversity, 'Graciano', 'Tempranillo Tinto', *Vitis vinifera L.*, wine.**

ABSTRACT

Climate change conditions compromise the sustainability of traditional winemaking regions. One efficient solution to cope with this situation is the use of alternative varieties, with better adaptation potential. However, this practice is not feasible in highly traditional regions, whose international relevance relies on the longstanding cultivation of a selected group of elite cultivars. In these cases, intra-varietal (or clonal) diversity can aid as a tool of adaptation to novel conditions, as it might provide better adaptive traits whilst maintaining varietal characteristics. Here, we explored the range of phenotypic diversity of 30 clonal selections of 'Tempranillo Tinto' and 13 of 'Graciano' for 27 traits related to phenology, agronomic performance, and oenological potential. These selections derive from a wide prospection performed in old vineyards of the demarcated winemaking region of Rioja more than 30 years ago by the Government of La Rioja, which were transferred to an experimental plot for their comparative study. The univariate and multivariate analyses of these traits during three consecutive seasons denoted a high level of intra-varietal diversity in both varieties, considerably higher to that observed in a set of commercial clones used as controls. In the case of 'Tempranillo Tinto', we identified a group of 13 clonal selections with significantly long veraison-to-harvest periods and late ripening times, of special interest to respond to projected warming conditions. In addition, some of these selections have additional beneficial attributes, like low bunch compactness or slow sugar accumulation. Our results support that old vineyards from traditional winemaking regions are reservoirs of clonal diversity of ancient grapevine varieties like 'Tempranillo Tinto' and 'Graciano'. Consequently, these sites need to be preserved and explored to ultimately develop new clones of interest to address current and future viticulture challenges.

SCIENTIFIC SESSION: **PLANT MATERIAL AND MANAGEMENT - POSTER**

Harnessing natural elicitors: enhancing post-harvest resistance in brazilian grapes with β-D-1,6-glucans

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Keywords: **elicitors, oligosaccharides, sustainable agriculture, plant innate immunity, grape production.**

ABSTRACT

This study aimed to evaluate the effectiveness of a β-D-1,6-glucan product derived from a regional oomycete, comparing it with traditional elicitors to determine its potential in inducing post-harvest resistance in grapes and promoting sustainable agricultural practices. Commercial grape varieties (Bordô and Niagara Rosada) were purchased from the local market. These grapes were treated with either water (Control), β-D-1,6-glucan, 200 mg L^{-1}), and ASM (Bion® 500 WG, 100 mg L^{-1}). Fruits treated with β-D-1,6-Glucan consistently showed lower AUDPC values across all conditions (varieties Bordô and Niagara Rosada, both wounded and unwounded). ASM initially showed lower AUDPC values for wounded Niagara grapes until the 8th day. However, by the 10th day, β-D-1,6-Glucan had the lowest AUDPC value. The highest TPC values were observed in fruits treated with β-D-1,6-Glucan, regardless of variety or presence or absence of injury. Fruits treated with β-D-1,6-Glucan exhibited the greatest pulp firmness compared to those treated with ASM and water. The results demonstrate that β-D-1,6-Glucan has significant potential as a sustainable alternative for enhancing post-harvest disease resistance in grapes, particularly against *Glomerella cingulata*. By effectively reducing disease severity and boosting plant immune responses, β-D-1,6-Glucan supports more sustainable agricultural practices. This natural elicitor offers a promising solution to reduce reliance on synthetic agrochemicals, paving the way for healthier and more environmentally friendly grape production.

SCIENTIFIC SESSION: **PLANT MATERIAL AND MANAGEMENT - POSTER**

Impact of different leaf area to fruit ratios on cv. Merlot Berry composition and wine sensory characteristics

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Keywords: **cluster thinning; severe shoot trimming; berry composition; wine; sensory characteristics.**

ABSTRACT

In this study were evaluated the effects of different leaf area to fruit ratios obtained by cluster thinning and severe shoot trimming on berry and wine composition, and wine sensory characteristics of Merlot variety, in the context of climate change challenges related to grapevine ripening and the corresponding high alcohol content in wine. The study was conducted during seasons 2017 and 2018 in the experimental vineyard of the Institute of Agriculture and Tourism in Poreč, Istria winegrowing region, Croatia. Two different crop sizes were obtained by cluster thinning (obtained by thinning 35% of clusters) and its respective full crop control (where cluster thinning was not applied), and combined in a two-factorial design with severe shoot trimming (to 70 cm of total canopy height at late veraison) and its respective high canopy treatment (130 cm of total canopy height). In both seasons cluster thinning resulted in higher Brix in grape juice and higher alcohol in wine than full crop size, whereas severe shoot trimming obtained lower values of Brix than high canopy treatment. Total anthocyanins and total phenolics in wine were increased by cluster thinning, whereas severe shoot trimming had no any significant effect on wine phenolic content. Several sensory characteristics of wine were positively affected by cluster thinning in both seasons, including aroma intensity, wine body and overall wine quality, whereas severe shoot trimming wines were in one season characterized by increased perception of vegetal aroma, acidity and bitterness, and decreased perception of body, persistency and taste balance. Our results demonstrate that practices which affect the leaf area to fruit ratio have a major impact on wine sensorial characteristics concluding that their choice should be based on the desired wine style.

Mountain vineyard micro-relief affects intra-plot vine growth and yield

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Keywords: **micro-relief, NDVI, plant physiology.**

ABSTRACT

This study evaluated micro-relief impacts on enology and production within the plot, comparing the lower and higher intra-plot zones while considering the same soil type, irrigation and vine management. A soil zonation study was conducted in a vineyard in Ugarteche, Mendoza, Argentina. The study was conducted over a two-year period with a sample size of n=23. The treatments were placed at a single-meter elevation differential. The study mapped calcareous, phosphorus, NDVI and contour lines at 25-centimeter intervals across the entire plot. Even considering notable elevation differences of up to one meter between points within the same row, contour and planting lines exhibited high parallelism. These depression lines run across the entire barracks, some extending across the entire property (100 ha). Phenology, canopy temperature and yield were monitored at the highest and lowest points. The NDVI was related to contour lines in areas of equal calcium and phosphorus contents. The NDVI variation within the same row and same soil type, the NDVI was related to changes in micro-relief. Temperature variation was 1.5°C lower in the lower zone and up to 2°C lower in the upper zone *(p=0.037)*. This thermal difference changes physiological parameters of the plants, resulting in uneven phenology (7 days) and yield parameters (1.78 kg/plant in lowest points and 2.25 kg/plant in highest points).

Grape nitrogen composition, can it be modified by foliar applications of calcium and silicon?

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Keywords: **amino acids, Tempranillo, Ca, Si, foliar applications.**

ABSTRACT

Nitrogen compounds are determinant in plant functions, involved in the yeast metabolism and the must fermentation processes, and affect the production of higher alcohols and esters, responsible for some desirable aromas in wines. Calcium (Ca) is an essential macronutrient for plant growth, plays a key role in the fruit development and its deficiency can lead to disease or even plant deterioration. Silicon (Si) is able to increase plant tolerance to stresses and to promote enzymatic activities in charge of nitrate reduction and assimilation. The aim was to evaluate the influence of foliar treatments on grape nitrogen composition. A vineyard of Tempranillo grafted on R-110, trained on a single vertical trellis with East-West orientation, 2,976 plants/ha and located in Logroño (456 m.a.s.l.), Spain, was used in the study. Based on the doses recommended by the manufacturer, four treatments (with 3 replicates each) were applied (200 ml/plant), at veraison and one week later: Ca (120 mM), Si (120 mM), Ca+Si (120 mM + 120 mM) and water (control). The surfactant Genapol (0.1% v/v) was added to all of them. At harvest, 40 berries per treatment and replicate were sampled and frozen for subsequent analysis of nitrogen compounds by HPLC. Statistical differences were analysed using SPSS software, comparing means by Duncan's test ($p \leq 0.05$). This pioneering study showed increases in the total amino acids concentration as well as in the most of the individual amino acids (14 of 20 studied) in the Tempranillo grapes from Ca and Ca+Si treatments. Likewise, Ca increased the content of nitrogen easily assimilated by yeasts. The Si treatment also increased the total amino acids content but only 6 of the free amino acids. Thus, foliar applications of Ca and Ca+Si could be a good tool to improve the grape nitrogen composition, especially in those from nitrogen-poor vineyards.

SCIENTIFIC SESSION: **PLANT MATERIAL AND MANAGEMENT - POSTER**

Grape varieties mapping through spectral signatures: resources for grapevine diversity characterization and monitoring

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Keywords: **spectral analysis, grapevine diversity, variety identification, physico-chemical basis, vineyard monitoring.**

ABSTRACT

It is well known that different plant species exhibit distinct reflectance spectra. This variation is also observable within a single species, a phenomenon we have applied to grapevines. Previous studies have reported that grape varieties can be differentiated based on subtle spectral features detected at specific wavelengths. In this study, we present preliminary results from an investigation with two primary objectives: first, to identify specific spectral features for various grape varieties; and second, to determine the physico-chemical basis for these differences. Experimental data acquisition included both field and laboratory spectroradiometry, as well as chemical analysis of vine leaves. For the first objective, in the absence of a standard spectrum for grapevines, we characterized internal spectral features unique to each variety. For the second objective, we combined information from published research with our radiometric and chemical analysis data. The results are summarized as follows: a mapping of wavelengths where the reflectance spectra are characteristic for six grapevine varieties—Cabernet Sauvignon, Chardonnay, Merlot, Pinot Noir, Syrah, and Welschriesling; relationships between these features enabled accurate variety identification; and physico-chemical factors such as chemical composition, internal cell structure, and water-holding capacity were identified as the origins of spectral differences. These findings have potential applications in the development of vineyard monitoring methods aimed at variety identification, health status assessment, and regulation of permitted varieties in controlled regions.

SCIENTIFIC SESSION: **PLANT MATERIAL AND MANAGEMENT - POSTER**

Native plant growth-promoting rhizobacteria from Mendoza promotes adventitious root production of Vitis sp. woody cuttings

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Keywords: **grapevine nursery, plant propagation, rhizobacteria, drylands, grapevine rootstocks.**

ABSTRACT

Plant Growth Promoting Rhizobacteria (PGPR) have direct and indirect mechanisms that stimulate plant growth and development. Our group has isolated and characterized two native rhizobacteria strains: Pseudomonas 42P4 and Enterobacter 64S1 from Mendoza, Argentina which exhibit growth-promoting activity, including auxin production.

Synthetic auxins are conventionally employed to stimulate the rooting of woody vine cuttings. This study aimed to assess the effect of these two strains on the rooting of woody cuttings from *Vitis vinifera* cv. Malbec own-rooted and grafted onto four American rootstocks: 1103 P, 110 R, 101-14 MGt, and SO4. Woody cutting bases were incubated for 12 h in solutions of 1) Pseudomonas 42P4 x 107 UFC mL-1, 2) Enterobacter 64S1 x 107 UFC mL-1, 3) autoclaved LB medium, 4) water, and 5) a quick-dip immersion (30 s) of Indole-3-butyric acid (IBA) 1000 ppm (as commonly used in grapevine nurseries). Then, cuttings were forced at 28°C for 21 days. Rooting parameters (percentage of basal callusing, root percentage, and number and biomass of roots per cutting) were determined. In addition, the percentage of the grafting union was measured in grafted cuttings.

Pseudomonas 42P4 increased the root percentage akin to the IBA treatment, root number, and root biomass per cutting of Malbec own-rooted cuttings. Conversely, the strain Enterobacter 64S1 inhibited the rooting of Malbec cuttings. 42P4 also improved the rooting of Malbec grafted onto the 1103 Paulsen rootstock, but not onto 101-14, 110 Richter and SO4. 42P4 increased the grafting scion-rootstock union of SO4, but not in 110 Ritcher, 1103 Paulsen and 101-14. In summary, Pseudomonas 42P4 could be used to promote the rooting of Malbec cuttings and grafted cuttings onto 1103 Paulsen. This strain can also enhance the grafting union of SO4. These results suggest that Pseudomonas 42P4 could be used as a potential sustainable tool for the production of ungrafted and grafted vines.

SCIENTIFIC SESSION: **PLANT MATERIAL AND MANAGEMENT - POSTER**

Meso and microclimate influence on Malbec, Syrah and Bonarda vine physiology and yield during a heatwave in Mendoza, Argentina

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Keywords: ***Vitis vinifera,*** **semi-arid climate, temperature, sprinkler aerial irrigation, climate change.**

ABSTRACT

Meso and microclimates (air temperature, radiation and relative humidity, in particular) influence physiological processes, grape ripening, and yield. Heatwave linked to climate change has been increasing both in length and frequency worldwide. In the semi-arid condition of Mendoza viticultural area (33°00'30.2"S), at the foot of the Andes Mountain (430-2.000 m a.s.l.), heatwaves have been intensifying, being necessary to develop mitigation tools to cope with. Overhead spray water treatment (OSWT) in vineyards, is a useful strategy to reduce physiological stress and increase yield. The aims of this work were 1) to calculate meso and microclimate indexes and 2) analyze their links to physiological processes, vine performances and ripening pattern in OSWT during heatwaves. Three cultivars Malbec, Bonarda and Syrah were treated in UNCuyo experimental vineyard, where a weather station allowed to characterize the mesoclimate. Within the canopy (microclimate) iButton temperature sensors were used. One heatwave (8 days-long) was identified during 2024 growing season. Physiological measurements, leaf and berry temperature were registered previous, during and after the heatwave. Four berry samples were collected from veraison to harvest (23 ± 1 Brix) to assess juice technological parameters. Previous to heatwave until harvest, temperature, relative humidity, and solar radiation indexes were calculated at meso scale; a thermal accumulation index was also calculated at micro scale at the same period. Correlation and regression were calculated between climate and physiological variables. OSWT decreased the thermal accumulation and increased the humidity within the canopy, which allowed the vines experience less physiological stress. Ripening patterns and yield were impacted differently by OSWT depending on the length of the varietal growing cycle, being most effective when the heatwave occurred late in the growing season. When it occurs in advance, varieties may show some recovery capacity, also including ripening and yield.

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Short-term closure in inter-rows support higher spider species richness than managed inter-rows in vineyards

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Keywords: **biodiversity indicators, generalist predators, viticulture, Mendoza, Argentina.**

ABSTRACT

The biodiversity present in a vineyard is today an acknowledged component in the characterization of our terroirs. The concept also includes spider communities associated with vineyard vegetation and ground, which constitutes possible indicators of a balanced viticultural ecosystem. Species living in inter-row's ground of vineyards are affected by tillage, agrochemical applications, and type of vegetation cover, among others. These practices may negatively impact biodiversity and the ecosystem services it provides. Here, we analyzed the effect of recent closure inter-rows on ground spider abundance and richness to evaluate whether these modifications in management have short-term effects on spider communities in vineyards. We worked in nine vineyards distributed across the "First viticultural zone" and the Uco Valley in Mendoza province, Argentina. Vineyards use similar inter-row management (mowed, spontaneous cover vegetation). Each vineyard had inter-rows closed to human activities since October 2022 (two months before spider sampling). No phytosanitary applications were carried out in the plots seven days before sampling. We collected spiders using pitfall traps that were placed in managed and closed inter-rows in December of 2022 and remained open for seven days. The number of spiders collected was similar in both inter-rows, but we found that closure inter-rows had significantly higher species richness than managed inter-rows ($t = 21.19$; $p = 0.046$). We did not find differences in spider composition between both inter-rows. However, three spider families were favored by the closures, Anyphaenidae (cursorial), Theridiidae and Titanoecidae (both web builders). These spiders are strongly associated with vegetation (height and species composition); therefore, the absence of mowing clearly benefits their settlement. Our results showed that adding inter-row closures in vineyards, even in the short-term, increased the number of spider species being an important method of conserving the biodiversity of the vineyards.

Phenolic composition of Chilean Pinot noir commercial wines from two traditional and two emerging cool zones

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Keywords: **Casablanca[1], Leyda[2], San Antonio[3], Bío-Bío[4], Mulchén[5], Osorno[6], Río Bueno[7].**

ABSTRACT

Regionality (broadly referred to as terroir) is an important concept for winemakers and wine consumers, as it refers to how a wine is recognized based on its geographical origin [1].

Pinot noir *(Vitis vinifera L.)* is a very popular cultivar, particularly in cool-climate wine growing regions, where it produces fine, elegant, and expressive wines [2]. Pinot noir accounts for over 4000 ha of vineyards from across Chile [3]. Chile is still only 9th globally in hectares of Pinot noir planted. Provenance in Chile is governed by Origin Denominations (OD), for which typicity should also be evident in terms of regional sensory profiles of wine from a given grape cultivar.

Climate change is indeed altering traditional viticultural landscapes, and regions that were once considered too cold for certain grape varietals are now becoming viable options. In Chile, as temperatures rise and weather patterns shift, new cold viticultural regions are emerging, especially in the southern parts of the country. For Pinot Noir, a grape variety that thrives in cooler climates, these emerging regions could offer promising opportunities. As the climate warms, traditional grape-growing regions may become too warm for Pinot Noir, making these new, cooler regions increasingly attractive for its cultivation.

The aim of this work was to compare the phenolic composition of commercial wines of cv. Pinot noir from two traditional cool coastal production OD: Casablanca and Leyda, and two emerging OD: South and Austral. Total phenols, tannins and anthocyanins were measured, as well as the profile of anthocyanins and low molecular weight phenolic compounds by HPLC-DAD.

A preliminary knowledge of the interaction between production area and phenolic composition of Pinot noir wines was obtained, allowing the samples to be grouped by area and year of production. The behavior of the variables was similar in each area for both vintages studied.

SCIENTIFIC SESSION: **PLANT MATERIAL AND MANAGEMENT - POSTER**

Chemical and sensory variability of Cabernet sauvignon wines from commercial vineyards in Luján de Cuyo and Uco Valley, Mendoza, Argentina

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Keywords: **characterization, phenolic composition, sensory attributes, geographical origin, Cabernet sauvignon.**

ABSTRACT

Cabernet Sauvignon, the most widespread red wine variety in the world, is the third most cultivated variety in Argentina after Malbec and Bonarda, with 13,200 ha mainly cultivated in Mendoza. In this province, the main Cabernet Sauvignon growing regions are Luján de Cuyo (20.1%), and Uco Valley (23.3%). Several precedents highlight the importance of the terroir concept in the choice of wines by consumers, who in many cases are willing to pay a higher price for the origin or provenance of them. In turn, the variability factors that define a terroir could significantly modify the chemical composition and sensory expression of the wines. To our knowledge, there is very little published information on the chemical composition of Cabernet sauvignon wines from Mendoza. Therefore, this work aimed to interpret the influence of the growing area on the phenolic composition and organoleptic characteristics of Cabernet sauvignon wines. During the 2023 season, 30 kg of grapes were harvested (25 ± 1°Brix) in triplicate from commercial vineyards of different locations of Luján de Cuyo (Las Compuertas, Perdriel, Agrelo, Ugarteche) and Uco Valley (Gualtallary, Los Arboles), and made into wine (18 experimental units) in 25 L food plastic fermenters following a standard protocol (14 days at 25°C). In all cases, the plants were homogeneous in terms of vigour, balance, and cultural management, ranging in age from 15 to 25 years. Wines were analyzed for basic chemistry, as well as for phenolic composition (global and anthocyanin profile) and color parameters (CIELAB). Additionally, a Flash Profile sensory analysis was performed with 20 panelists in 2 sessions. Principal Components Analysis (PCA), including chemical variables, described the Gualtallary wines with higher titratable acidity, tannins, and polymeric pigments; Agrelo samples were characterized by more anthocyanins and color saturation followed by Las Compuertas and Perdriel. Finally, Ugarteche wines showed the lowest phenolic load.

SCIENTIFIC SESSION: **PLANT MATERIAL AND MANAGEMENT - POSTER**

Use of UV-C light for inactivation of microorganisms in grape juice used as concentrated

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Keywords: **UV-C, concentrated juice, yeast, spoilage, inactivation.**

ABSTRACT

The concentrated juice industry in Mendoza and San Juan faced new challenges; food processing and preservation techniques are continuously being developed to conform to modern consumer demands for safe and healthier foods. Modern consumers demand tasty, healthier, natural and fresh-like foods, produced in an environmentally friendly manner with sustainable methods and small carbon footprints. Consequently, in the past two decades non-thermal technologies have received increasing attention due to their potential for inactivating spoilage and pathogenic microorganisms. Numerous studies have proven that the germicidal Ultraviolet-C light treatment holds considerable promises in juice processing as an alternative to traditional thermal treatment. The UV-C component of light within 240-265 nm is used for microbial inactivation. The aim of this work is to evaluate the use of UV-C light of 254 nm to reduce spoilage yeast viability of concentrated grape juice. *Saccharomyces cerevisiae* and *Zygosaccharomyces rouxii* yeasts were inoculated in white grape juice and exposed to different time and UV-C light radiation in a continuous turbulent flow circulation system. The trials were: control without treatment; 0,4 J/mL for 25 s; 0,83 J/mL for 54 s; 1,16 J/mL for 80 s; 1,4 J/mL for 106 s; 1,83 J/mL for 134 s; 2,16 J/mL for 160 s and 2,4 J/mL for 186 s. The results were measured as colony counts (CFU/mL) developed in specific culture media (pour plate in PDA for S. *cerevisiae*; MYG50A for Z. rouxii) and the response of the live cells and inactivation phases. Significant decreases of 3.5 Log cycles were reached in *Saccharomyces cerevisiae* with 1.49 J/mL; and 4.2 Log cycles for *Zygosaccharomyces rouxii* with 4.8 J/mL; and no significant differences were detected in the physical- chemistry characteristics of the juice that were exposed to the radiations mentioned. This technology to inactivate microorganisms, in products that are easily degraded by conventional heat treatments, such as grape juice, could lead to significant benefits in maintaining the quality. However, it must be done correctly to ensure the required safe limit through appropriate control the dosage and exposure of UV-C to the fruit juice. For further research, combining this technology with other physical methods, such as temperature, cross flow filtration and even ultrasonic technologies, would be promising to control the spoilage by these microorganisms.

The key role of germplasm collections to preserve grapevine diversity: the case of the INTA Mendoza collection

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Keywords: **genetic diversity, conservation, autochthonous varieties.**

ABSTRACT

Between 6000 and 10,000 cultivars of *Vitis vinifera L.* exist worldwide, which are cultivated for different purposes. These existing cultivars originated since grapevine cultivation and domestication commenced 11,000 years ago. Germplasm collections around the world have played a key role conserving this huge genetic diversity during longtime. This genetic diversity is nowadays being deeper explored as a key adaptation factor to climate change. Exploring old varieties and new breeding programs look for traits related to resistance to biotic and abiotic factors, later phenological stages, low berry sugar content or increased berry and wine quality. The INTA Mendoza grapevine collection conserves more than 1000 accessions from 35 different countries, including a collection with 70 autochthonous varieties (e.g. *criollas*). This collection was founded in 1948, incorporating accessions that came from the collection of the Escuela Nacional de Vitivinicultura, founded in 1897 with around 600 accessions. It's important to note that many French varieties (including Malbec) arrived in Argentina in 1853. So, particularly interesting, it might conserve prephylloxeric material from some European varieties and some varieties that were lost in Europe later. Indeed, there are around 166 accessions that remain unidentified, and some of them, not identified through molecular markers and without correspondence in international databases. This collection, which is probably the most important in the Southern Hemisphere in terms of genetic diversity and rare genotypes, represents a tool to increase variability facing the conditions imposed by climate change. It served in the 60's and 70's to identify the varieties present in Argentinian vineyards, to conserve unique *criollas* varieties (e.g. the only 5 existing plants of some varieties were conserved here for more than 50 years), and several other genetic studies. These advancements in science and industry were only possible due to the efforts to maintain and conserve these accessions in the long term, which must be guaranteed in the future despite variable political and economic contexts.

SCIENTIFIC SESSION: **PLANT MATERIAL AND MANAGEMENT - POSTER**

Comparison of regulated deficit irrigation and pruning system on Touriga Franca and Sousão *(Vitis vinifera L.)* grapevines

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Keywords: **water supply, ripeness; grape composition.**

ABSTRACT

In wine-growing regions with a Mediterranean climate the extreme summer dryness conditions, exert a huge constraint on both the yield and the quality of the grapes. The vines are also growing under a high intensity of solar radiation, temperature and a high vapour pressure deficit. The decrease in the amount of water available for the grapevines and the increase in evapotranspiration make necessary finding strategies to reduce vineyard water needs. Regulated Deficit Irrigation (RDI) is a strategy that has been successfully used. However, due to the scarcity of water the complementarity with other practices can improve water saving and alleviate the severe stresses during ripening period.

The aim of this work was to compare the RDI and pruning system on grapevine physiology, yield and grape quality parameters at harvest of the Portuguese varieties Touriga Franca and Sousão grown under Mediterranean conditions. Two pruning system, single Cordon and single Guyot in combination with two RDI strategies were compared for both varieties. The study was conducted during two consecutive seasons (2018-2019) in a vineyard located in northeastern Portugal (41º31´N; 7º5´W; 326 m a.s.l.). The vineyard was planted in 2011 on 1103 P rootstock. Three irrigation treatments were implemented: a control (100% ETc) and two deficit irrigations treatments, RDI 25 (25% ETc) and RDI 50 (50% ETc). During the growing season, physiological parameters were monitored in both varieties. After veraison the biometric characteristics of grapes (longitudinal diameter, equatorial diameter and weight) were measured and at harvest, yield and yield components and grape composition were evaluated. The results showed that deficit irrigation significantly decreased the grapevine water status (lower predawn leaf water potential) during berry ripening. Guyot pruned vines showed a better water status compared to cordon, particularly in the treatments with less irrigation. Yield components had an increase in the more irrigated treatments and vine water productivity was significantly higher in the RDI treatments in both varieties. The differences among treatments were not statistically significant in both varieties in most of the grape quality parameters.

SCIENTIFIC SESSION: **PLANT MATERIAL AND MANAGEMENT - POSTER**

Indication of standards for evaluating the nutritional status of Brazilian vines

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Keywords: **nutritional status of grapevines, CND, discriminant analysis, fertilization in vineyards, *Vitis vinifera L.***

ABSTRACT

Guidelines for nutrient application in vineyards are commonly defined by tissue analysis with a single set of sampling guidelines and interpretations for all the cultivars and regions (counties), not considering the differences in nutrient requirements among the cultivars and the different soil and climatic conditions among the counties. This study aimed at verifying the nutritional similarity among grapevine cultivars in different counties and to propose nutritional reference values for prominent cultivars and growing regions. The study was conducted on a database of 143 complete leaf samples (limb + petiole), collected in different years, in vineyards of Cabernet Franc; Cabernet Sauvignon; Chardonnay; Gewurztraminer; Malbec; Merlot; Pinot Noir; Pinotage; Ruby Cabernet; Sauvignon Blanc; Syrah; Tannat; Tempranillo and Viognier. The vineyards were located in two regions in Brazil: Dom Pedrito e Maçambará, both in the campaign region of the state of Rio Grande do Sul. Leaf samples were prepared and submitted for analysis for N, S, P, K, Ca, Mg, Zn, Cu, Mn, Fe and B. The results obtained for leaf nutrients were analyzed by the CND (Compositional Nutrients Diagnosis) method. Critical levels (Cl), upper limit (UL) and lower limit (LL) were calculated. The nutritional status of grapevines varies markedly between the regions of the municipalities. Utilizing the CND method we propose critical levels, upper and lower limits of nutrients for each county. The universality of nutritional standards, however, should be evaluated on a regional basis.

SCIENTIFIC SESSION: **PLANT MATERIAL AND MANAGEMENT - POSTER**

Turning vineyards into suitable habitats for pest-controlling birds

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Keywords: **ecosystem services, biodiversity, viticulture, participative research**

ABSTRACT

The challenges that viticultural systems are currently facing regarding global change along with the search for sustainable management practices have led the industry to engage in multidisciplinary teams (i.e. agronomists, ecologists, biologists, among others) to address them. Trellis vineyards are not very conducive to the establishment of many pest-controlling bird species. However, some simple management practices based on a deep understanding of the natural history of the involved species could increase their presence, generating benefits in multiple dimensions (environmental, economic, and social). To increase the abundance of a native predator of invertebrates, the House Wren *(Troglodytes aedon)*, we installed nest boxes in a vineyard in Las Compuertas (Mendoza, Argentina) following a row pattern from the edge to the centre of the crop. Additionally, we analysed the area where it captures its prey to verify its role as a biological control agent within the crop. Results from three consecutive years show that as bird breeding seasons progress, both the construction of nests and the number of reproductive nests increase towards the interior of the crop. We expected birds to gradually occupied nests from the borders of the vineyard. However, contrary to our expectations, not only boxes from the border and the interior were occupied but also insect predation occurred almost exclusively in the vineyard, indicating its role as potential biological control agent. To ensure the efficiency of these practices, they must be carefully monitored. For this reason, the monitoring was carried out mainly by the field workers themselves after receiving instruction. Their involvement increased their commitment to the project, contributing to the development of efficient, sustainable, and long-term practices.

Strategies for climate change adaptations: effects of late apical leaf removal in grapevine ripening dynamic and plant water status

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ABSTRACT

Climate change significantly impacts grapevine physiology and wine quality particularly in regions where *terroir* is a strictly regulated concept and only a limited number of varieties is allowed. Leaf area management modulates grapevine water status and ripening kinetics, through regulating of source/sink relationships and plant transpiration. This study conducted in Burgundy, France, from 2020 to 2023, assessed apical leaf removal as maturation slowing strategy and a water deficit mitigation strategy on *Vitis vinifera* cv Pinot Noir and Chardonnay. Six treatments were applied: moderate leaf-removal (⅓ foliage removal; LR-) and intense leaf-removal (⅔ foliage removal; LR+) at bunch closure, late intense leaf-removal (LLR+) 10 days after veraison, and moderate and intense bunch removal at bunch closure, all compared to a control. Methods included tracking veraison progression, $\delta^{13}C$ isotopic analysis and Fourier transform infrared spectroscopy performed on randomly sampled berries at harvest. During winter, pruning weight was carried out to asses vegetative expression. LLR+ presented significantly lower sugar contents throughout the analyzed seasons, while pH values followed a downward trend compared to the control. Veraison kinetics and mid-veraison date were significantly delayed in the LLR+ treatment, with an average delay of 4 days in mid-veraison date compared to the control. The isotopic analysis of $\delta^{13}C$ showed substantially lower stress in plants under LLR+ treatment. LLR+ tended to lower vegetative expression compared to the other treatments. In conclusion, intense apical defoliation constitutes an effective strategy to adapt viticulture to warmer and drier conditions, consistently delaying veraison, reducing sugar content at harvest, and improving plant water status.

SCIENTIFIC SESSION: **PLANT MATERIAL AND MANAGEMENT - POSTER**

Managing irrigation in viticulture to face climate change and preserve terroir concept: the case study of Aglianico grapevine in Campania region (Italy)

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Keywords: **climate change, irrigation management, water stress.**

ABSTRACT

The concept of terroir strongly depends on the processes of the soil-plant-atmosphere (SPA) system, particularly the relationship between grape characteristics and plant water stress. In southern Italy, climate change effects affect the SPA system’s behavior and, thus, the quantity and quality of grape production. In some cases, irrigation may be necessary to maintain the terroir concept and the current grapevine variety on the territory. In this context, within the Agritech National Research Center project (https://agritechcenter.it/it), we study the procedures for optimized irrigation management in support of the achievement of the field enological goal. The proposed approach is multidisciplinary and based on two main steps:

1. Identify functional homogeneous zones (fHZs) of the vineyard through an environmental analysis;
2. Use and test field sensors to monitor plant and soil water status to define the optimal timing and volume of irrigation to achieve the desired field oenological goals.

The experiment was conducted on an Aglianico vineyard of Tenuta Donna Elvira winery (Montemiletto – AV). The SPA system is monitored through commercial and non-commercial sensors (e.g., on vine Bioristor sensor of CNR-IMEM). The irrigation supply was realized through an automated drip irrigation system (MySOLEM) according to the measured leaf water potential (leaf at midday), maintaining its value between 1.2 and 1.5 bar during the ripening period. The results of the first year of experimentation showed a diversification of production between the theses both in quantitative terms (+ 12% yield per plant irrigated thesis) and qualitatively with an increase in acidity of about 10% (from 8.2 to 9 g/l Tartaric Acid), a small reduction in sugar content (from 24.8 to 24.4 °Brix) and a similar pH (about 3.1). The contribution will integrate the experimental results of the current year (2024) and the analyses of further qualitative parameters of the grapes (e.g., polyphenols, anthocyanins, etc.)

SCIENTIFIC SESSION: **PLANT MATERIAL AND MANAGEMENT - POSTER**

Real-time spore monitoring in vineyards by automatic air-flow cytometry

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Keywords: **grapevines, downy and powdery mildew, spore trap, real-time spore quantification.**

ABSTRACT

Fungal and fungal-like diseases such as powdery *(Erysiphe necator)* and downy mildew *(Plasmopara viticola)* can cause drastic yield/quality losses in grapevine production. Therefore, frequent and time-precise fungicide treatments are required. Disease pressure forecasting models, with reliable data on meteorological conditions and spores (fungi reproductive units) airborne concentration are essential for decision-making process of fungicide application. Considering that precise information about spore concentration is still lacking on these models, the goal of this work is to provide measured ambient spores concentrations in real-time. For this, we use an automatic air-flow cytometer developed by Swisens AG (SwisensPoleno Jupiter) for the detection and quantification of E. *necator* and P. *viticola* spores. The instrument identifies each aerosol particle using holographic imaging and fluorescence spectroscopy combined with artificial intelligence-based post-processing. In the first step, we performed laboratory measurements to obtain training data for machine learning, using naturally and artificially downy and powdery mildew-infected leaves. To differentiate and classify fungal spores measured by SwisensPoleno, we trained a multimodal Convolutional Neural Network. It resulted in 90% of correct classifications for E. *necator* and 93% for P. *viticola*. In addition to lab trials, four SwisensPoleno devices were placed in Changins vineyards for the 2023 season. As reference, a 7-day recording volumetric spore trap (Burkard®) was used. Manual disease assessment based on visual symptoms was performed during the season on vines close to the spore traps and revealed that 47% and 21% of the leaves showed downy or powdery mildew symptoms, respectively. Spores collected by the Burkard trap and counted manually in the two first weeks of August-2023 revealed an increased spore concentration for both P. *viticola* (33 and 26 spores/m^3/day, respectively) and E. *necator* (26 versus 13 spores/m3/day) in the first week (st-6th of August 2023). Data correlation between Burkard spore trap, symptom observations, and fungal spore concentrations by SwisensPoleno is under investigation.

SCIENTIFIC SESSION: **PLANT MATERIAL AND MANAGEMENT - POSTER**

Biodiversity conservation of plant and native bee communities on ecological infrastructures the Uco Valley Vineyards

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Keywords: **landscape, configuration, biological corridors, patches.**

ABSTRACT

The new vineyards in the Uco Valley, Mendoza, are established in areas dominated by native plant communities. This region, located at the foothills of the Andes Mountains, is crossed by alluvial channels and has very heterogeneous soil profiles. Consequently, many vineyards preserve various ecological infrastructures (EIs): patches and biological corridors that connect extensive natural areas.

In this framework, we aimed to characterize the plant and native bee communities present in different EIs in three vineyards of the Uco Valley, across a gradient of connectivity and area occupied by such infrastructures. These EIs have not undergone deforestation or other disturbances, apart from fragmentation during the establishment of the surrounding vineyards. During the summer of 2023, vegetation sampling was conducted in six EIs, two per vineyard, using the Point Quadrat method, and bee sampling through timed captures. Generally, all evaluated EIs exhibited high coverage of native plant species, with a predominance of dicotyledonous and native plants over grasses and exotic species. Additionally, the presence of tree species and the dominance of shrub species are consistent with the typical plant community physiognomy of this region. Specifically, analyzing the results according to a gradient of patch connectivity and area allocated to EIs, it was observed that both the richness and diversity of plant species decreased with lower connectivity and area. Conversely, the highest values of richness and abundance of native bees were obtained in vineyards with lower connectivity and area but with higher availability of floral resources.

These results support the idea that the conservation of native bees in agricultural environments is more closely linked to the habitat quality offered by different EIs (associated with composition) than to their configuration.

SCIENTIFIC SESSION: **PLANT MATERIAL AND MANAGEMENT - POSTER**

Terroir expression in organic farming. Study of the autochthonous variety Pedro Ximénez in warm climate conditions

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Keywords: **organic farming, Pedro Ximenez, physiology, warm climate.**

ABSTRACT

Terroir is currently understood as the unique characteristics of a specific location which influence crops. These characteristics, which encompass climatic, edaphological and biodiversity factors, have taken on special importance in recent years due to the effects associated with climate change and changes in cropping trends. *Vitis vinifera,* is of economic importance and the third most important crop. Furthermore, it uses high volumes of pesticides and hervicides in conventional management systems.

This research has evaluated the physiological, agronomic and enological response of the Pedro Ximénez cultivar, in conventional and organic cultivation. For this purpose, two plots with organic and conventional management systems were compared. Seven-year-old grapevines grafted on 161-49C rootstock were used. The grapevines were pruned in a simple cordon, with a space between rows and plants of 2.40 × 1.10 m, respectively.

During ripening,from August to October, photosynthetic capacity, stomatal conductance and intrinsic water use efficiency were measured. In addition, the physicochemical composition of grape must was analysed and agronomic parameters such as bunch weight and pruning weight were evaluated.

The main results show that no significant differences in gs and WUEi were found between management, although a difference in AN just before harvest was identified, suggesting that the use of phytosanitary products could be dispensable in organic management. In addition, grape must under organic management showed a higher concentration of sugar, amine nitrogen (α-NH2) and yeast assimilable nitrogen (FAN) compared to conventional management, which presented higher pH and L-malic acid values. Finally, no significant differences in bunch and pruning weights were observed between the two management systems, indicating that final yield was not negatively affected by organic management. In conclusion, the preliminary results indicate that organic management of Pedro Ximénez cultivar in warm areas is feasible and could contribute to the increase of organic agriculture in the wine industry.

SCIENTIFIC SESSION: **PLANT MATERIAL AND MANAGEMENT - POSTER**

Impacts of extreme heat and changing climate on production of anthocyanins in Cabernet Sauvignon

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ABSTRACT

Climate change is having a significant impact on grape production and quality via increases in the severity and frequency of extremes such as droughts, flooding, and heat waves (HWs). Anthocyanins are considered one of the most important classes of compounds for red wine production and are known to be sensitive to water and temperature stress. Observational data from a large-scale project across multiple sites in Napa Valley, California, show that warmer appellations have lower anthocyanin concentrations in Cabernet Sauvignon across three years as compared to cooler sites across the region, yet several other factors contributed to a large amount of variation in the results. Moreover, results suggest that small differences in time exposed to extreme temperatures have a substantial impact on anthocyanin production, providing a relatively stark picture of red wine production in the context of climate change. Experimental evidence further illustrates the impacts of high temperatures on grape quality. We present results from a field trial conducted over three years (2019-2021) in a commercial vineyard in Lodi, CA evaluating the impact of variable irrigation prior to, and during, HWs on winegrape chemistry in Cabernet Sauvignon. Our study shows that supplemental irrigation (2-3x evapotranspiration (ET)) reduced the degradation of anthocyanins, compared to the control treatment (60% ET), as well as resulting in higher yield. However, applying excessive water (3x, or 180% ET) had no additional beneficial effects on anthocyanins, or yield, relative to a more moderate supplemental application (2x, or 120% ET). The results from observational and experimental data provide an initial roadmap for viticultural decision making in response to climate change and increasing exposure to extreme temperatures by illustrating that both local climate and management practices can have significant impacts on the production, and degradation, of anthocyanins in red wine grapes.

First report of pruning and site effects on Torrontés Riojano in La Rioja, Argentina

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Keywords: **Torrontés Riojano, pruning intensity, site effect, vine balance, berry and must quality**

ABSTRACT

In Chilecito, La Rioja Province, Argentina, Torrontés Riojano (TR) is the major autochthonous variety for winemaking, yielding golden and aromatic berries and distinctive muscatel-tasting wines. This white cultivar, resulting from the natural cross between Muscat of Alexandría x Criolla Chica, is traditionally trained in “parral”, a horizontal trellis system aimed at managing vigorous canopies.

Pruning is an essential agricultural practice in vineyard management. This practice allows regulating plant vigour and improving vineyard production by modifying yield components and, consequently, wine characteristics.

We tested three pruning intensities in two environmentally contrasting sites: Colonias de Malligasta and Nonogasta, historically related to TR production and winemaking in Chilecito.

Pruning treatments were control (regular pruning), low bud load (60% of buds with respect to control), and high bud load (80% of buds with respect to control). Pruning weight, bunch number and weight, yield, berry soluble solids and must acidity were assessed in the 2021-22 and 2022-23 seasons.

Pruning treatments and contrasting sites significantly influenced yield components. Pruning intensities modulated vine vegetative vs. productive balance. High bud load in both sites increased bunch number, while seasonal effects only affected bunch number in Nonogasta. Yield varied among sites and between seasons with higher values for warmer, dryer and less saline Nonogasta. Higher soluble solids were found in low bud load pruning treatments at both sites. Total titratable acidity showed significant differences among seasons, at both sites. This variable was significantly higher in the 2021- 2022 season.

To the best of our knowledge, this is the first report on pruning and site effects on TR in Argentina. Further berry and wine chemistry will provide deeper insight.

SCIENTIFIC SESSION: **PLANT MATERIAL AND MANAGEMENT - POSTER**

Exploring local variety diversity in supreme terroir from Lisbon wine region

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Keywords: **minority and local varieties, Portuguese Ampelographic Collection, Lisbon wine region.**

ABSTRACT

The grapevine *(Vitis vinifera L.)* stands as the foremost fruit crop in Portugal, with an enduring association with wine production that spans centuries. Portugal boasts significant diversity and richness in its grapevine germplasm, encompassing both the cultivated subspecies *vinifera* and the wild vine populations, subspecies *sylvestris*.

The Lisbon Wine Region (LwR) comprises nine secondary regions: Colares, Carcavelos, and Bucelas (located in the south near Lisbon); Alenquer, Arruda, Torres Vedras, Lourinhã, and Óbidos (in the central region); and Encostas d'Aire (northern region near the Beiras region). Historically, the LwR, previously known as the Estremadura wine region, is located northwest of Lisbon. Approximately fifty years ago, this region was primarily associated with the high-volume production of wine, which was often of mediocre quality. With a singular focus on enhancing wine quality, initiated fifteen years ago through vine restructuring initiatives, the Lisboa wine region has prioritized the cultivation of the most prominent French varieties alongside eleven traditional autochthonous varieties from its nine sub-regions. This shift has led to the neglect of nearly 38 older varieties. However, all these varieties are preserved in the Portuguese Ampelographic Collection, located in Dois Portos (Torres Vedras, Portugal), which boasts the highest varietal diversity of old and minority Portuguese varieties.

Over the past five years, several agronomic and oenological studies have been conducted in these 38 minority varieties, focusing on key phenological stages such as budburst, flowering, veraison, and ripeness. Our previous findings suggest that the local varietal diversity not only enriches the quality of the wines produced but also results in wines with distinct and remarkable characteristics, each unique in its own right.

SCIENTIFIC SESSION: **PLANT MATERIAL AND MANAGEMENT - POSTER**

Can Terroir withstand with winter pruning mechanization?

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Keywords: **vineyard, pruning mechanization, terroir.**

ABSTRACT

Terroir relates the sensory attributes of wine to the environmental conditions in which the grapes are grown, including climate, soil, variety, and human practices, and how these factors interact. Meanwhile, the increasing cost of hand labor, often associated with difficulties in finding skilled workers, is driving increased interest in winter pruning mechanization among Portuguese winegrowers.

To assess the impact of winter pruning mechanization on yield components and berry quality at harvest, a three-year study was conducted from 2021 to 2023 on the autochthonous Touriga Nacional variety grafted on 110 R rootstock, involving 20-year-old vines. The study was established in a 0.20 ha experimental plot of within Quinta da Almoínha, located in Dois Portos, Lisboa wine region. A complete randomized block design was employed, featuring two replications and 10 vines per replica. The study aimed to compare a short mechanical precision box-hedged pruning (SMP) method with no follow-up correction of node number to the manual spur pruning (HP) used in the region. Both pruning treatments were performed on the same date to ensure consistency.

The results indicate that despite the bud load being approximately 8 times higher in the SMP compared to the HP (retaining 14-16 nodes per vine), the vines compensate for yield. This self-regulation mechanism results in a significant offset effect, leading to a reduction in budbreak of approximately 60% compared to HP, as well as a decrease in shoot fertility to around 35-40% of HP. The number of berries per cluster, as well as the berry weight and volume, were also reduced by SMP (70%, 90%, and 95% of HP, respectively), as a result of impaired flower formation and/or reduced fruit set, and berry growth due to source limitation. The yield of the SMP method increased 1.5 times compared to HP, with three times the number of clusters of HP but with half the weight per cluster. The SMP postponed complete berry maturation, with a lower soluble solid content at HP harvest (approximately 90% of HP content), delaying the harvest. No changes in pH, malic and tartaric acid content, or total acidity were observed.

The mechanization of winter pruning can indeed impact grape ripening, thereby influencing the characteristics of wine. However, with efficient management, winegrowers can preserve the unique expression of their vineyards' terroir. These findings underscore a resilient strategy in a dynamic wine sector facing mounting pressures for heightened efficiency and competitiveness.

SCIENTIFIC SESSION: **PLANT MATERIAL AND MANAGEMENT - POSTER**

Effects of the 140Ru rootstock on the hydraulic efficiency and safety of Cabernet Sauvignon and Syrah grapevines under field conditions in a hyper-arid environment

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Keywords: **Water relations, Pressure volume curves, Leaf hydraulic conductance.**

ABSTRACT

Rootstock selection is crucial for mitigating abiotic stress, such as drought. This study evaluated the effects of the 140 Ruggeri (140 Ru) rootstock on the physiological responses of Syrah (Sy) and Cabernet Sauvignon (CS), two genotypes with contrasting water-use strategies. The study was conducted in February 2023 in northern Chile under hyper-arid conditions, with an average temperature of 20.4°C and 67.9 mm annual rainfall. The experiment involved 8-year-old irrigated CS and Sy vines, both own-rooted and grafted onto 140 Ru, in a randomized block design. A two-way ANOVA ($p \leq 0.05$) assessed the effects of genotype, rootstock, and their interaction on stomatal sensitivity (K_{sen}), stomatal conductance (g_s), residual leaf conductance (g_{res}), osmotic potential (PSIo), turgor loss point (TLP), leaf water potential at 50% loss of conductance (P50), and maximum hydraulic conductance (K_{max}). Relationships between variables were estimated using regression analysis via the least squares method. Percent loss of conductance (PLC) and water potential (P_{50}) were calculated using a Weibull function with bootstrap methods. No significant interactions or individual effects of the factors were found. Average K_{sen} was 61.5 mmol m^{-2} s^{-1}, and g_{res} was 4.5 mmol m^{-2} s^{-1}. The averages for TLP and PSIo were -2.0 and -1.4 MPa, respectively. Own-rooted CS showed greater sensitivity (P50 = -1.2 MPa) than own-rooted Sy (P_{50} = -1.8 MPa), but P_{50} values were similar when grafted onto 140 Ru. K_{sen} was significantly related to g_{res} in 140 Ru grafted vines (R^2 = 0.4, P = 0.027), but not in own-rooted vines. K_{max} was significantly related to TLP in vines grafted onto 140 Ru. We conclude that 140 Ru improves leaf tolerance to hydraulic conductance loss, with compensation between TLP and K_{max}. Additionally, coordination between g_s and K_{max} suggests a link between productivity and hydraulic efficiency, with a possible trade-off with drought tolerance.

Malbec

SCIENTIFIC SESSION

NOV 20, 2024 | 13.30 PM | SCIENTIFIC SESSION: **MALBEC I - PLENARY CONFERENCE (KEYNOTE SPEAKER)**

The Malbec genome A keystone to understand the molecular bases of clonal variation

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Keywords: **diploid assembly, clonal variation, phenotypic diversity, transcriptomics.**

ABSTRACT

Established grapevine cultivars (*Vitis vinifera* L. ssp. *vinifera*) must be clonally propagated to preserve their varietal attributes, due to their highly heterozygous genomes. Cultivar Malbec originated in France from the outcross of Prunelard and Magdeleine Noire des Charentes. Malbec is a black-berried cultivar appreciated for producing high-quality wines, and particularly relevant for Argentina winemaking industry. Here, we have built a diploid genome assembly of Malbec, after trio binning of PacBio long reads into the two haploid complements inherited from either parent. After haplotype-aware deduplication and corrections, complete assemblies for the two haplophases were obtained with very low haplotype switch-error rate (<0.025). The haplophases alignment identified >25% of polymorphic regions. Gene annotation pipeline included RNA-seq transcriptome assembly and *ab initio* prediction evidence, resulting in similar gene models for both haplophases. However, gene enrichment analysis of each haplophases retrieved differences, associated with relevant pathways such as the stilbene biosynthesis. Quality controls of the obtained assemblies were conducted by performing comparisons with the two latest versions of the grapevines reference genome (PN40024 v4 and v5). Moreover, to prove the utility of the obtained assemblies a transcriptomic analysis was conducted, to identify differences underlying clonal phenotypic variation. Results obtained with both haplophases were consistent, although some differences were observed when differential genes expression analysis were performed with each haplophase, suggesting haplotype specific expression of some relevant genes. In this direction, differentially expressed genes were identified to explain differences on the berries' composition of different clones. Overall, we are confident that the obtained reference genome will be a keystone for upcoming works seeking to unravel the molecular bases of clonal phenotypic variation of relevant traits for the industry.

Introduction

The diploid genomes of grapevine cultivars are characterized by enormous diversity, including the many differences that typically distinguish the two haplotypes within a cultivar. The high and uneven heterozygosity of cultivated grapevines is most likely the consequence of their origin, since cultivars have originated from the outcrossing of preexisting genetically divergent cultivars (This et al., 2006). Interestingly, this relevant feature is not represented by the genotype of the available grapevines reference genomes (Jaillon et al., 2007), which was generated after several rounds of selfing (Velt et al., 2023).

Therefore, cultivars are progenies with desired phenotypic traits, that have been vegetatively propagated to retain those attributes. Even though vegetative propagation mostly ensures uniformity within cultivars, in the absence of outcrossing it also favors the accumulation of somatic mutations (Carbonell-Bejerano et al., 2019). In fact, somatic variations occur at the genetic (Vondras et al., 2019) and transcriptomic (Grimplet et al., 2019) levels, generating intra-cultivar variation and introducing phenotypic novelties (Arrizabalaga et al., 2018). Moreover, growers usually select somatic variants that might have relevance for the industry to propagate them, labelling these selections as clones or even as different cultivars. Therefore, somatic diversity has been relevant for viticulture as a source of trait innovation and adaptation (Carbonell-Bejerano et al., 2019). Considering that the global wine market is slow at accepting new varieties, a deep understanding of the variation that exists within elite varieties is crucial for intra-cultivar improvement and to meet emerging challenges from climate change (Wolkovich et al., 2018).

In this global context, Argentina is one of the top ten wine producers of the world and more than half of the wines produced in this country include Malbec, either as single varietal or in blends (INV, 2019). Malbec originated in the Cahors region (France) from the outcross of Prunelard and Magdeleine Noire des Charentes (Boursiquot et al., 2009). Malbec was introduced to Mendoza (Argentina) in the 1850s, showing a notorious adaptability and phenotypic plasticity, producing high-quality wines under very different growing conditions. In this direction, several studies have reported the great clonal diversity that exists within Malbec at the phenotypic level, including berries composition (Muñoz et al., 2014) and phenological development (van Houten et al., 2020). Also, clonal diversity has been reported at the molecular level within Malbec, including epigenetic (Varela et al., 2021) and genetic (Calderón et al., 2021) variation.

The main objective here is to present the phased and annotated genome assembly of Malbec, represented by its two haplophases, to serve as reference for intra-cultivar variation studies. Moreover, here we employed the obtained assembly in a transcriptome analysis to investigate the molecular bases of Malbec clones that differ in fruit traits relevant for the winemaking industry. The transcriptomic analysis was performed following a haplotype-aware scheme and the results obtained using each assembled haplophase as reference were compared. This allowed us to identify -potential- reference biases, and to spot haplotype-specific differentially expressed genes, that correlated with the clonal variation in berry composition.

Materials and methods

Plant material: For genome assembly samples were collected from the Malbec clone accession 136N, implanted at the Vivero Mercier Argentina (Mendoza, Argentina, 33.09° S, 68.87° W). Samples of Malbec parental cultivars were requested to the *Institut Français de la Vigne et du Vin* (VInopôle Sud-Ouest, France), corresponding to clone 1232 of Prunelard (reference number: 08-04-00004) and the unique available accession of Magdeleine Noire des Charentes (reference number: 08-04-00075).

DNA extractions, library preparation and genomic sequencing: For PCR-free Illumina sequencing, DNA was obtained from roots for all three cultivars. For the parental cultivars solely roots were used, because this tissue derives from the L2 meristem cell layer (as gametes do in grapevine) and its genotype should be closer to the inherited by Malbec. For Prunelard and Magdeleine, DNA extractions were performed with the DNeasy Plant mini kit (Qiagen). For Malbec, high molecular weight (HMW) DNA was obtained with the Nanobind plant nuclei kit (Circulomics-PacBio). Leaves were used for long read sequencing because it was the only tissue yielding the amount of HMW DNA needed for library preparation. Five PacBio Sequel I SMRT cells were loaded with the same SMRT-bell library and were sequenced with the PacBio Sequel I sequencer. Illumina PCR-free sequencing libraries were produced from gDNA of roots, using the NxSeq-AmpFREE Low DNA Library Kit (Lucigen) and sequenced to obtain paired-end short reads (150 bp).

Genome de novo assembly: The assembler Canu v1.8 was employed for *de novo* genome assembly using the TrioBinning module (Koren et al., 2018). Here, parental-specific *k-mers* from the short-reads of the parental cultivars (Prunelard and Magdeleine) were used as template to split long reads of the child (Malbec) into the haploid complements. The assembly size metrics were tested along with the quality of the phasing process, to reduce haplotype switch errors (Rhie et al., 2020). This was performed with Merqury v1.3 (Rhie et al., 2020), based on the count of haplotype specific *k-mers* (i.e., *hap-mers*) from the short reads of Magdeleine and Prunelard as compared to Malbec short reads and the assembly *k-mers*. *Hap-mers* were used to determine phase blocks, defined as sets of markers inherited from the same parental haplotype (Rhie et al., 2020). To perform miss-assembly corrections, RaGOO v1.1 was used to split contigs that may generate spurious structural variations using the PN40024 12X.v2 as reference. A final manual deduplication was conducted based on the gene content of the contigs spotted as haplotype switches by Merqury, and on BUSCO duplicated genes identified using the orthologue plant core genes database (eudicotyledons_odb10) and BUSCO v3.0.2. When ≥2 BUSCO genes with different IDs were duplicated in the same order in another region of the same haplophase assembly, the duplicated copy spotted by Merqury as haplotype-switch error was considered as an artifactual haplotype duplication leaked to the wrong haplophase. RagTag v1.0.1, using the PN40024 12X.v2 assembly as reference, was employed for the final scaffolding of the deduplicated haplophases into the pseudo-molecules that represent the 19 chromosomes of grapevine haploid complement.

Genome annotation: EDTA v1.9.6 was employed for the annotation of repeats and transposable elements (TEs), and to softmask the repeated regions. For gene annotation a pipeline combining gene evidence obtained from different sources based on EVidenceModeler v1.1.1 was implemented. Here, *de novo* assembled transcripts, *ab initio* predictions and gene lift-over data were combined. Transcriptome assembly was produced from an RNA-seq dataset obtained from berry pericarp of eight different Malbec clones and their biological replicates. For transcriptome assembly, the trimmed RNA-seq reads were aligned to the diploid Malbec genome assembly using HiSat2 v2.2.1. The obtained alignments (*bam* files) were merged into a single *bam* using samtools v1.10 and assembled into potential transcripts with StringTie v2.2.1. TransDecoder v5.7.0 was used to identify the likely coding sequences (CDs), adding them to the annotation files. *Ab initio* gene predictions were performed with Augustus v3.5.0. Also, a lift-over of the PN40024.v4 gene annotation to the Malbec haplophases assemblies was conducted with Liftoff v1.6.1. The weighed consensus gene models for Malbec diploid and unmasked genome assembly were obtained with EVidenceModeler, using the evidence obtained from the described sources. The final combination of evidence inputs and weights was selected after comparing the obtained gene models to the deeply curated PN40024.v4. Functional annotation to predict gene ontology (GO) classes and gene functional description (DE) was performed with Panzzer2, using as input the *fasta* files containing all the protein sequences of each haplophase. Finally, EDTA v1.9.6 was used to annotate centromeric repeats on the Malbec diploid assembly.

Phenotypic and transcriptomic clonal variation: A survey focused on berry composition variation was performed on 27 Malbec clones, with three biological replicates. All analyzed plants were located in the same plot at Vivero Mercier Argentina (Luján de Cuyo, Mendoza, Argentina), implanted since 2002. Therefore, the analyzed plants have been exposed to the same cultural treatments and environmental conditions ever since. Phenotypic measurements were conducted during 2018 on mature berries. For each biological replicate a random sample of 50 berries was obtained and the pulp was separated from the skin. Four Malbec clones (595, 596, 136N and 505) were selected after a ranking-based procedure, based on phenotypic data obtained for the 27 clones in 2018. The selected samples combined high, mid and low values for the surveyed traits, aiming to represent as much as possible of the observed variation. Berries used for total RNA extraction were sampled during *veraison* stage (when 75% of berries were colored); a transcriptionally active stage for genes involved in secondary metabolism pathways (Massonnet et al., 2017).

All forthcoming bioinformatic procedures were performed following a haplotype-aware scheme, using separately and in parallel both Malbec haplophases as reference genomes. Alignment of the trimmed reads was conducted with STAR, the assembly of the aligned reads with StringTie, and GffCompare was used for extraction and annotation of transcripts. The read counting of the aligned *bam* files was performed with FeatureCount. Heatmaps and PCAs displaying the global gene expression were built in R, based on the regularized log transformation of the normalized counts (rld), obtained with DESeq2. To detect differentially expressed genes (DEG) with DESeq2, pairwise comparisons among the four clones were performed. The threshold to consider a gene to be differentially expressed was set to a p-value<0.01 (FDR-adjusted) and an absolute value of log2 fold-change $|LFC|\geq 1$. For all GO enrichment analysis the g:GOSt function of g:Profiler was implemented using the PN40024.v4 functional annotation as reference. Aiming to compare DEGs and BPs identified with each of Malbec haplophases, the orthologue genes obtained with Orthofinder were employed. The aggregate scores and z-scores were obtained and graphically represented with the R package GeneTonic.

Results and discussion

Here we obtained the haplotype-resolved and annotated genome for Malbec, composed of the two haploid complements inherited from its parental cultivars: Prunelard and Magdeleine. We tested Malbec diploid assembly utility as reference genome, by performing an evaluation of the transcriptomic differences underlying clonal phenotypic variation.

Malbec genome assembly was obtained in a trio-based approach, applying the prior knowledge of Malbec pedigree. The use of parental genomic reads improved the phasing and evaluation of the assembly processes (Fig. 1). The estimated assembly accuracy for Malbec (QV > 40) indicates that error *k*-mers in the haplophase assemblies are < 0.00001%, which is slightly above the accuracy (QV=37.43) reported for the PN40024v4 reference genome (Velt et al., 2023). Parental-specific *k*-mers (*hap*-mers) from short read sequencing of Malbec parents identified very few blocks that were apparently switched (<0.025%) (Fig. 1). The diploid assembly also enabled a genome-wide study of the variation between the two Malbec haplotypes that showed ca. 25% of polymorphic regions. Almost half of Malbec genome consists of repetitive sequences and transposable elements (TE), with long terminal repeats (LTRs) representing the most abundant class of TEs (Fig. 1). This is in agreement to the observed in other grapevine cultivars, including the PN40024v5 (T2T) (Shi et al., 2023). Also, annotated gene number was similar in the two Malbec haplophases and to the PN40024v4 and v5 latest versions of the reference genome. Interestingly, in Malbec close to 6% of genes did not have a counterpart mapping on the other haplophase. Furthermore, an enrichment of the resveratrol biosynthetic pathway in Malbec-Mag specific genes was observed, suggesting for a putative higher contribution of this haplotype to a key secondary metabolite in grapevines.

We searched for consistent phenotypic and transcriptomic variation among Malbec clones that were cultivated in the same vineyard for over 20 years. Four clones were selected for analysis, based on their consistent variation in berry composition during 2018 and 2019 seasons. Clone 595 had reproducible higher levels of total polyphenols and anthocyanins berry content at harvest. At the same time, it was the only clone with significant transcriptomic differences from the others (Figs. 2A and 2B). Functional enrichment of DEGs indicated for abiotic stress response deregulation in 595 compared to the other three clones. On the other hand, phenylpropanoid and anthocyanin biosynthesis genes were consistently upregulated in 595, in agreement with the observed phenotypic differences (Fig. 2C). In our analysis, statically enriched processes correlated with the phenotype of the mature berry. Particularly, we identified ABA-related DEGs in Malbec clone 595 that might be major drivers of its global transcriptional profile and phenotype (Fig. 2C). These expression patterns suggest that ABA over-accumulation or hypersensitivity could be a feature of clone 595. We hypothesize that somatic mutations in VviPYL1 of clone 595 could trigger its over-expression and the hyperactivated ABA gene expression responses compared to other clones (Fig. 2C).

The overexpression of *VviUFGT* in 595 compared to the other three clones could ultimately result in high berry anthocyanin content of this clone, since UFGT plays a critical role in the synthesis and accumulation of anthocyanins in grape berries (Fig. 2). Therefore, ABA signal hyper-activation in 595 could potentially over-activate the flavonoid pathway leading to the higher phenolic character in 595 fruits (Fig. 2B). In addition, the putative allele-specific overexpression of *VvMYB157/MYB66* in 595 could be involved in the deregulation of the ABA signaling and the upregulation of the anthocyanin biosynthesis pathways characterizing this clonal line (Fig. 7B). *VvMYB157* might be particularly relevant in Malbec clonal anthocyanin content variation, since this cultivar is homozygous for *VvMAYBA1* and *VvMYBA2* loci and no evidence of differential gene expression was detected here.

Conclusions

We have assembled the diploid genome of Malbec in two haplophases of the expected size, phase and gene composition. Similar results were obtained in our RNA-seq comparison of Malbec clonal variants with either haplophase used as reference, nonetheless some haplotype-specific gene expression differences could be spotted thanks to the phased genome assembly. Finally, the obtained assembly allowed us to propose the occurrence of a somatic variant, causing the hyperactivation of ABA signaling and the differential activity of a MYB transcription factor might be responsible for the increased berry anthocyanin content in clone 595. We consider this assembly will be a keystone in future analyses, to unravel the genetic bases of the clonal variation for other relevant traits for the wine industry, such as the fruit set rate and fungal pathogens tolerance.

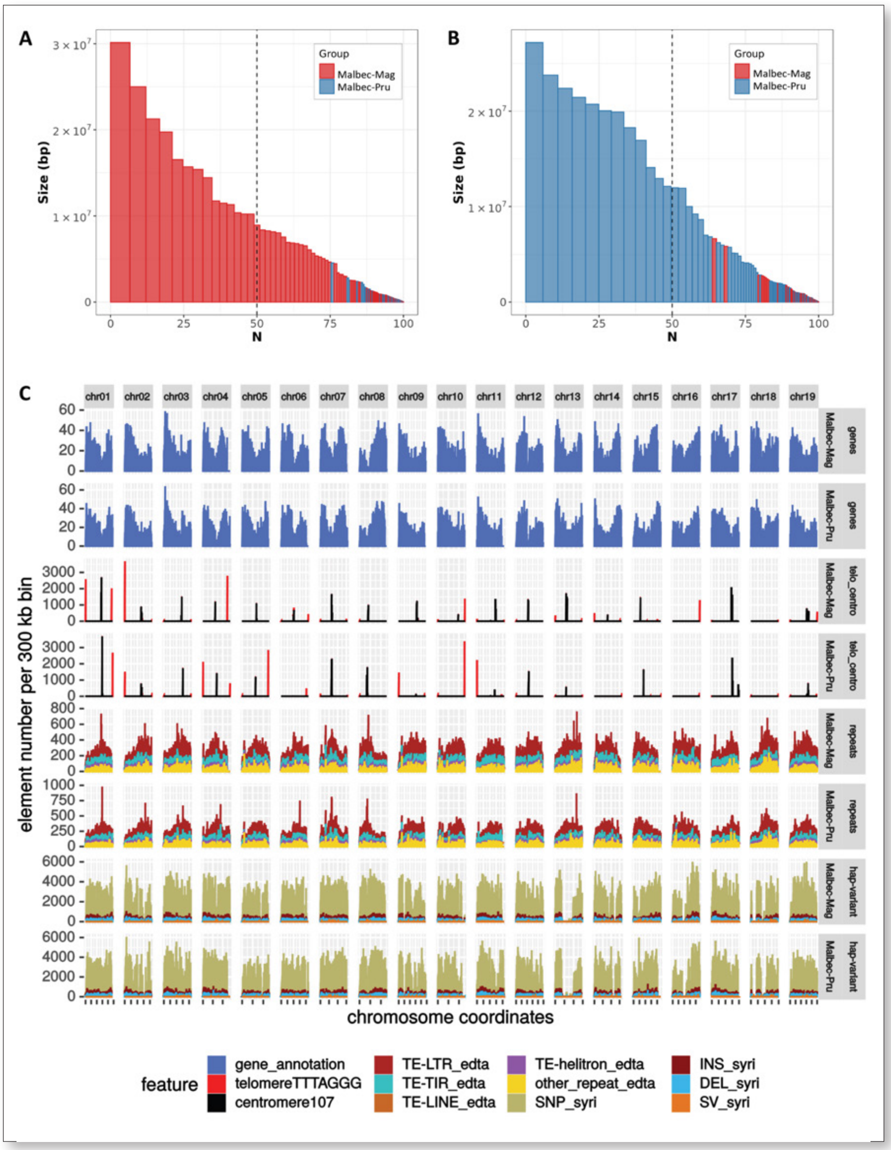

Figure 1. Malbec phased blocks and distribution of annotated features on the obtained assemblies.

(A) Malbec-Mag and (B) Malbec-Pru assemblies phasing evaluation. (C) Annotated features along the 19 scaffolded pseudomolecules for Malbec haplophases, including: gene density, centromeres, telomeres, transposable elements and haplotype variants (SNPs, INDELs, SVs). Temperature in the Growing Season (R pearson 0.75; p value 0.0001), (C) Grapes' Total Acidity at harvest and January Minimum Temperature (R pearson 0.83; p value 0.0001), (D) Berry weight at harvest and Number of days above 30ºC (R pearson -0.67; p value 0.01).

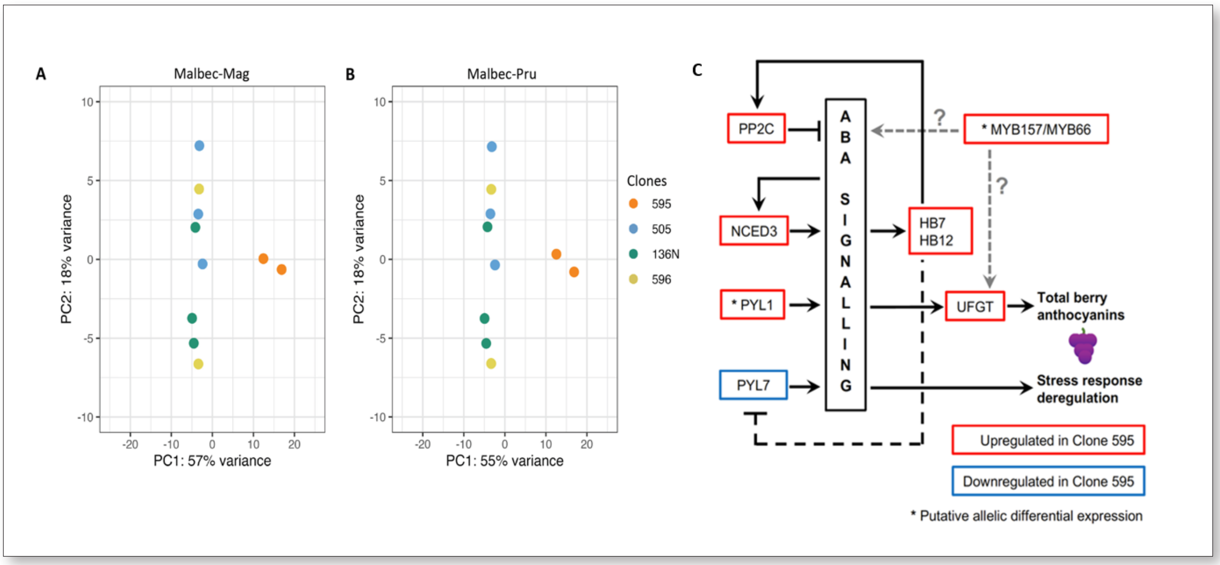

Figure 2. Transcriptomic clonal diversity and proposed gene expression model for clone 595. A) and B) PCAs showing the transcriptomic clonal differentiation retrieved with both Malbec assemblies, each dot represents a biological replicate for the four analyzed clones. (C) Proposed model for the origin of the higher berry anthocyanin content in Malbec clone 595.

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NOV 20, 2024 | 14 PM | SCIENTIFIC SESSION: **MALBEC I - SCIENTIFIC ORAL**

Argentine Malbec market: comparative study of global chemical parameters and sensory properties within low, medium, and high price segments

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Keywords: **Malbec, wine, Argentine market, price segments, chemical properties, sensory properties.**

ABSTRACT

Malbec, Argentina's emblematic wine, is appreciated worldwide for its unique characteristics and distinctive organoleptic profile. As demand for Malbec wines increases locally in Argentina and international markets, there is a need to better understand the relationship between the price of these wines and their chemical and sensory characteristics. The aim of this study was to describe and quantify the sensory attributes and chemical parameters (in particular, phenolics) of Argentinean Malbec wines of different price segments. In order to observe the differences between each price range, the eight best-selling wines from the low, medium, and high price categories were analyzed. Wine general analytical parameters and phenolics composition were determined and a descriptive analysis was performed with a trained panel. The results show that it was only possible to differentiate between the high- and low-price ranges. Both ranges exhibited variability, including different types of wines. Significant differences were identified in several parameters such as O.D.280, titratable acidity, malic acid, volatile acidity, alcohol, glucose and total sugars. There were also significant differences in anthocyanins, LPP, SPP, TPP and tannins. The high-price range was characterized by higher alcohol content, greater polyphenol concentration, and greater color intensity. Sensorially, they were distinguished by the descriptors wood, astringency, and color. The low-price range was recognized by low color intensity and higher total sugar content. This is the first study to clearly establish the sensory differences among different price ranges of Argentine wines. Our study has demonstrated that wine pricing is not determined in a subjective or arbitrary manner; rather, wines produced for a specific segment are intentionally designed to achieve the desired sensory and chemical characteristics.

Introduction:

Malbec, Argentina's emblematic wine, is appreciated worldwide for its unique characteristics and distinctive organoleptic profile. In 2023, of the total Malbec wine sold, 51% was distributed in the domestic market, while 49% was exported. Notably, Malbec accounted for 64% of all Argentine wine exports (I.N.V., 2024). As the demand for Malbec wines continues to rise both domestically in Argentina and internationally, it becomes increasingly important to understand the relationship between the price of these wines and their chemical and sensory characteristics. This knowledge could offer significant advantages to wine producers, enabling them to optimize production processes, improve wine quality, and strategically position their products in the market to maximize profitability.

Research studies around the world have explored the relationship between the chemical and sensory characteristics of wines concerning various attributes such as price, region of origin, vineyard management, and even the impact of global climate change. Bruwer & Johnson (2010) demonstrated that wine characteristics such as grape variety, barrel aging and physicochemical and sensory attributes significantly influence wine price. Other authors (Boselli et al., 2004), who focused on the appellation d'origine contrôlée (DOC) of Italian wines and their sensory profiles, illustrated the methodological rigor required for this type of analysis. Moreover, Lecocq & Visser (2006) examined the complex interactions between wine prices and intrinsic and extrinsic characteristics in the French market. They highlighted the significant role of consumer preferences and the chemical composition of wines in determining market prices, underlining the importance of both technical and perceptual considerations in pricing strategies. Similarly, Cox (2009) explored red wine consumption patterns in an Australian urban setting, identifying variability in consumer perceptions and a lack of clear correlation between perceived quality and purchase intentions. This emphasizes the need for robust methods to accurately measure wine enjoyment and consumer behavior.

Locally, Antoniolli et al. (2011) indicated that the relationship between consumers' willingness-to-pay price and blind tasting quality of Mendoza wines is not always direct. This research focuses on wines produced in Mendoza, Argentina. Fanzone et al. (2011, 2012) determined that Malbec wines have a higher polyphenolic content compared to other varieties, and they conducted the first characterization of individual phenolic compounds from Mendoza, Argentina. Orrego (2014) explored European consumers' willingness to pay for Argentine Malbec, focusing on its geographical origin. This work provided a deep understanding of the perceived quality and value of Malbec wines in the international context. Additionally, another contribution to this topic was linked to the study of the hedonic prices of Argentine wines in the U.S. market, to evaluate the effect of the most important wine attributes on price (San Martín et al., 2008). Similar to our study, Cáceres et al. (2012) studied wines and grapes from the Cabernet Sauvignon variety across three different price categories and found no correlation between higher prices and polyphenol concentration. Differences were observed only in tannin concentration. An & Yu (2023) studied the influence of sensory attributes on the estimated price of Pinot Noir wines in New Zealand, analyzing 78 commercial wines. They conducted a descriptive analysis with a trained panel, along with phenolic analyses. They found that the descriptors "aging potential" and "oak influence" had a significant impact on the prices estimated by experts. Working specifically with the Malbec variety Fanzone et al., (2012) studied the phenolic and polysaccharide composition across three price ranges (high, medium, and low) for Malbec and Cabernet Sauvignon wines. Fanzone conducted a comprehensive study of phenolic groups and individual phenolic compounds, although the sensory analysis had some limitations. These limitations included a small number of training sessions. Furthermore, this study only evaluated color and mouthfeel descriptors, which were used without any reference standard.

While previous studies have provided valuable insights, particularly in the area of phenolic compounds, there is still a lack of comprehensive information at the sensory level, and even more so in linking phenolic composition with sensory attributes in Malbec wines. In this context, our study aimed to describe and quantify the sensory attributes and chemical parameters (in particular, phenolics) of Argentinean Malbec wines of different price segments. To observe the differences between each price range, the eight best-selling wines from the low, medium, and high price categories were analyzed both chemically and sensorial.

Materials and methods:

The top eight selling Malbec wines from the three main price ranges in the Argentine market were evaluated, conducting three repetitions for both general analytical assays and sensory evaluations. The selected wines were categorized into the following price categories: Low Range Malbec, priced from $400 (USD 2.00) to $930 (USD 4.65); Medium Range Malbec, priced from $931 (USD 4.66) to $2000 (USD 10.00); and High Range Malbec, priced above $2001 (USD 10.01), based on prices from the year 2021.

Sensory analysis

Considering the sensory description of wines, in this research, we implemented a methodological approach based on Descriptive Analysis as outlined by Heymann (2010), adapted to examine three distinct price ranges in Malbec wines. For this study, the evaluated wines will fall under three denominations: "Low Range," "Medium Range," and "High Range."

Twelve panelists, aged between 21 to 64 years, nine of whom had prior experience in descriptive analysis, were recruited from the database of the Enological Studies Center of INTA EEA Mendoza. These panelists participated in twelve 45-minute training sessions over a period of three weeks. The training was followed by nine 45-minute evaluation sessions over four weeks (Heymann & Noble, 1987; Hopfer et al., 2012). Each wine range was tasted at least twice in a blind setting during the training sessions. Evaluations were conducted in the sensory laboratory of the Enological Studies Center of INTA EEA Mendoza, using black technical glasses (ISO 3591:1985) for the assessment of olfactory and gustatory aspects. For the attributes of aromas and flavors, panelists were presented with subsets of wines during the training sessions and asked to generate, combine, and define all perceived attributes regarding aromas and flavors.

After defining the general organoleptic characteristics of all tasted samples, totaling 28, reference standards were developed.

The requirement was set to evaluate each sample in three instances. In this context, it would be impractical to expect a sensory panel to effectively evaluate more than 24 samples. After training, at the beginning of each evaluation session, participants practiced with reference standards for each initially defined olfactory and gustatory attribute. Eight wines per session were evaluated using a Williams Latin square design.

For their evaluation, panelists used electronic devices (smartphones) to indicate the intensity found for each descriptor and in each proposed wine, marking on a scale from 0 to 10 according to the perceived intensity of the descriptor in question.

All wines were evaluated in three independent rounds. Regarding visual assessments, clear technical glass cups (ISO 3591:1985) were used. Panelists were tested for color vision in the first training session using pseudoisochromatic color test plates and all were considered to have normal color vision, as they could identify at least six of the seven test plates correctly. Wines evaluated in each session were selected randomly, considering both price ranges and the necessary repetitions. In each session, panelists received wines in numbered cups with each wine and three random digits, ensuring no association with the previously established nomenclature for each sample.

Chemical analysis

In this study, all analyzed samples underwent a standardized pre-treatment process to ensure uniformity at the time of analysis and homogeneous conditions across all cases. During the tasting sessions for each batch of samples, 50 mL of each evaluated wine was extracted and placed into 50 mL Falcon tubes, which were properly labeled and arranged in racks. The samples were subsequently stored in a freezer at -20°C for freezing. Once all samples were collected, they were thawed at room temperature for four hours in the laboratory as an initial step before commencing with the respective analyses.

The general parameters analyzed included volatile acidity (g/L), alcohol content (% v/v), glucose (g/L), fructose (g/L), total residual sugars (g/L), titratable acidity (g/L), pH, lactic acid (g/L), malic acid (g/L), density, and absorbance at 280nm (OD 280nm). These determinations were conducted using an infrared autoanalyzer, W&G Company Model OenoFoss 2017, located at the INTA EEA Mendoza Enological Studies Center.

Prior to the phenolic parameters determination, wine samples were centrifuged (11,000 g, 5 min) and filtered (0.45 μm). Absorbance measurements were conducted using a UV-Visible spectrophotometer (Perkin-Elmer Lambda 25, Hartford, CT, USA). Tannin content [eq. (+)-catechin, mg/L] was determined via the protein precipitation method proposed by Harbertson et al., 2002. Total anthocyanin concentration (eq. malvidin-3-glucoside, mg/L), and the proportion of small polymeric pigments (SPP), large polymeric pigments (LPP), and total polymeric pigments (SPP + LPP) were measured following methodologies described in previous studies (J. Harbertson et al., 2003). Iron-reactive phenolic compounds (total phenols) were analyzed following the technique proposed by Heredia et al., 2006.

For the characterization of wine color, the CIELAB color space was used (Gordillo et al., 2012), following the recommendations of the International Commission on Illumination (Central Bureau Vienna, 2004). The CIELAB parameters [L* (lightness, 0 black and 100 white), Cab (saturation), hab (hue; red, green, yellow), and the coordinates ab* (red/green; yellow/blue)] were calculated from the absorption spectrum (380–780 nm) at 1 nm intervals using 1 mm path length glass cuvettes, utilizing the R package colorscience (Color Science Methods and Data [R Package Colorscience Version 1.0.8], 2019).

The relationship between significant ($p < 0.05$) chemical and sensory attributes was analyzed by multiple factor analysis. Figure 1 shows correlation plot (A) and wine score (B). The first two components explained 65% of the variability.

The high-range wines were characterized by wood, animal leather, nut, astringency, color intensity and violet hue. The degree of overlap between vectors indicates the strength of the relationship between chemical and sensory variables (Figure 1A). As expected, astringency was correlated with the tannin content of the wines. Similarly, violet hue showed a correlation with anthocyanins, while color intensity was linked to the CIELAB parameters a* and b*. The red hue was associated with hab, as well as with descriptors such as wood and animal leather, which were in turn correlated with polymeric pigments. On the other hand, the low-range wines were correlated with fruity and floral notes. These descriptors were correlated with L, malic acid, and sugar. Interestingly, the fruit and floral sensory descriptors showed a negative correlation with aging-related descriptors, such as wood, animal leather, and polymeric pigments. Finally, the wines in the mid-price range were characterized by hab and b*, volatile acidity and tartaric acidity Figure 1B shows the individuals wine scores from the different price ranges. Ninety-five percent confidence ellipses were constructed, so non-overlapping ellipses indicate statistically significant differences. There were differences between the high and low-range. In the case of the high-price range, the ellipse was more dispersed, reflecting the variability in this category, which ranges priced above U$D 14.01. For wines in the medium-price range, the ellipse was more compact, indicating a greater similarity among these wines in terms of their sensory and chemical characteristics.

In the medium-price range, there is an overlap with the low- and high-range, but with a greater influence of other descriptors typical of more evolved or structurally complex wines, such as Nut, Animal Leather, and Red Hue. The interaction between phenolic compounds, such as tannins, and lignans present in oak wood leads to the formation of complexes that release olfactory descriptors like almonds and nuts. Furthermore, the influence of indigenous or added microorganisms during the winemaking process, such as native yeasts, has been discussed by Esteve-Marzos et al. (2001). These microorganisms can produce volatile compounds, such as fatty acids or ethyl phenols, which contribute to animal leather notes. These characteristics may be associated with a more complex style of wines, linked to wines that have undergone some oak aging or are also called Reserva. In the medium wine range, we find characteristics attributable to wines from the low range and others similar to the high price range.

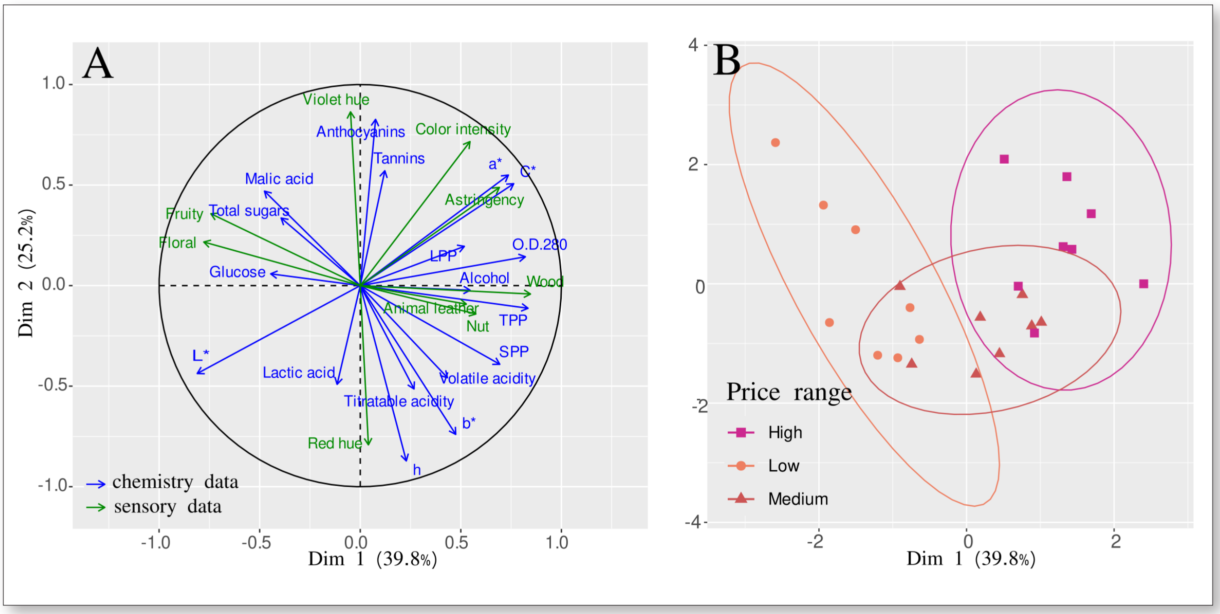

Figure 1. Multiple factor analysis (MFA) of significant chemical and sensory attributes (A) Circle plot of MFA correlations among significant chemical attributes (blue) and sensory attributes (green); (B) MFA individual plot showing wine scores.

Conclusion:

This is the first study to clearly establish the sensory differences among different price ranges of Malbec Argentine wines. The results show that it was only possible to differentiate between the high- and low-price ranges. Both segments exhibited some variability, including different types of wines. The mid-price wines showed very little variability and overlapped with both the high- and low-ranges. The high-price range was characterized by higher alcohol content, greater polyphenol concentration, and greater color intensity. Sensorially, they were distinguished by the descriptors wood, astringency, and color. The low-price range was recognized by low color intensity and higher total sugar content. The most related sensory descriptors were floral and fruity, although they did not significantly explain this range. Our study has demonstrated that wine pricing is not determined in a subjective or arbitrary manner; rather, wines produced for a specific segment are intentionally designed to achieve the desired sensory and chemical characteristics. We could identify distinctive descriptors that differentiate various wine ranges and explain pricing based on specific sensory and chemical characteristics. These results provide invaluable information for the wine industry, offering the opportunity to enhance quality, marketing strategies, and product positioning, grounded on scientific evidence and objective criteria. Further research is required on this subject and its connection to viticultural practices, environmental factors, winemaking techniques, and the aging process. It would also be important to conduct preference and acceptance studies, linking this information with the results of descriptive analysis to determine which descriptors are preferred by consumers in each price range.

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NOV 20, 2024 | 14.15 PM | SCIENTIFIC SESSION: **MALBEC I - SCIENTIFIC ORAL**

Phenology and thermal demand of Malbec grapes under double-pruning management in the subtropical conditions of Brazil

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Keywords: **double-pruning, Malbec, phenology, climate condition, season duration.**

ABSTRACT

The 'Malbec' cultivar *(Vitis vinifera)*, of French origin, has consolidated its cultivation in Argentine vineyards, in the region near the Andes Mountains and irrigated by the Mendoza River, resulting in wines with high typicity, internationally recognized, and distinguished by a large number of enthusiasts in Brazilian territory. With the expansion of viticulture, new cultivation techniques are emerging, such as double pruning, which has allowed the reversal of the vine's productive season, with fruiting and phenolic maturation occurring during the winter period in Southeast Brazil. Thus, the objective of this study was to characterize the duration of phenological stages and thermal requirement of 'Malbec' grapes, cultivated in the double pruning system, under subtropical climate conditions. The experiment was conducted in the vineyard established at Fazenda Santa Lúcia do Tietê, in the municipality of Mineiros do Tietê - São Paulo. The vines were grafted onto Paulsen 1103 rootstock, trained in a trellis system with a spacing of 3.0 x 1.0 m. Training pruning was performed in August 2022, and production pruning in February 2023. The experimental design was randomized blocks, comprising 40 vines divided into 8 blocks with 5 plants per experimental plot. The duration of phenological stages was evaluated, measured by the duration of each phenological phase, and the thermal requirement was characterized. Climatic data were obtained from a meteorological station installed in the vineyard, where the sum of degree-days from pruning to harvest was calculated. The obtained data were subjected to Descriptive Statistics analysis. The duration of the 'Malbec' productive season was 171 days after pruning (DAP). Regarding the thermal requirement, 'Malbec' presented an average of 2102.5 degree-days. The use of the double pruning technique enabled a season close to that of the same variety produced in Mendoza. Further studies are necessary to highlight the variety's behavior in repeated harvests.

Introduction:

The grape variety 'Malbec' *(Vitis vinifera)* originated in France, with a long history of cultivation. However, its presence became consolidated in Argentine vineyards, especially in the Andes Mountain region irrigated by the Mendoza River and around the city of Mendoza, notably in Luján de Cuyo (Johnson, 2008). Currently, 'Malbec' wines enjoy an emblematic status in Argentina, being widely recognized and valued in the international scene (INTA, 2007). Nevertheless, other countries have ventured into 'Malbec' production to meet the growing global demand for wines, such as Brazil (OIV, 2021). According to Eveche and Liberato (2022), Malbec red wine is the most consumed among Brazilians.

With the high demand for wine consumption, the need for increased production is linked to new producing regions. In viticulture, phenology studies are fundamental to provide an indicator of the climate of the potential production region and to understand the chemical changes that occur during fruit ripening (Callili et al., 2023). Therefore, the characterization of the duration of phenological phases is important for a better understanding of the influence of annual climatic conditions on vine development and will assist in decision-making regarding cultural and phytosanitary vineyard management, as well as in the logistics of wine raw material processing, in order to minimize fruit quality loss (Sánchez et al., 2023).

In Brazil, grape ripening and harvest occur in the summer, conditions that are not ideal for the production of fine wines. This happens due to higher rainfall, high cloud cover, high temperatures, and lower thermal amplitude. This scenario leads to the emergence of fungal diseases, compromising the health of the grapes and consequently creating unfavorable conditions for their full ripening, as there is a dilution of compounds in the berries that influence wine quality (Borghezan, 2017). For the production of quality wines, it is crucial that grapes have adequate phenolic and aromatic ripeness. To address issues of inadequate ripening and fruit health, double pruning is an indispensable management alternative for the production of fine wines (Leeuwen, 2022). The double pruning technique, pioneered by the Empresa de Pesquisa Agropecuária de Minas Gerais (EPAMIG), involves reversing the grapevine's season to the autumn and winter period (Regina et al., 2006). The technique consists of two prunings on the vine: the first pruning in mid-August for shoot formation, removing the inflorescences, and between January and February, the fruit production pruning is performed, shifting the ripening and harvesting period to the months of June to August, during the winter season with lower precipitation (Favero et al., 2008). The change in ripening and harvesting time aims to avoid the rainy season in the summer, increasing the potential for accumulation of soluble solids, organic acid balance, and other quality components for winemaking (Mota et al., 2009).

However, variables such as climate patterns can influence the duration of phenological seasons and thermal demand (Tecchio et al., 2019). Characterizing phenological stages and measuring thermal demands are used to identify the climatic potential of a particular region for grape production. In viticulture, phenology, temperature requirements, and grape maturation development are essential, with establishing a balance between soluble solids and acidity levels being fundamental (Callili et al., 2022). Double pruning is the alternative to these conditions, favoring the production of *vinifera* grapes in regions where there was no tradition of viticulture, thus creating new 'terroirs' (Pereira et al., 2020). This technology generates fine winter wines with high levels of healthiness, sugar accumulation, acidity balance, and concentration of anthocyanins and tannins, factors responsible for the color and structure of the wine (Souza et al., 2020). In this context, the objective of the present study was to characterize the duration of phenological stages and the thermal requirement of 'Malbec', cultivated under double pruning, in subtropical climate conditions, and contribute to the production of fine winter wines in Southeast Brazil.

Materials and methods:
The experiment was conducted in the vineyard established at Fazenda Santa Lúcia do Tietê SN Bairro das Contendas, located in the municipality of Mineiros do Tietê - São Paulo, situated at 22°32'25'' S, 48°24'13'' W, and 580 meters above sea level. According to the Köppen-Geiger climate classification, the region is characterized as Cfa, a hot-summer humid subtropical climate, with the average temperature of the warmest month exceeding 22 ºC and in the coldest month below 18ºC (Cunha & Martins, 2009). The 'Malbec' grapevines were grafted onto Paulsen 1103 rootstock, trained using the trellis system with a spacing of 3.0 x 1.0 m. Training pruning was performed in August 2022, and production pruning was carried out in February 2023. The vines were arranged in planting rows with 40 plants, totaling 8 blocks with 5 plants per experimental plot, in a randomized block experimental design. The climatic data were obtained from a meteorological station owned by the vineyard property and were made available through a platform that provided meteorological data for the period of the year 2023. During the production seasons, from July to December, the average minimum temperature was 16.4°C in 2023, while the average maximum temperature was 28.8°C in 2020. The accumulated precipitation during this period was 477 mm in 2023, with a tendency for concentration in the summer months (Figure 1). The duration of each phenological phase was determined in days after pruning (DAP), through visual observations made three times a week. The periods evaluated included from Pruning to Budburst, Full bloom to Setting, Setting to Veraison, Veraison to Ripening and Total Degree Days. Thermal demand was quantified using the concept of degree-days (GD), calculating the sum of the average temperature minus 10°C multiplied by the number of days after pruning, according to the equation proposed by Winkler (1965): GD = Σ (average temperature - 10°C) × days after pruning. For the duration of phenological stages and thermal requirement, the obtained data were subjected to Descriptive Statistics analysis.

Results and discussion:
The duration of the 'Malbec' grape season from pruning to budbreak and flowering was, respectively, 11.7 and 43.2 days, and from flowering to fruit set was 3 days. It was found that the longest period between phenological stages was between ripening and harvest, which lasted on average from 95 to 171 days after pruning (DAP), respectively. Thus, the duration of the 'Malbec' grape's productive season was 171 days after pruning (DAP) (Table 1). In a study conducted by Nascimento et al. (2015) in 2015, under Brazilian semi-arid conditions, in the sub-medium of the São Francisco Valley, the Malbec variety had a season of 116 days, highlighting the influence of climate on the duration of phenological stages. In the Mendoza region, Argentina, the duration of the 'Malbec' grape season was 180 days (INV, 2004), 9 days longer than the present study (Table 1). The Mendoza region is considered a desert climate according to Köppen and Geiger, classified as BWk, with harsh winters, hot summers, very high radiation, and low cloudiness. These conditions are similar to the autumn and winter of the subtropical condition,

which presents a large thermal amplitude between day and night and low relative humidity, with an annual average of 30% (Governo de Mendoza, 2017). From February onwards, the grape harvest begins in the Argentine vineyards of 'Malbec'. During spring in Mendoza (September to November), the average temperatures range between 10°C and 25°C. In summer (December to February), temperatures can reach up to 35°C during the day and drop to around 15°C at night. In autumn (March to May), temperatures gradually decrease to a range between 5°C and 20°C. In winter (June to August), temperatures are lower, ranging between -2°C and 15°C (Mezzatesta et al., 2022). Although the double pruning harvest occurs in winter under subtropical climate conditions, there are higher temperatures compared to the traditional cultivation region in Argentina during the harvest, resulting in a 9-day reduction in the 'Malbec' harvest in the double pruning management. The phenological characterization of grapevines varies depending on the climatic conditions of each region (Farias, 2017) and has been widely studied in various wine regions in Brazil. Thus, studies establishing thermal indices are indispensable for viticultural activity, as they can demonstrate variations in thermal requirements and the number of days to complete the season for the same cultivar (Tomazetti et al., 2015). However, the expansion of vine cultivation exposes plants to climatic conditions different from those known in their place of origin, which can cause phenological alterations (Alves; Tonietto, 2017). Grapevines change their phenological behavior and the necessary thermal accumulation to complete the season when grown in locations with distinct micrometeorological conditions (Pires; Lima, 2018), which can interfere with plant growth and development, as well as the productive and qualitative characteristics of the fruits. One possible application of this research is to allow the adaptation of 'Malbec' in this subtropical region due to its adaptation. In the evaluated season, the variety produced grapes with suitable characteristics for the production of quality fine wines, showing promise for this non-traditional region in fine grape production, even when compared to the Mendoza region in Argentina. Regarding thermal requirements, the season of the 'Malbec' vine averaged 2102.5-degree days (GD), while the duration of the following phenological phases was measured in days after pruning over one production season: budburst, full-bloom, setting, veraison, and ripening were 179.8, 500.5, 56.5, 625.6, and 740.1 GD, respectively (Table 2). In the present study, the results of thermal accumulation (GD) for the 'Malbec' cultivar were very close to those found in an experiment conducted under Aw climate conditions in northeastern Brazil, with thermal requirements of 1,580.03 degree-days (Moraes et al., 2015). Double pruning, by occurring in colder months during its maturation, tends to increase thermal requirements compared to traditional cultivation regions. However, there is a scarcity of studies on the thermal requirements of the ‘Malbec’ grape variety, especially in the context of double pruning management under subtropical conditions, which is evident in the current literature. Mendoza is known for its dry, sunny, continental climate with significant daily temperature variations. These characteristics are favorable for the cultivation of 'Malbec' grapes, providing a slow and balanced ripening of the grapes. Altitude in Mendoza has a great influence on the main determinants of terroir: temperature, thermal amplitude, and luminosity (Deis & Kaiser, 2020).

The thermal requirement of the 'Malbec' grape variety in the region of Mendoza, Argentina, refers to the ideal climatic conditions for the healthy growth and development of this variety. The average temperature during the growing season is a crucial factor in determining the success of 'Malbec' cultivation (Goldner, 2007).

Conclusion:

The duration of the 'Malbec' cultivar season was 171 days with 2102.5-degree days (GD). Under subtropical climate conditions, double pruning management in the 'Malbec' cultivar provided suitable conditions for the development of phenological stages and grape ripening.

Figure 1. Cumulative precipitation as a function of average temperature in the 2023 season.

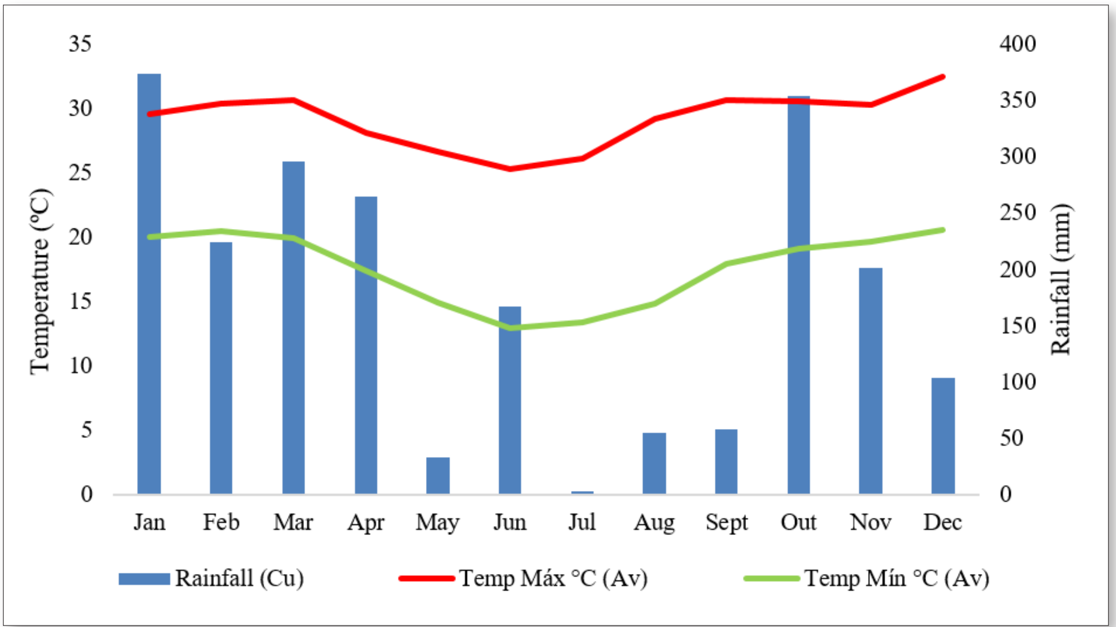

Table 1. Phenological characterization and thermal requirement of 'Malbec' grapes under double pruning management produced in subtropical conditions, counted in days after pruning (DAP).

Descriptive statistics	Budburst	Full-bloom	Setting	Veraison	Ripening
Mean	11,7	43,2	45,9	94,7	171,0
Standard Error	0,3	0,6	0,6	0,5	0,4
Standard deviation	0,8	1,6	1,7	1,3	1,2
Minimun	10,0	42,0	45,0	94,0	171,0
Maximum	12,8	46,6	49,2	96,8	171,0
CV (%)	0,7	1,4	1,4	1,1	1,0

Table 2. Characterization of the thermal requirement of 'Malbec' grapes under double pruning management at different phenological stages, produced in subtropical conditions.

Descriptive statistics	PR/BD	BD/FB	FB/ST	ST/VR	VR/RP	GD (TDD)
Mean	179,8	500,5	56,5	625,6	740,1	2102,5
Standard Error	5,0	13,9	3,0	5,0	4,1	0,2
Standard deviation	14,2	39,2	8,6	14,2	11,7	0,5
Minimun	152,1	476,9	46,0	596,2	721,2	2101,6
Maximum	200,2	586,9	63,0	633,0	746,4	2102,9
CV (%)	11,9	32,8	7,2	11,9	9,8	0,4

Legend: PR/BD: Pruning to Budburst; BD/FB: Budburst to Full bloom; FB/ST: Full bloom to Setting; ST/VR: Setting to Veraison; VR/RP: Veraison to Ripening; GD (TDD): Total Degree Days.

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NOV 20, 2024 | 14.30 PM | SCIENTIFIC SESSION: **MALBEC I - FLASH ORAL**

Laying the foundations for argentine viticulture: knowledge, innovation, and the introduction of french grape varietals in Mendoza, c.1850-1940

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Keywords: **Malbec, Mendoza, viticulture, social history, economic history.**

ABSTRACT

This paper summarizes ongoing historical research examining the impact of the introduction of French (and later Italian) grape varietals on viticultural and winemaking practices in Mendoza, c.1850-1940. While this study looks broadly at several grapes (including Semillon, Chardonnay, Cabernet Franc and Cabernet Sauvignon), the present discussion will focus on Malbec, considering the influence of foreign experts and specialised institutions in processes of acclimation and propagation, the adoption and circulation of knowledge regarding new techniques and technologies.

An acquaintance of Michel Aimé Pouget, interviewed several decades after the death of the man indelibly associated with the arrival of Malbec in Argentina, observed: *'Oí decir que regalaba púas de cepas francesas.'* Another contemporary remembered: *'Pouget enseñó a muchas personas a injertar la vid... en viña francesa le conocí las variedades de Pinot Negro, Cabernet, y Malbeck,'*[1] comments that highlight the diversity of networks and smaller exchanges involved in the spread of new grapes and methods during this initial, transformative period.

The landscape of viticulture and winemaking in the region had already been significantly altered by the last quarter of the 19th century, when the great waves of immigrants (largely from Mediterranean, wine producing and wine consuming cultures), sparked a second revolution in the sector, incorporating methods and traditions of their own. Taking a micro-historical approach and drawing on archival records from the private holdings of several wineries, the INTA and INV, I examine the new, emerging networks (formal and informal), that drove the transfer of knowledge and shaped standard practice in this second formative period. Final comments turn to the present, the lasting impact of such traditional practices as reproduction through massal selection on Argentina's unique viticultural patrimony today.

1. Juan Draghi, Miguel Aimé Pouget y su Obra, Junta de Estudios Históricos (Mendoza, 1936), pp. 57-59

NOV 20, 2024 | 14.35 PM | SCIENTIFIC SESSION: **MALBEC I - FLASH ORAL**

Beyond Malbec: exploring winerie's perspectives on diversification strategies in Argentina's wine industry

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Keywords: **Malbec; wine; diversification; business strategies; Argentina.**

ABSTRACT

This paper delves into Argentina's wine industry, celebrated for its premium Malbec wines, and examines the imperative for diversification amidst concerns over reliance on a singular varietal. Drawing upon insights from two comprehensive survey instruments, the study reveals a palpable interest among wineries in introducing new grape varieties and tapping into emerging market segments like sparkling, white, and rosé wines. Despite industry accolades, challenges such as navigating a challenging macroeconomic environment, adapting to evolving consumer behaviors, and addressing environmental sustainability are acknowledged. As the industry navigates these complexities, strategic diversification and sustainability emerge as pivotal factors for ensuring long-term competitiveness and growth in the global wine market. By leveraging these insights and adopting innovative strategies, Argentina's wine industry can enhance its resilience and appeal in an ever-evolving market landscape.

Introduction:
While Argentina consumes over eight million hectoliters of wine annually, boasts one of the highest wine consumption rates per capita globally (OIV, 2022), and maintains a robust national wine market, its wine industry garners international recognition for its consolidated business model centered on producing premium bottled Malbec wines for export (Depetris-Chauvin & Villanueva, 2024). Annually, the Argentine wine industry exports approximately three million hectoliters of wine, equating to roughly 1 billion U.S. dollars (OIV, 2022). Notably, Malbec wines now constitute over half of Argentina's wine exports, with varietal wines (including Malbec) comprising 90 percent of total exports.

Over the past two decades, Argentine wine exports have mirrored global trade patterns, characterized by stagnant volumes but escalating values driven by premiumization (Villanueva et al., 2022; Del Rey & Loose, 2023). Despite grappling with a volatile domestic landscape marked by significant fluctuations in the real exchange rate, the industry's export development appears steady and robust. Although export volumes stabilized in recent years, relative prices surged, signaling an overall enhancement in the quality of local wines. However, Argentine wine exporters face numerous constraints, including macroeconomic challenges such as pronounced price fluctuations, heavy export duties, and a dearth of favorable international trade agreements. Microeconomic hurdles include industry concentration, with only ten firms controlling a significant portion of wine exports, leading to disparities in production and business capabilities (Villanueva et al., 2022). Despite the nation's abundance of natural resources, achieving sustained economic growth necessitates diversifying the export structure towards differentiated, value-added goods, a goal that remains largely unmet over the past 15 years. Although wine holds potential as a flagship product for international market penetration, Argentina's wine competitiveness lags behind global counterparts, partly due to its dependence on exchange rates, hindering foreign sales growth (Merino, 2022). Despite these challenges, Argentina has cultivated a strong wine-country image, with global recognition of Malbec wines as emblematic of high-quality Argentinean viticulture (Rodrigues et al., 2020).

Despite the relative success in Malbec production, the country wine sector has the potential to offer the world a more diverse range of wines. Moreover, increasing saturated markets and competition from other producing countries, changes in global consumption in favour of white wines and the need to reduce risks of extreme specialization suggest that the country should try to adopt a better balance between specialization and differentiation (Villanueva et al. 2023).

The objective of this paper is to explore wineries' perspectives on diversification strategies beyond Malbec and the challenges faced by the Argentinean wine industry.

Materials and methods:

This work is based on two surveys.

The first survey was answered by 230 wineries, corresponding to a response rate of 26.3% of the total population of Argentinean wineries. The 45-minute questionnaire was divided into five sections and had 137 questions. Questions range from winery profile (age, size, ownership, location, sales, unit prices, export amount, and employment) to the winery's production, marketing, and sales functions, and relay data for their "entry-level" and "premium level" wines. Questions related to the production process assess the decision-making regarding vineyard management and the winemaking process, and those questions focused on the marketing process concentrate on promotion, distribution, and export sales decisions. The questionnaire also provides data and information regarding technological and human resources (personnel skills, training, human capital availability, and quality) and the perceived level of sector competitiveness that Argentinean wineries face. The survey used during the fieldwork assessed the interaction between wineries' dynamics and characteristics and their participation in export markets. The survey results identify the main barriers actors perceive for quality upgrading, participating, and upgrading into global wine markets, how these have impacted their activities, and the strategies implemented to overcome or modify those barriers.

The second survey is currently under implementation. The objective of this survey is to understand the perception of Argentinean producers in terms of the prospect for different types of wines both in the domestic and international markets. The survey asks about plants to introduce new grape varieties and wine styles and analyse the different perceived risks for different diversification strategies. The survey also collect information on perceived challenges in the Argentine wine sector. To implement this survey, wineries were stratified geographically and the sample was also segmented by wineries' size (production in liters). We are currently working closely with the implementing partners to secure a sample representative of the industry. As of today 32 wineries has responded the survey and we will continue collecting data until we reach a sample size around 10%-12% of the population (between 80 and 100 wineries)

Results and discussion:

Provisory results (final results and tables will be incorporated end of April when we finalize our second survey):

Most winemakers in Argentina are satisfied (44.83%) or very satisfied (36.21%) with their current grape mix. However, among the 230 respondents, 38% expressed that they would like to have more grape variety, 27% mentioned that would like to have their current grape varieties but with different clones and 24% declared that they would never change their current grape varieties. Among those interviews, 65% of the producers declared that they are planning to introduce and develop wines from new grape varieties in the next 3-5 years.

The survey results indicate varying expectations among Argentine winemakers regarding the future development of the international market for different types of wines. Notably, for Malbec wines, respondents anticipate relatively stable demand, with over one-third expecting no change and a significant portion projecting a slight increase but no respondent expecting fast growth for Malbec exports. This is consistent with the idea that this segment of the market is becoming a mature market with less dynamism going forward. Malbec-based blends are expected to see consistent demand, with a notable portion foreseeing some increase. However, for other red blend wines excluding Malbec, as well as red single varietals like Cabernet Sauvignon, Cabernet Franc and Merlot, the majority anticipate an increase in demand, reflecting optimism in these segments. Appellation of origin red wines also garner positive outlooks, with a significant portion of winemakers predicting growth. Conversely, Torrontés wines are anticipated to face challenges, with a substantial portion expecting a decrease in international demand. Meanwhile, there's notable optimism for sparkling wines, rosé wines, and other white wines, with a majority anticipating increased demand in these categories. Overall, while there are some concerns for specific wine types like Torrontés, the general sentiment among Argentine winemakers suggests cautious optimism and anticipation of growth in various segments of the international wine market.

Comparing the outlook for the domestic and international markets reveals several similarities and differences. Both markets anticipate stable or growing demand for Malbec and Malbec-based blends. However, while the international market is cautious about Torrontés wines, the domestic market shows more optimism. Additionally, there's greater positivity for sparkling wines domestically, whereas rosé wines are viewed more favorably internationally. Overall, while there are shared sentiments towards certain wine types, variations in outlook reflect differing consumer preferences and market dynamics between domestic and international markets.

The survey results on the attractiveness of various development strategies highlight several key findings. Focusing on new grape varieties and new terroirs garnered mixed responses, with a notable portion expressing neutrality or slight interest, while others found these strategies very attractive. In contrast, focusing on new consumer markets emerged as highly attractive, with nearly half of respondents expressing strong interest. Similarly, the focus on bio/natural wines garnered considerable enthusiasm, with over half of respondents finding it very attractive. Strategies centered around low-alcohol or non-alcoholic wines and complementary activities like events and tourism also received significant interest, with a substantial portion considering them very attractive. Overall, the survey suggests a keen interest in exploring new consumer markets, bio/natural wines, and complementary activities among Argentine winemakers, indicating a readiness to diversify and innovate within the industry.

The questionnaire also asked about the perceived challenges in the Argentine wine sector over the next 3-5 years. The answers provide insights into the perceived priorities and concerns within the industry. Key observations include a significant consensus on certain issues, such as the need to adapt to changing tastes and consumer behaviors both domestically and internationally, with 65% of respondents agreeing. Respondents also express a strong inclination towards adapting to changes in macroeconomic conditions and market regulations, with 55% and 50% agreement, respectively.

Additionally, there's notable emphasis on environmental sustainability, with concerns about water access, reducing the carbon footprint, and preserving vine and wine landscapes garnering significant attention. This indicates a growing awareness of environmental challenges and the importance of sustainability within the industry. Furthermore, there's recognition of the need to address public health concerns and social responsibility issues, with respondents expressing interest in adapting alcohol content to public health policies and improving corporate social responsibility practices.

On the other hand, challenges such as the introduction of more resilient grape varieties, developing a country image beyond Malbec, and optimizing sector organizations receive more varied responses, suggesting differing perspectives on their significance or feasibility. Overall, the survey highlights a diverse range of challenges facing the Argentine wine sector, emphasizing the importance of adaptability, sustainability, and responsiveness to both market dynamics and societal concerns in shaping the industry's future direction.

Conclusion:

Argentina's wine industry is robust, with significant domestic consumption and a strong presence in international markets, particularly in premium Malbec wines. However, there are concerns about over-dependence on Malbec and the need for diversification to sustain long-term growth.

Survey results suggest that while most winemakers are satisfied with their current grape mix, there's a significant interest in introducing new grape varieties and developing wines from them. There's optimism for growth in various segments of the international wine market, including red blends, red single varietals, appellation of origin red wines, sparkling wines, rosé wines, and other white wines. Strategies such as focusing on new consumer markets, bio/natural wines, low-alcohol or non-alcoholic wines, and complementary activities like events and tourism are viewed as attractive options for diversification and innovation within the industry. Respondents acknowledge the need to adapt to changing consumer behaviors and market regulations, as well as macroeconomic conditions. Environmental sustainability emerges as a significant concern, with a focus on issues such as water access, reducing the carbon footprint, and preserving vine and wine landscapes. There's also recognition of the importance of addressing public health concerns and improving corporate social responsibility practices within the industry. Challenges related to introducing more resilient grape varieties, developing a country image beyond Malbec, and optimizing sector organizations receive varied responses, indicating differing perspectives on their significance or feasibility.

These conclusions need to be taken with caution as we are still implementing our second survey. Moreover, it is important to take into account that the optimal balance between differentiation and specialization varies depending on a country's unique strengths, market dynamics, and strategic objectives. While differentiation allows for showcasing diversity and cultural heritage, specialization offers efficiencies and competitive advantages. Countries often navigate this balance by strategically diversifying within a niche specialization, promoting regional diversity while maintaining a focused identity and market position. Ultimately, successful wine-producing countries seek to leverage both differentiation and specialization to maximize their competitiveness and appeal in the global wine market.

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NOV 20, 2024 | 14.40 PM | SCIENTIFIC SESSION: **MALBEC I - FLASH ORAL**

Preserving wine excellence: alternatives for controlling *Brettanomyces* spoilage in wines

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Keywords: ***Brettanomyces bruxellensis,*** **spoilage management, wine quality, electrodialysis technology, mineral nutrients.**

ABSTRACT

Brettanomyces bruxellensis is a world-renowned spoilage yeast that negatively impacts the chemical and sensory composition of wines. Through the enzymatic transformation of hydroxycinnamic acids into volatile phenols: 4-ethylphenol, 4-ethyl guaiacol and 4-ethylcatechol, which generate aromas that collectively are referred to as the 'Brett character', described as 'horsey', 'barnyard', 'smoky', and 'band-aid' notes. The production of these metabolites causes organoleptic deterioration in wines, and has a severe economic impact, especially for high-quality wines that require long maturation periods in oak barrels. *Brettanomyces*' resilience in wine conditions and ability to produce off-flavours make it a challenge for winemakers. Currently, the primary control technique involves adding sulfur dioxide (SO2); however, some *Brettanomyces* strains are developing resistance to this preservative agent. Therefore, new management strategies are necessary to control this spoilage yeast. Mineral nutrition could be a promising approach for controlling *Brettanomyces* growth in wine. This study explored the development of alternative methodologies to limit *Brettanomyces*' impact on wines by assessing the effectiveness of different electrodialysis (ED) treatment intensities in wine, aiming to prevent this spoilage yeast proliferation. The ED technique employs charged membranes to extract ions from and potentially limiting *Brettanomyces* growth in treated wines. Considering previous studies highlighting magnesium's critical role in *Brettanomyces* proliferation, this study aims to evaluate and validate the effectiveness of ED in lowering Mg^{2+} concentrations and efficiently inhibiting the development of *Brettanomyces* in wine. Pilot-scale trials demonstrated that a 40% ED treatment intensity removed 66% of the Mg^{2+}, reducing its concentration from 93 mg/L to 32 mg/L. Additionally, current research is focused on assessing *Brettanomyces* yeast's sensitivity to varying ED treatment intensities to identify the most effective intensity for preventing its proliferation. If successful in preventing *Brettanomyces* growth, this approach could revolutionize spoilage management and provide a step change for wineries.

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Biodiversity of *Saccharomyces cerevisiae* populations as components of the microbial fingerprint of the Malbec terroir

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Keywords: **microbial terroir, Malbec vineyard, *Saccharomyces cerevisiae*, yeasts biodiversity.**

ABSTRACT

The concept of wine terroir is of great significance and is in a state of continual evolution. Recent microbiome investigations across diverse wine-producing regions have facilitated the identification of the "microbial terroir" or microbial signature specific to particular terroirs. This study focuses on elucidating the role of yeast within the Malbec terroir of the "Zona Alta del Río Mendoza" region. The research proposes an in-depth examination of *Saccharomyces cerevisiae* populations at an intraspecific level, requiring a comprehensive sampling within vineyards. Representative yeast strains were isolated for subsequent molecular characterisation. Findings from extensive research suggest the presence of distinct *S. cerevisiae* populations characteristic of ZARM's vineyards, with evidence indicating stable diversity over time. Confirmation of diverse *S. cerevisiae* strains in various vineyard niches throughout the grapevine's vegetative cycle underscores their dynamic behaviour, with vine bark identified as a significant reservoir of genetic diversity. The study also highlights the influence of management practices on *S. cerevisiae* diversity, including proximity to wineries and the application of amendments like mulching, which may facilitate the influx of commercial strains and modify seasonal diversity. In conclusion, comprehensive investigations of each viticulture region are crucial to tailor the concept of wine yeast terroir to its unique environmental conditions.

Introduction:
The concept of wine terroir has evolved in accordance with the development of scientific research and the needs of market dynamics. The evolving molecular tools as the next generation sequencing techniques (NGS), allowed the establishment of the microbial terroir concept, commonly called the microbial signature of the terroir (Belda et al., 2017, Bokulich et al, 2014). The access to microbiomes provide a perspective very valuable to view the terroir, including a taxonomically very global view. Even when the fungal microbiome is addressed, yeast populations, being key

microorganisms in wine production, are not reflected in the global framework.

The yeasts are part of the natural microbial communities of grapes in the vineyard ecosystem (Ribéreau-Gayon et al., 2006). It is generally thought that a particular yeast population is associated with a given grape variety in a specific geographical location, and a regional or terroir character is introduced into the winemaking process via this association (Pretorius, 2000; Raspor et al., 2006; Valero et al., 2005). Thus, characterization and preserving grapes yeast biodiversity from specific regions represent an important issue to starter culture development to future challenges (Fleet, 2008; Pretorius 2020).

Argentina is an important wine producer in South America. Although it has an extensive history of oenology and viticulture, the knowledge about the ecology of the microorganisms involved in local fermentations is scarce. The development of knowledge in local ecosystems is essential for understanding the winemaking process and for generating products with local characteristics, to adding value and diversification of Argentina wines. The "Zona Alta del Río Mendoza" (ZARM) is the major viticulture region of Argentina, where Malbec grapes, the emblematic Argentinean wine, have found favourable conditions to express their distinctive qualities (INV, 2023).

The present work review the researches made during the last 20 yeast by the Wine Microbiology Laboratory of EEA Mendoza INTA to face the key hypothesis: The *S. cerevisiae* yeast population in Malbec vineyards are part of the microbial terroir and influence the chemical and sensorial profile of the wines in a unique manner.

Materials and methods:

Vineyards: 8 vineyards from ZARM region were selected. Plots of 0.5 to 2 ha were delimited in each vineyard and 10 sampling points were defined. Vineyards were named with capital letters: T, NL, NP, ID, CR, CB, S and CZ.

Vineyard niches (combination of sampling time and type of sample): stages of the annual growth grape cycle studied were sampled including Harvest (H04, H10, H11), Post-Harvest (PH), Winter Dormancy or Pruning (PR), Sprouting (SPR), Early Veraison (EV), Advanced Veraison (AV). Samples were collected according to its availability, soil and bark at each stage of the growth cycle, berries in veraison and harvest and buds in winter and at sprouting in spring.

Isolation and molecular typing of yeasts: Samples collected from each of the ten sites distributed throughout the vineyards were individually processed. Enrichment through fermentation at 25 °C allowed *S. cerevisiae* development. Grapes were aseptically crushed, while soil, bark, and buds were placed in sterilized grape must (24 °Brix and pH 3.5). Samples were taken when 75% of the sugar was consumed and decimal dilutions were spread onto WL Nutrient Agar medium with 50 µg/mL chloramphenicol. Plates were incubated, counted and 10-20 colonies from each sample were purified on YPD agar and seeded on Lysine agar medium in order to confirm Saccharomyces genus.

Molecular *S. cerevisiae* strain typing was carried out by interdelta PCR (Legras and Karst, 2003), according to these authors amplification of interdelta patterns was considered evidence of *S. cerevisiae* species assignment.

Diversity analysis: each amplification band was considered as a different locus, and estimators were calculated using Popgene 1.32 and Estimate S softwares: Average genetic diversity (h): intra-population genetic diversity calculated as average diversity per locus; Coefficient of interpopulation genetic diversity (Gst): it quantifies the level of differentiation among populations considering the total genetic diversity of the populations (Ht) and the genetic diversity of each population (Hs); Nei's coefficient of genetic identity among populations: it considers all isolates from every population; Ratio between the number of molecular patterns and the number of S. cereviasie isolates expressed as a percentage was calculated as an approximate estimative biodiversity; and ecological diversity indexes were calculated: richness (S), the Shannon (H') index, and evenness (J). Since the populations to be compared had different number of *S. cerevisiae* isolates, rarefaction, was applied to standardize the diversity indexes by sampling effort (Gonzalez et al. 2023).

Results and discussion:
The current investigation into the yeast component of Terroir in Malbec vineyards within the "Zona Alta del Río Mendoza" (ZARM) region aims to address several fundamental inquiries. These questions are pivotal for understanding the intricate dynamics of yeast populations within the context of Terroir, shedding light on the mechanisms underpinning the unique characteristics of wines produced in the ZARM region.

1. Are there specific strains of *S. cerevisiae* distributed within terroirs that can be considered representative?
The biodiversity of *S. cerevisiae* yeasts in 8 Malbec vineyards distributed in the ZARM wine region were molecularly assessed (Mercado et al. 2011). The vineyards showed different populations of *S. cerevisiae*, both in number and diversity, observing vineyards with high and low polymorphism. A very heterogeneous distribution of yeasts was observed within each vineyard.

The presence of distinctive strains specific to the ZARM region could not be conclusively demonstrated; however, a close genetic relationship was observed among the various populations identified. This observation suggests that the notion of terroir yeasts may be applicable to more confined geographical areas rather than the expansive vineyard landscapes characteristic of "new world" wine regions. Moreover, it is noteworthy that the contemporary understanding of wine terroir encompasses a microbial dimension, notably the *S. cerevisiae* terroir fingerprint, which may be more associated with a closely related yeast population rather than a strain dispersed widely throughout the region.

2. What are the primary reservoirs of yeast biodiversity within ZARM vineyards throughout a complete annual vine cycle?
To evaluate the presence and persistence of *S. cerevisiae* in vineyard niches, an exhaustive sampling plan was developed during a complete grapevine growth cycle in 2 vineyards of the ZARM (Gonzalez, 2020; Gonzalez et al. 2022). In general, *S. cerevisiae* strains were widespread and at high number during the harvest period and their distribution and number and biodiversity were reduced in autumn and winter.

A dynamic change in the *S. cerevisiae* population in the vineyard during a complete annual grapevine growth cycle was observed. As expected, the grapes harbored the highest number and biodiversity of *S. cerevisiae*. Their populations increased in distribution and biodiversity during maturity stages from veraison to ripening stage. Moreover, a succession of *S. cerevisiae* strains was observed in grapes as maturation progressed, and only few strains were repeatedly isolated. Presence of *S. cerevisiae* in soil samples was low throughout all the period analysed. Bark samples exhibited a high number and biodiversity of *S. cerevisiae* strains being different to the grow cicle stage. Also S.cerevisiae strains could be recovered from grape buds in sprint samples.

These findings indicate that vine bark may serve as the primary reservoir of *S. cerevisiae* strains, from which dispersion into the vineyard ecosystem occurs, subsequently leading to colonization of grapes and eventual participation in alcoholic fermentation. Buds represent a secondary site where yeast could overwinter and persist within the vineyard environment. In contrast, soil appears to be a less suitable reservoir for *S. cerevisiae*. The dynamic of changes was dependent of the vineyard, since both evaluated were different in location, size, agronomic management, and it was reflected in the S.cerevisiae niche populations.

3. Do these *Saccharomyces cerevisiae* populations persist within the same vineyards across different vintages?

The evaluation of S.cerevisiae strains in mature Malbec grapes from two vineyards in different harvests revealed that the *S. cerevisiae* community of each season was characterized by a complete change in the population composition and the appearance of new strains. *S. cerevisiae* strains isolated from grapes during H04, H10 and H11 showed completely different molecular patterns and distribution in the vineyard sites, however their biodiversity was similar in every vintage (Gonzalez et al. 2023). These results evidenced a "non-perennial" behaviour of *S. cerevisiae* populations, that have been also observed in other studies carried out in other wine-growing areas (Valero et al., 2007; Schuller and Casal, 2007; Börlin et al., 2016). Moreover, it was proposed the hypothesis that long-term time may be a key factor for genetic differentiation in *S. cerevisiae* populations resident in vineyards.

In addition, an assessment of annual diversity and its evolution across vintages was conducted using rarefaction of the Shannon index (H′), as described by Gonzalez et al. (2023). The findings revealed a consistent preservation of *S. cerevisiae* biodiversity within vineyards over time. Notably, genetic diversity analyses indicated the presence of closely related *S. cerevisiae* populations unique to each vineyard.

These results imply that the concept of yeast terroir is intricately linked to the sustained diversity of *S. cerevisiae* across both temporal and spatial dimensions, rather than the persistence of specific indigenous strains within a particular area or winery over time

4. How do viticulture and oenological practices influence the *Saccharomyces cerevisiae* populations within the Terroir?

Interdelta-PCR molecular profiles of widely used commercial wine strains were compared with the populations of the 8 vineyards of the ZARM and with the niche samples during the complete growth cycle. Some correlations with viticulture practises were observed.

Firstly, two commercial strains strains were found distributed in vineyards exhibiting low biodiversity and located in close proximity to wine cellars, and as reported by Mercado et al. (2011). This finding suggests the dissemination of commercial strains from wineries to adjacent vineyards, facilitated by water run-off and winery residues, a phenomenon previously previously (Schuller y Casal, 2007). Although commercial strains lack specific competitive advantages for survival in vineyard environments, their widespread introduction during the vintage season could lead to the temporary replacement of indigenous strains, emphasising the need for careful management of winery waste.

Furthermore, analysis of *S. cerevisiae* populations across various niches throughout the annual vine cycle revealed a close association between populations in one vineyard and seven commercial strains. Notably, the most persistent and highly isolated molecular patterns within this vineyard were closely related to commercially utilised *S. cerevisiae* strains prevalent in the ZARM region. This vineyard, situated within the winery's plot, may be influenced by certain agricultural practices. Specifically, the incorporation of mulching from pomace and seeds—surplus materials from the commercial winery potentially harbouring high populations of commercial yeasts used in winemaking—could be contributing factors.

The results obtained suggest that viticulture and oenological practises could facilitate the arrival of commercial *S. cerevisiae* strains from the winery to the vineyard ecosystem, and consequently, modifies the ecotypic populations of *S. cerevisiae* present in this ecosystem.

5. Which physiological traits of yeasts enable their persistence within the vineyard environment throughout the year?

To study a plausible vineyard acclimatization of *S. cerevisiae*, 30 representative yeasts were forced to grow under different stressful conditions simulating variations in the vine substrate and temperature, the main seasonal environmental factor causing *S. cerevisiae* population differentiation during the annual cycle in the ZARM region (Gonzalez et al., 2020; 2022). Overall, the 30 strains were able to grow in the sub-lethal stressful conditions by modifying both biological growth parameters (μmax and latency time) according to the stressor. Some treatments produced a homogeneous response in all the group and others evidenced the diverse strain ability to overcome stresses. Despite the differences in maximum growth rate, all the yeasts were able to grow both at winter and summer temperatures found in the ZARM region, suggesting that *S. cerevisiae* could survive and be acclimatized to the vineyard seasonal environmental conditions. The presence of copper (the most currently used fungicides in the vineyard) generated the most diverse response in the 30 strain evaluated affecting mainly the lag phase. The effect of factors associated with the plant substrate, as nitrogen, glucose and pH, were homogeneous on the strain's growth. Our results suggest that *S. cerevisiae* seem to be adapted to fluctuant conditions of glucose and nitrogen and add more evidence to the hypothesis of *S. cerevisiae* acclimatization to the vineyard ecosystem.

Finally, 10 *S. cerevisiae* strains presented a less variable behaviour under the 10 treatments assayed, suggesting that they would be able to adapt to the changing conditions of the vine annual cycle. Interestingly, this group represented the more repeatedly strains recovered and shared between grapes and bark samples during the last three maturity stages of the vine annual growth cycle studied (Gonzalez et al., 2020; 2022).

Therefore, this study provides valuable evidence supporting the hypothesis of *S. cerevisiae* vineyard niche acclimatization and how this fitness ability could enable the strains to survive in other plant tissues when fruit season is over in the vine growth cycle.

Conclusion:

The discussion of the concept of microbial terroir applied to viticulture areas represents a challenging task.

We have analysed the lifestyle of *S. cerevisiae* (including its molecular diversity and phenotypic traits linked to its adaptation to a challenging environment) trying to understand what is happening in our vineyards. We have been able to verify that the winery's management of the vineyard environment can modify this ecosystem. We postulate the change of idea from "terroir yeast" to "terroir Saccharomyces population" with a sustained diversity that could be reflected in the personality of its wines. Furthermore, the high biodiversity of native yeasts is a valuable resource of our vineyards, which represents a reservoir of genetic and phenotypic diversity to face future challenges and its conservation is strategic.

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NOV 20, 2024 | 15.30 PM | SCIENTIFIC SESSION: **MALBEC II - CONFERENCE**

Terroir is not a Myth: A 14-year research into wine's fingerprints across place and time

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ABSTRACT

The concept of terroir plays a key role in determining the phenolic and sensory typicity of Malbec wines in Mendoza. This study explores the influence of climate, elevation, and soil diversity across different subregions of Mendoza on the chemical and sensory characteristics of Malbec. The investigation focused on 14 Geographical Indications (GIs) and multiple vineyards, evaluating phenolic composition, sensory attributes, and the effects of aging over three consecutive vintages. Results showed that climate variability, particularly growing degree days (GDD) and solar radiation, as well as soil composition, significantly influence the phenolic profiles of Malbec wines. Subregions with higher elevations, such as the Uco Valley, exhibited higher concentrations of anthocyanins and flavonols, which contributed to more pronounced acidity and firmer tannic structure. In contrast, warmer subregions like Luján de Cuyo showed greater variability in flavonols and tannins, reinforcing the role of terroir in shaping wine characteristics. Soil contrasts within the same vineyard also affected vine root morphology and phenolic expression, with shallower soils increasing phenolic content under mild water stress. These findings suggest that targeted vineyard management practices could optimize grapevine performance and berry quality. Aging also played a critical role in how the terroir imprint evolved over time. Compared to California, Malbec wines from Mendoza retained higher anthocyanin concentrations and evolved more slowly during aging, resulting in a broader aromatic profile with tertiary notes such as leather, tobacco, and spices. These results provide evidence that terroir, including its climate, soil, and aging dynamics, plays an integral part in shaping the phenolic and sensory profiles of Malbec. Future research could further explore these findings to support precision viticulture strategies tailored to the unique characteristics of each subregion.

Introduction

Wine is a complex matrix containing both volatile and non-volatile components that interact with each other, affecting the perception of aromas, flavors, and texture (Ebeler & Thorngate, 2009). While chemical profiling is important for distinguishing between regions, incorporating sensory perception provides a broader scope for communicating and interpreting the typicity of wines, in this case, from the regions where the grapes are grown. The economic and cultural value of wine has been closely tied to its origin. The notion of quality and reputation has traditionally been associated with the specific location of vineyards, their soils, and climate—what is now referred to as terroir. This concept describes the environmental conditions and cultural practices that directly influence the chemical composition and sensory attributes of wines.

Terroir, defined as a cultivated viticultural ecosystem, encompasses factors such as soil, topography, and the macro- and microclimate of a particular site (Seguin, 1986). Since this ecosystem is cultivated, humans play a crucial role in the expression of terroir (Leeuwen et al., 2018). Cultural and socioeconomic factors, along with viticultural and enological techniques, are integral components of terroir.

Over the past 14 years, extensive studies on terroir have been conducted in Mendoza, focusing on the sensory and chemical characterization of Malbec. These studies have explored the influence of climate across different Geographical Indications (GIs) of Mendoza, contrasting vintages, alluvial soils in high-elevation vineyards, and whether the region's chemical markers persist over time (Agazzi et al., 2018; Buscema & Boulton, 2015; Fanzone et al., 2010; Mezzatesta et al., 2022; Urvieta et al., 2021).

The climatic variability of Mendoza, with elevations ranging from 500 to 1600 meters above sea level and from warm to cold zones, allows for an extensive analysis of the behavior and adaptation of this variety in different environments. The qualitative and quantitative evaluation of phenolic compounds is a key methodology for measuring the impact of environmental conditions on the characteristics of Malbec, assessing its behavior in different harvests and regions (GIs and plots).
In this context, the identification of appellations helps producers and regions demonstrate, with data, that wines differ depending on their origin.

Recent studies have shown that climatic and edaphic variations in Mendoza's subregions generate wines with clearly differentiated sensory and chemical profiles, using advanced chemometric and sensometric techniques (Buscema & Boulton, 2015; Fanzone et al., 2010; Urvieta et al., 2021, 2024). Research covering climatic data from 1958 to 2019 highlights a significant influence of growing degree days on the chemical characteristics of Malbec wines, as well as a strong impact of vintage.

Additionally, recent studies have demonstrated that contrasting soils within the same region can significantly influence the phenolic composition of Malbec (Mezzatesta et al., 2022). This approach has identified key factors that determine the variability in wine quality and typicity, deepening the understanding of the "parcela", or "climat" concept used in regions like Burgundy, France.

While climate and soil conditions influence the chemistry and sensory profile of Mendoza's wines, aging is equally crucial for determining whether these characteristics persist over time. Malbec wines and their evolution through the aging process have been evaluated in various geographical contexts, both in Mendoza and California (Agazzi et al., 2018; Vidal et al., 2023). These studies have provided a deeper understanding of the "temporal fingerprint" of wine, demonstrating how aging can either preserve or transform terroir characteristics.

The findings from these studies contribute to a more comprehensive understanding of terroir's impact on the diversity and typicity of Malbec wines in Mendoza, opening new opportunities for the development of precision viticulture and enology strategies aimed at highlighting the unique characteristics of each region.

Results and Discussion

Understanding the phenolic and sensory typicity of Malbec

In terms of phenolic composition, in 2010, the phenolic characterization of Malbec was reported, with results showing total polyphenols ranging from 1900 to 3500 mg L^{-1}, total anthocyanins from 260 to 800 mg L^{-1}, and color intensity from 9 to 25, demonstrating a wide variability for this cultivar in different zones of Mendoza (Fanzone et al., 2010). Beginning in 2010 with the comparison of Malbec from Mendoza, Argentina and California, USA, (Buscema & Boulton, 2015; King et al., 2014) focusing on the characterization of phenolic compounds, volatile compounds, and descriptive sensory analysis to deepen the understanding of Malbec. In 2016, another investigation was initiated, following the framework of the previous study but incorporating the concept of "parcela" with georeferenced data from the specific locations where the grapes were sourced, from 14 Geographical Indications (GIs) in Mendoza, covering three consecutive vintages. The research focused on the Mendoza region, particularly on representative areas such as the Uco Valley, the Primera Zona, and the Eastern Zone, selected for their variability in elevation, climate, and soil composition. These factors allowed for the study of the impact of terroir on the sensory and chemical typicity of Malbec (Urvieta et al., 2018, 2021, 2024).

For the terroir characterization, specific parcels were selected in each region, ensuring that viticultural conditions (plant material, trellising system, and cultural practices) were similar to minimize the influence of external variables. The Malbec grapes collected were vinified under controlled conditions, with repetitions in winemaking without oak contact, to ensure that the differences in the wines were attributable and correlated with environmental characteristics (elevation, growing degree days, precipitation, geographical location). The chemical analysis of the wines was carried out using high-performance liquid chromatography with diode-array detection (HPLC-DAD) to determine phenolic composition, including anthocyanins and low molecular weight compounds. Additionally, a descriptive sensory analysis was performed by a trained panel to measure the intensity and typicity of the organoleptic attributes.

Urvieta et al. (2021) analyzed the discrimination of different GIs in Mendoza based on their phenolic profiles over several vintages. The results showed that differences in the concentration of anthocyanins, flavonols, and tannins allowed the characterization of both viticultural regions and individual plots. Higher-elevation GIs, such as the Uco Valley, exhibited higher anthocyanin concentrations due to increased UV radiation and lower temperatures. In contrast, warmer regions like Luján de Cuyo showed greater variability in flavonols and anthocyanins. A significant vintage effect was also observed in the accumulation of these compounds, highlighting the importance of terroir and climatic conditions in the phenolic expression of Malbec.

Regarding sensory analysis, a Multiple Factor Analysis (MFA) was used to evaluate the discrimination of zones across vintages, integrating sensory data obtained from the three harvests (2016, 2017, and 2018). As shown in Figure 1, the influence of vintage on zone classification is clear. The Uco Valley and the Eastern Zone were better explained by the second dimension, while the Primera Zona showed greater consensus compared to the other two zones. The sensory descriptors, presented in Figure 5.1b, included spicy, vegetal/herbaceous, astringency, and smoky aromas, which were consistent across all three vintages. Red fruit aroma was associated with the Eastern Zone in 2016, but with the Uco Valley and the Primera Zona in 2018. (Urvieta et al., 2024).

The vintage effect was particularly notable in the 2016 harvest, which was characterized by a cold, rainy, and humid climate—conditions atypical for Mendoza. In contrast, the 2017 and 2018 vintages had climatic characteristics more typical of the region, which was reflected in both the chemical and sensory descriptors of the wines. This behavior reinforces the influence of the harvest year on the chemical composition and sensory properties of Mendoza's Malbec wines.

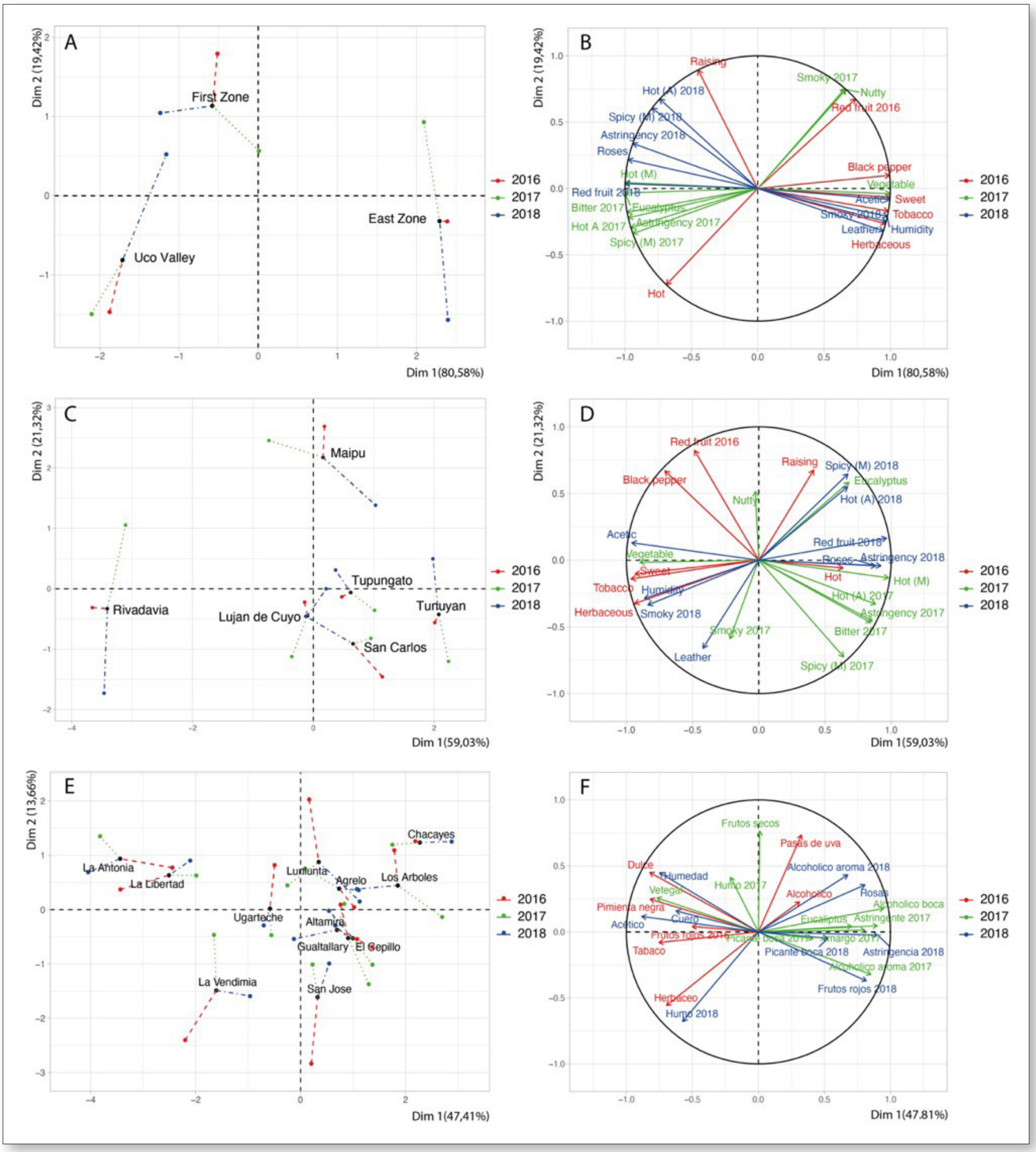

Figure 1. MFA with sensory variables from three years (2016-2018) using Zones (a and b), departments (c and d), and GIs (e and f) as classification variables. The correction graphs show a consensus MFA (a, c, and e), where the line length is inversely related to the strength of agreement.

Climate and soil diversity

The climatic and soil diversity in Mendoza plays a crucial role in the variability observed in Malbec wines from its different subregions. Factors such as elevation, soil texture, and water availability significantly impact the phenolic composition and sensory profile of the wine. Figure 2 shows the accumulation of Growing Degree Days (GDD) in the study areas in Mendoza, based on data collected from 1958 to 2019.

Urvieta et al. (2021) demonstrated that differences in solar radiation, temperature, and precipitation between Mendoza's subregions influence the accumulation of phenolic compounds and the ripening of Malbec grapes. Higher-elevation subregions, such as the Uco Valley, exhibited higher concentrations of anthocyanins and flavonols, due to a cooler climate and greater exposure to UV radiation. This phenomenon results in more pronounced acidity and a firmer tannic structure, which is consistent with previous analyses (Buscema, 2015).

Additionally, Mezzatesta et al. (2022) explored the impact of contrasting soils in a high-elevation vineyard and found that soil properties significantly affect the phenolic composition of Malbec. Shallow soils with higher clay and organic matter content led to greater fine root distribution but limited vegetative and reproductive growth. These conditions, particularly under mild water stress, enhanced the accumulation of phenolic compounds in the grape skins, leading to wines with more concentrated flavors and structure. In contrast, deeper soils with lower organic content resulted in more vigorous vegetative growth but lower phenolic content in the berries. These findings underscore the importance of soil management practices in optimizing grape quality and adapting vineyard strategies to specific terroir characteristics.

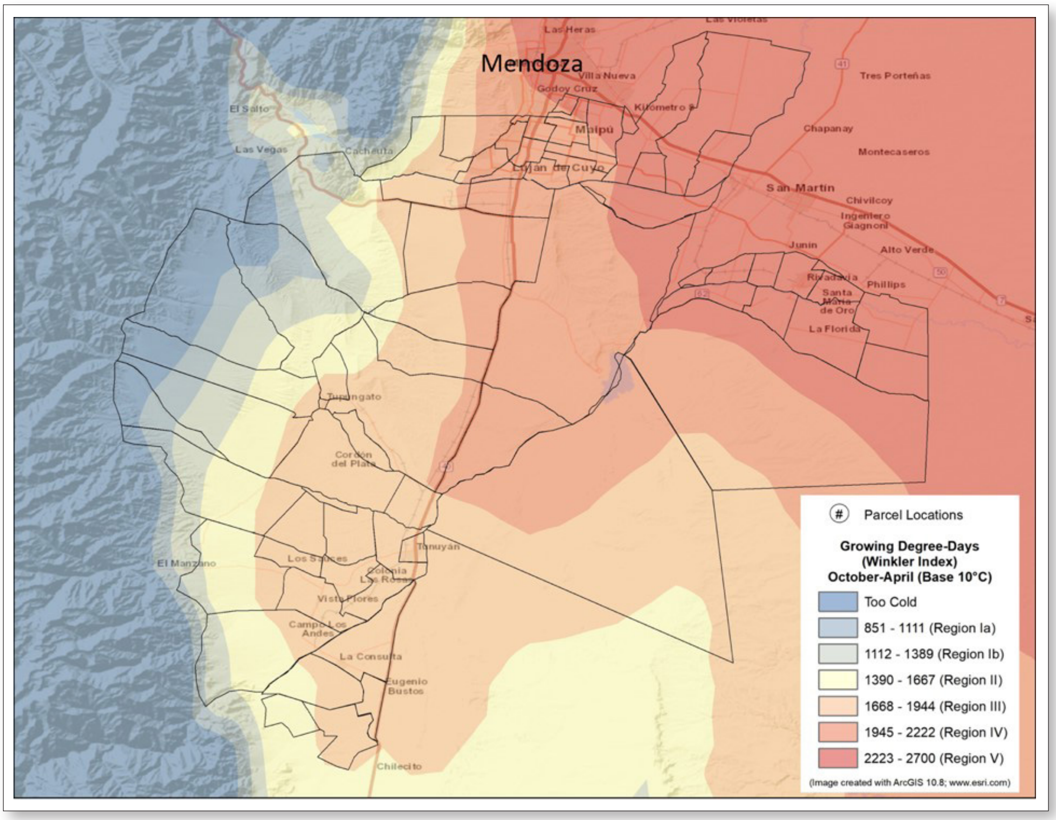

Figure 2. Average accumulation of Growing Degree Days (GDD) in Mendoza, obtained from monthly data with a spatial resolution of ~4 km. The GDD classification follows the scheme by Amerine & Winkler (1962), with upper and lower limits for Regions I to V. Figure adapted from Urvieta et al., 2021.

The time dimension. The fingerprint in time

The aging process plays a crucial role in the evolution of the sensory and chemical characteristics of Malbec, allowing us to observe how the "fingerprint" of terroir is preserved or transformed over time. The studies by Agazzi et al. (2018) and Pellegrino (2023) analyzed Malbec wines from Mendoza and California, providing a comparative perspective on how aging conditions affect these wines.

Agazzi et al. (2018) evaluated the evolution of phenolic compounds during barrel and bottle aging, showing that Mendoza wines, characterized by high concentrations of anthocyanins and tannins in their youth, undergo significant polymerization of these compounds over time. This results in a smoother and more complex sensory profile, where notes of ripe fruit give way to tertiary aromas such as leather, tobacco, and spices. A reduction in acidity and an increase in viscosity were also observed during this process, indicating the wine's integration and rounding as it ages.

In contrast, Pellegrino (2023) compared the aging of Malbec wines from Mendoza and California, revealing differences in the rate of phenolic compound evolution. Mendoza wines, subjected to a drier climate and greater thermal amplitude, exhibited prolonged retention of anthocyanins and slower oxidation compared to California wines. The Principal Component Analysis (PCA), shown in Figure 3, revealed significant differences in aromatic profiles in the seventh year (t7) according to the region of origin. A greater diversity of profiles was observed in the Mendoza samples, reflected by the wider dispersion of the sample scores in the PCA graph. In this analysis, Principal Component 1 (PC1) explained 99% of the variance. Mendoza wines were characterized by the presence of numerous compounds of interest, associated with a broad variety of aromas such as fruity and fresh, spicy, woody, and vanilla. In contrast, California wines exhibited less complex aromatic profiles, with compounds related to fruity, spicy, and woody descriptors.

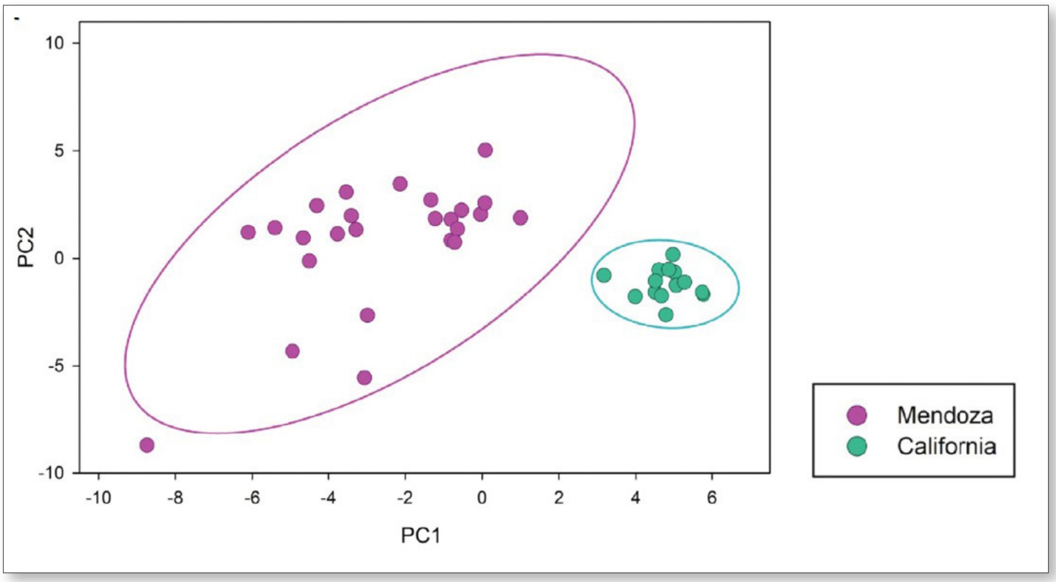

Figure 3. Principal Component Analysis (PCA) showing the separation of samples by region of origin in the seventh year (t7), using volatile composition. Argentinian wines are represented by pink dots, and California wines by cyan dots. Confidence ellipses w ere calculated at a significance level of α = 0.05.

These findings underscore the importance of aging as a critical dimension of terroir, where the initial characteristics imparted by climate and soil can evolve uniquely over time. A wine's ability to age and develop complexity is, therefore, an extension of its terroir, revealing how the "fingerprint of time" manifests in the final quality of Malbec.

Conclusion

This study suggests that terroir plays an important role in the phenolic and sensory typicity of Malbec in Mendoza. The variability in climate, elevation, and soil across the subregions appears to influence the differentiation of wines in terms of chemical and sensory composition, reinforcing the idea that terroir could generate wines with distinctive characteristics. The observed climatic and soil diversity, represented by accumulated growing degree days (GDD) and soil types, shows that these conditions can affect the phenolic composition of Malbec. Higher-elevation subregions, such as the Uco Valley, tended to present higher concentrations of anthocyanins and flavonols, while contrasting soils within the same region proved to be key factors in vineyard management and the potential quality of the grapes. The analysis of aging suggests that the initial characteristics of terroir are preserved or transformed over time. Mendoza wines showed a slower and more complex evolution compared to California wines, which may reflect the terroir's ability to influence not only the early stages of the wine but also its capacity to age and develop complexity. Together, these findings provide evidence to further explore the impact of terroir on the diversity and quality of Malbec wines and offer a foundation for the development of precision viticulture strategies that consider the unique characteristics of each region over time.

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NOV 20, 2024 | 16 PM | SCIENTIFIC SESSION: **MALBEC II - SCIENTIFIC ORAL**

Assessing the influence of climate change and clonal diversity on berry composition of Malbec

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ABSTRACT

Over the 21st century, the projected increases in regional temperatures and shifts in rainfall patterns and extreme weather events are expected to have important consequences on viticulture. They vary from short-term impacts on wine volume and quality, to long-term issues such as varietal or vineyard suitability to remain economically sustainability. With a focus on Malbec in France, this study aimed to assess the influence of climate change and clonal diversity on berry composition. The first part investigated the extent to which climate change has altered the berry composition of Malbec, cultivated in the Touraine sub-region of the Loire Valley. A long-term evaluation (1971-2020) was made concerning the modifications in sugar and total acidity content, including the ripening speed and specific heat requirements to reach different sugar levels. The second part evaluated the berry composition traits (sugar, total acidity, pH and berry weight) of 216 Malbec clones, prospected initially in Cahors and Touraine (France), including Mendoza (Argentina). These selected clones were then studied during 7 consecutive seasons (2014-2020) to understand the influence of the intra-varietal diversity of Malbec on berry composition. The results showed important modifications for berry composition and ripening speed, with significant higher sugar and lower total acidity contents over the past 50 years. Findings further revealed a strong intra-varietal diversity for the studied berry composition traits, highlighting the importance of gaining a deeper understanding of the intra-varietal spectrum and their adaptive potential to climate change.

Introduction:
The sustainability of the wine sector under current and expected climate changes is a key environmental concern for winegrowers. They are experiencing warmer temperatures, increased droughts and extreme

weather events, urging them to strategically plan for long term resilience. Studies are showing that current climate change related impacts are already significant, for instance, advancing vine phenology increases exposure to spring frost damages or warmer ripening periods decouples technological maturity from phenolic maturity (Van Leeuwen et al., 2024). Within this context of framing adaptation roadmaps, a rapidly changing climate is questioning the ecological fitness of traditional (e.g. Pinot noir in Burgundy) or established grapevine varieties (e.g. Sauvignon blanc in Marlborough) to remain suitable over the next century. In interaction with their abiotic environment, each variety has specific climatic needs and tolerances to produce wine (Parker et al., 2020), resulting in fine ecological niches in which it thrives. As wine regions are shifting to warmer and likely drier climate classes, climate change may cause regions to move outside a variety's fitness range. Resulting from a crossing between Magdeleine noire des Charentes and Prunelard, Malbec (syn. Cot), is believed to have originated in southwestern France. In 2016, around 6 100 hectares (ha) were planted in France (Anderson and Nelgen 2020). Despite expanding vineyard surfaces in France since the 1970s, it was in Argentina that Malbec received great interest following its introduction in 1868 (Calderón et al., 2021), becoming the most planted variety in the country (40 401 ha) with a national share of 19.6% of the total vineyard area in 2016. While these two countries account for 89% of its global surface, that is Argentina (77.3%) and France (11.7%), Malbec was the 15th most planted grapevine variety worldwide with a total area of 52 233ha across 19 countries (Anderson and Nelgen 2020). Considering climate change, some studies have looked at shifting viticultural suitability areas for Malbec (Cabré et al., 2016; Solman et al., 2018) or at management practices to improve berry composition (Morgani et al., 2023). Still, little is known regarding the extent to which climate change has altered the berry composition and ripening speed of Malbec, critical for assessing future vulnerability and deciding on adaptation solutions.

The process of vegetative propagation is used to clonally reproduce and preserve the specific attributes of Malbec. However, due to its long propagation history and its geographical spread (Calderón et al., 2021), genetic variations (i.e. spontaneous mutations) have also accumulated over time, giving rise to multiple clones for Malbec. These clones display different phenotypic characteristics for traits such as phenology, cluster weight (van Houten et al., 2020) or anthocyanin profiles (Muñoz et al., 2014). Gaining a deeper understanding of the extent of this intra-varietal diversity and its effects on berry composition is important to reflect the adaptive potential of Malbec. Firstly, it may allow to consider alternative clones (e.g. delayed phenology or higher acidity) likely more suitable to future climates (van Houten et al., 2020). Yet at the same time, offer a significant resource of biodiversity in the face of uncertain climate outcomes where natural climate variability still occurs in the context of global warming. As shown for cultivar diversity (Morales-Castilla et al., 2020), increasing clonal diversity may be a powerful way to reduce the degree of climate sensitivity. The study aims to assess the influence of (1) climate change and (2) clonal diversity on berry composition of Malbec, cultivated in France. To address these two objectives, the study used two large data sets consisting of sugar and total acidity measurements for (1) a network of Malbec vineyards in the Touraine sub-region of the Loire Valley, France from 1971 to 2020 and (2) a population of Malbec clones cultivated in an experimental vineyard in Cahors, France between 2014 and 2020. The first database investigates the long-term modifications in sugar and total acidity content as well as the trends and heat requirements for berry ripening dynamics. The second database looks at the 216 selections of Malbec clones, sourced originally from different wine regions in France (Cahors and Touraine) and Argentina (Mendoza). The study concludes by discussing the findings within the context of climate change adaptation.

Materials and methods:

1) Berry composition data in Touraine, France

Berry composition corresponded to the measurements of sugar (g/L^{-1}) and total acidity (g/L^{-1} H2SO4) content between 1971 and 2020. The number of yearly observations is 45 in total as data was missing for 1981, 1982, 1987, 1989 and because of spring frost damages, 1991 was excluded. Grapes were sampled weekly between veraison and harvest from a network of Malbec vineyards, located in the Touraine sub-region of the Loire Valley, France. To obtain an aggregated and single regional value for each sampling date, sugar or total acidity values were average from the network of vineyards to reduce the local terrain effects. To understand the modifications in sugar and total acidity content over time, linear regression analysis was performed using the first four sampling points of each growing season to estimate berry composition on a common day of the year (DOY). For each sampling point, the sugar to total acidity ratios were also calculated and expressed as a maturation index (MI). The trends in ripening speed were then evaluated as a linear regression of the MI values and their corresponding heat accumulation units between 1 July and day before the corresponding sampling date (Van Leeuwen et al., 2023). For estimated sugar contents at 170 g/L^{-1} to 220 g/L^{-1} during the ripening period, heat requirements were also established using the Grapevine Sugar Ripeness model (Parker et al., 2020).

2) Clonal diversity data in Cahors, France

A conservatory vineyard containing 180 Malbec clones, selected in the Cahors region, was planted in 1989 on the rootstock 3309C (Figure 1). From 2014 to 2020, these 180 genotypes were closely followed during ripening and at two separate dates, 200 berries were sampled to measure sugar content (g/L^{-1}), total acidity (g/L^{-1} H2SO4), pH and berry weight (g). Two additional vineyards were planted next two each other, about 200 m from the conservatory. The first experimental vineyard was planted in 2003 on Riparia rootstock with 7 certified Malbec clones (i.e. 42, 46, 595, 598, 1127 and 1128) alongside 29 clone selections of the Touraine region, France. The second vineyard was planted in 2012 on Riparia rootstock with 4 certified Malbec clones (i.e. 595, 1127, 1128 and 1342) alongside 7 clone selections from Argentina. The clonal material from Argentina was selected in 2006 from vines in the Mendoza wine region. As for the conservatory vineyard, berry sampling took place in the two experimental vineyards during ripening, allowing to measure at two or three intervals sugar content (g/L^{-1}), total acidity (g/L^{-1} H2SO4), pH and berry weight (g). To understand the intra-varietal diversity of Malbec and its impact on berry composition, all the results were standardized using the reference 595 Malbec clone, allowing to compare the collections despite different locations, planting dates or rootstocks. The 595 Malbec clone is widely planted in France, representing 25% of national nursery harvested scion material since 2005 for all Malbec clones. A principal component analysis (PCA) was used to summarize the information of all available years for the different clones.

Results and discussion:

Over the past 50 years, sugar content (g/L^{-1}) has significantly increased for Malbec in Touraine, France (Figure 1). The results show that sugar content has risen from 96.7 g/L^{-1} in 1970s (1971-1980) to 163.2 g/L^{-1} in 2010s (2011-2020) for a similar sampling date (DOY 244, 1 Sep). At the same time, total acidity (g/L^{-1} H2SO4) has seen a decrease from 17.7 g/L^{-1} in 1970s to 9.4 g/L^{-1} in 2010s, resulting also in a significant increase in the sugar to total acidity ratio and therefore the maturation index (i.e. from 6.9 to 20.1 over the 50 years). While other management factors are contributing (e.g. evolving leaf-to-fruit ratios), climate change related impacts (e.g. warmer temperatures, increased droughts) are key factors affecting berry composition and ripening speed.

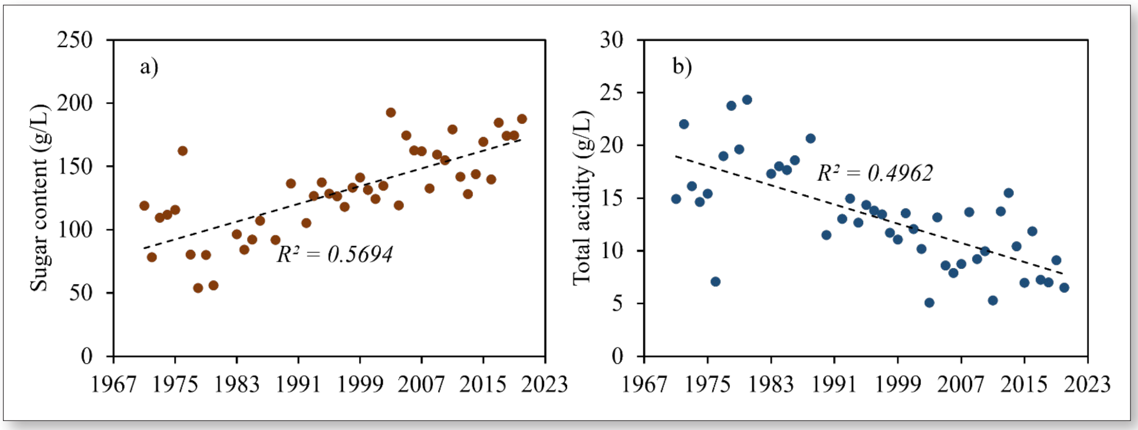

Figure 1. Modification in (a) sugar and (b) total acidity content for DOY 244 (1 Sep) from 1971 to 2020 from a network of Malbec vineyards, located in the Touraine sub-region of the Loire Valley, France. (Data source: Laboratoire d'analyses Inovalys, Tours, France).

Considering the influence of the intra-varietal diversity of Malbec on berry composition in Cahors (France), Table 1 show that the sugar content varied on average from 182 to 222 g/L (2014-2020), when comparing data on a similar sampling date, close to harvest. Significant differences were also observed for total acidity, pH and berry weight, where the clone 595 had lower sugar content, higher acidity and higher berry weight compared to the population mean. For the Touraine and Argentine selected clones, we observe that the clones displayed a similar variability around the population mean, with a higher total acidity content for the Argentine clones. The PCA shows the clustering pattern of the clones for the different vineyards *(results not shown)*.

Table 1. Influence of Malbec intra-varietal diversity on berry composition. For each trait, values were averaged over the 7 consecutive growing seasons of 2014-2020 in Cahors, France. (Data source: Association Expérimentation Ferme Départementale, Anglars-Juillac, France)

Vineyard	Selection	Sugar (g)	Total acidity (g/L)	pH	Berry weight (g)
Conservatory 180 clones	*Clone 595*	199	5.0	3.2	501
	Population	206 (182-222)	4.7 (3.4-6.4)	3.2 (2.7-3.4)	493 (348-641)
Touraine 29 clones	*Clone 595*	205	4.9	3.2	453
	Population	210 (185-228)	4.5 (2.7-5.8)	3.3 (3.0-3.5)	497 (363-591)
Argentine 7 clones	*Clone 595*	204	5.0	3.1	458
	Population	206 (189-218)	5.1 (4.4-6.0)	3.2 (3.1-3.3)	480 (388-543)

Conclusion:

In the context of assessing vulnerability and deciding on climate change adaptation, understanding the extent to which climate change has altered berry composition and ripening speed is critical. With a focus on Malbec in France, this study showed significant modifications in sugar and total acidity content from 1971 to 2020 in Touraine, France, including increasing ripening speeds. Heat requirements to reach different sugar levels were also calculated, allowing to update the scientific understanding on Malbec. The findings further displayed a strong intra-varietal diversity for berry composition traits of 216 selected Malbec clones during consecutive seasons from 2014 to 2020 in Cahors, France. These results highlight the importance of gaining a deeper understanding of the intra-varietal spectrum of cultivated grapevine varieties and their adaptive potential to climate change. Compared to other varietal innovation strategies, intra-varietal diversity can provide adaptation solutions for winegrowers to sustain local wine identity in a global changing climate.

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Exploring the causes of the intra-varietal fruit set rate variation in cv. Malbec

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ABSTRACT

Malbec is a black-berried cultivar of international relevance used for high-quality winemaking. However, its tendency to poor fruit set and excessive fruitlet abscission compromises its grape production. Here, we have characterized the reproductive performance of 25 clonal selections of Malbec grown under even conditions during two consecutive seasons (2022 and 2023). We evaluated different reproductive traits at flowering (i.e., number of flowers per inflorescence) and at harvest time (including the number of berries per cluster). After combining traditional and image-based phenotyping methodologies, a wide range of intra-varietal variation was observed. For example, fruit set rate was found to range from 13.1 to 65.8% (in 2022) and from 9.8 to 50.0% (in 2023), and cluster weight varied from 40.6 g to 232.9 g (in 2022) and from 23.8 g to 193.5 g (in 2023). Univariate and multivariate analyses were useful to cluster the 25 clones into three divergent groups with high phenotypic homogeneity within each group, consistent between seasons. Interestingly, this analysis led to the identification of four clonal selections with highly contrasting features, including two with markedly compromised fruit set-related features and two with better reproductive performance, which were used as controls. The in-depth evaluation of these four selections during 2024 season allowed us to identify the potential causes of their low fruit set, which included low pollen viability and different flower anomalies that might hinder flower pollination and/or ovule fertilization processes. The identification and further characterization of these somatic variants of Malbec pave the way to reveal the physiological and molecular mechanisms involved in grapevine fruit set, a relevant trait for the grape and wine industry.

Introduction:

Malbec is Argentina's most relevant grape cultivar, covering an area of more than 46,000 ha across the country (www.oiv.int). Malbec wines are highly appreciated worldwide, due to its rich polyphenol content and its particular anthocyanins profile that translates into deep-purple-coloured wines with high potential for ageing (Fanzone et al. 2012). According to historical records, Malbec was introduced in the Argentinian region of Mendoza during the 1850s, and currently it is successfully cultivated in almost all the country. Obviously, the wide diffusion of Malbec across Argentina was accompanied by an intense vegetative multiplication process to maintain varietal attributes. This process ultimately led to a wide range of intra-varietal (or clonal) diversity that is observable at both phenotypic (Muñoz et al., 2014; van Houten et al., 2020) and molecular levels (Calderón et al., 2021, Calderón et al., 2024). However, it has been reported that Malbec shows unstable yields, mainly due to seasonal variations in bud fruitfulness and the occurrence of reproductive disorders that end up in poor fruit set and fruitlet abscission (Carrillo et al., 2022). Therefore, further analyses are needed to better understand how different clonal genotypes behave for the aforementioned reproductive traits.

Balanced and stable yields are essential for grape growers and winemakers. In grapevine, the proportion of flower ovaries in the inflorescence that successfully become fruits after pollination and fertilization processes (fruit set) is a major component of seasonal yield variation (Dry et al, 2010). Fruit set can be affected by genetically-determined reproductive dysfunctions that lead to an excessive number of seedless berries and/or live green ovaries (LGOs, or “shot” berries), which compromise grape yield (Dry et al, 2010). In addition, adverse environmental conditions at pre-flowering and flowering times (i.e., low temperature and heavy rains) might decrease this conversion in highly susceptible cultivars, ending up in unsustainable yields (Tello et al., 2021). In this regard, intra-varietal diversity might be a solution to overcome such problems, especially in cultivars prone to reproductive disorders. Previous works indicate that clonal selections of other elite cultivars store a wide range of phenotypic diversity, higher to that currently used at a commercial level (Portu et al., 2024). In fact, it is rather common to find clones of ancient cultivars with marked varying features in fruit set-related traits (Grimplet et al., 2019; Portu et al., 2024; Tello et al., 2018). The exploitation of such clonal diversity is especially relevant in winemaking regions where cultural and commercial demands strongly limit cultivar replacement.

Here, we explored the phenotypic diversity of 25 clonal selections of Malbec grown under the same conditions for two consecutive seasons. We studied diverse traits related to their reproductive performance, to assess the range of phenotypic diversity available for its potential use to counteract the reported poor fruit set of this cultivar. We identified a wide range of clonal variation for the analysed traits, and this variation turned to be consistent between years. The detailed analysis of four clones with contrasting features during a third season was useful to note the specific causes of their variation. On one hand, it was observed that reproductive dysfunctions were associated to different causes in different clonal selections. On the other hand, some clones exhibited better fruit set performance, of interest for cultivar improvement. Overall, this work explores the intra-varietal diversity available for Malbec and points out some variants whose in-depth analysis might aid to reveal the physiological and molecular mechanisms involved in the determination of yield in grapevine.

Materials and methods:

We analyzed 25 clonal selections of Malbec (Table 1), each one represented by three biological replicates. Clones are grown in an experimental vineyard of Vivero Mercier Argentina (Perdriel, Mendoza) since 2002, and maintained under common conditions. We studied six traits, depicted in Table 1, during two consecutive seasons (2021-22 and 2022-23) using five inflorescences/clusters per plant and following the methods detailed in Tello et al. (2021). The number of flowers per inflorescence was estimated using a modified version of the FIJI-compatible image system developed by Ibáñez et al. (2020).

According to 2021-22 and 2022-23 results, clonal selections 505, 508, 510, and 515 (with contrasting reproductive performance) were chosen for their in-depth analysis in 2023-24 season. Thus, in addition to the traits evaluated in previous seasons, we also considered the number of dropped ovaries, seedless berries, and LGOs, to calculate the indices of millerandage and coulure as in Dry et al. (2010). In addition, clones were inspected for pollen viability, using the differential staining method and the image-based automatic approach detailed in Tello et al. (2018). Lastly, observations of flowers at full flowering were performed with a magnifying glass to detect possible structural malformations.

Experimental data were subjected to a series of statistical analyses (correlation tests, hierarchical clustering on principal components -HCPC-, and analysis of variance) to explore the relationships between traits and clonal selections. Results were considered statistically significant at $p<0.05$. All tests were conducted in R v.4.0.

Results and discussion:

In this work, we have characterized the reproductive performance of 25 clonal selections of Malbec through the description of six fruit set-related traits during two consecutive seasons. The average fruit set value in cv. Malbec found here (38.4 and 32.1%, in 2022 and 2023, respectively) was slightly lower to the value indicated by Ibáñez et al. (2020) for one clone of this cultivar in the winemaking region of Rioja, northern Spain (41.5%). However, we found marked differences in fruit set among Malbec clones, with values that ranged from 13.1 to 65.8%, and from 9.8 to 50.1% in 2022 and 2023, respectively (Table 1). Differences in fruit set rate between clones have been also indicated for other cultivars, as reported for four clones of Tempranillo Tinto (Grimplet et al., 2019). Interestingly, we found a significant high correlation between 2022 and 2023 fruit set data ($r= 0.71$; $p<0.001$), indicating that this trait is under strong genetic control, as previously indicated in inter-varietal reports (Zinelabidine et al., 2021). Beyond the intra-varietal diversity observed for fruit set, we also found a wide range of diversity for the number of berries per bunch, and bunch weight (Table 1).

We conducted a hierarchical clustering on principal components (HCPC) analysis to identify groups of individuals with similar reproductive performance. As observed in Figure 1, Malbec clonal selections arranged in three different groups, consistent between seasons. Only three clones (502, 511 and 596) showed an inconsistent grouping in the two evaluated seasons, indicating a potential major sensitivity to environment. These three groups of clonal selections were found to significantly differ in the number of berries per cluster at harvest and the fruit set rate (data not shown). Interestingly, we found that the group with the lowest number of berries at harvest time had the lowest values of fruit set. However, the low number of flowers of the individuals with the highest fruit set rates limited the final number of berries in the cluster at harvest time. A negative relationship between fruit set and the number of flowers in the inflorescence has also been reported by Zinelabidine et al. (2021) after the study of 114 grapevine varieties of different origin and use. This suggests that the compensation effect observed between flower number and fruit set values at the inter-varietal level (Ibáñez et al. 2020) might also apply at the intra-varietal level. In fact, the selection of clones with both high number of flowers per inflorescence and high fruit set values might render in the production of grape bunches with extremely high values of compactness. This undesired feature might favour the appearance of diverse pests and diseases (like Botrytis bunch rot) and uneven ripeness, which ultimately compromise grape yield and quality (Tello and Ibáñez, 2018).

In view of these results, we selected two clonal selections (510 and 515) with consistent low yield and limited fruit set for their detailed description in a third season. For comparison purposes, another two selections with better reproductive performance were also analysed (505 and 508) and used as controls. Phenotypic descriptions confirmed the lower bunch weight and number of berries in selections 510 and 515 compared to 505 and 508, as observed in the two previous seasons. It also confirmed their low fruit set rates (Figure 2). We also observed a higher number of seedless berries and LGOs in 510 and 515 compared to 505 and 508, which caused a significantly higher millerandage rate in these two low-yielding selections. In addition, 510 and 515 had a higher drop of pre-fruit set ovaries, leading to their significantly higher coulure values (Figure 2). Altogether, these alterations determined that selections 510 and 515 had bunches with fewer regular seeded berries that ultimately caused their low yield. Low pollen viability has been previously linked to reduced seed and fruit production in sensitive cultivars (Tello et al., 2021). Accordingly, we found it to be one of the causes likely explaining the poor reproductive performance observed in clone 510, as observed in Figure 2. However, pollen viability in 515 did not significantly differ from those observed in 505 and 508. In the case of clone 515, the detailed observation of its flower structures was useful to detect different abnormalities, including crinkled and poorly developed stamens, among other malformations. As previously reported (Coito et al., 2019), the detected anomalies could hinder flower functionality by altering pollination and/or ovule fertilization processes. These dysfunctions might ultimately explain the limited reproductive performance observed in this clonal selection of Malbec.

Conclusion:

Intra-varietal diversity is a powerful tool of adaptation and improvement in elite cultivars of difficult replacement like Malbec. The high diversity observed for the fruit-set related traits analysed in the 25 clonal selections explored in this work suggests that it can be used to overcome its reported tendency to poor fruit set. In particular, the identification of Malbec variants with better reproductive performance might avoid the use of costly management practices that ultimately reduce production profits. In addition, the identification of the complex genetic determinism of grapevine yield components can be relevant to develop long-term strategies to optimize production levels whilst maintaining grape quality. The in-depth study of the fruit set-defective Malbec somatic variants identified in this work will reveal the genetic causes of their contrasting phenotypic features. This task will be eased by the recent availability of a reference genome for this cultivar (Calderón et al., 2024).

Table 1. Phenotypic diversity observed for 25 clonal selections of cv. Malbec for six fruit-set related traits two consecutive seasons. 2022 and 2023 mean values for each selection are shown separated by a slash ("/").

Clonal selection	Bunch weight (g)	Berries weight g)	N Berries	Berry weight (g)	N flowers	Fruit set (%)
136S	74.9 / 73.4	68.7 / 68.8	51.8 / 59.4	1.3 / 1.2	129.1 / 233.9	41.6 / 29.5
42	140.7 / 193.5	130.4 / 180.7	112.3 / 137.9	1.0 / 1.3	239.1 / 501.9	52.4 / 28.3
46	232.9 / 181.8	215.8 / 170.1	141.0 / 140.4	1.5 / 1.2	360.5 / 401.2	41.4 / 35.3
501	92.6 / 67.3	84.4 / 62.2	65.0 / 50.7	1.4 / 1.2	257.9 / 273.4	22.8 / 18.6
502	91.2 / 128.6	85.9 / 118.3	70.8 / 108.7	1.2 / 1.1	161.3 / 241.9	43.7 / 46.0
504	48.9 / 80.8	44.9 / 76.6	35.9 / 73.8	1.3 / 1.0	204.3 / 207.2	19.2 / 35.6
505	156.4 / 121.8	147.5 / 113.8	98.1 / 88.9	1.5 / 1.3	156.6 / 211.3	64.6 / 45.6
506	78.2 / 73.8	73.0 / 70.2	50.4 / 57.3	1.5 / 1.2	160.2 / 234.1	31.7 / 23.6
507	59.5 / 57.6	55.9 / 53.1	48.3 / 41.3	1.2 / 1.2	157.1 / 239.0	30.1 / 17.6
508	155.7 / 140.1	145.2 / 130.1	101.2 / 103.6	1.5 / 1.2	166.3 / 217.7	65.8 / 50.1
509	121.3 / 121.1	113.4 / 113.0	68.6 / 102.4	1.6 / 1.1	112.4 / 243.7	60.7 / 44.0
510	61.0 / 23.8	55.3 / 21.2	58.1 / 23.1	1.0 / 0.9	238.9 / 258.7	26.1 / 9.8
511	117.6 / 76.5	111.0 / 69.9	68.9 / 61.5	1.6 / 1.2	141.6 / 201.2	52.6 / 29.9
512	94.7 / 84.0	89.3 / 78.6	56.8 / 65.1	1.6 / 1.2	136.0 / 178.0	44.9 / 37.0
513	50.5 / 52.8	47.8 / 48.9	42.8 / 49.8	1.1 / 1.0	137.9 / 201.7	31.9 / 26.3
514	156.3 / 127.4	146.4 / 119.8	93.2 / 93.9	1.6 / 1.3	212.3 / 246.8	44.8 / 38.3
515	50.7 / 63.7	46.2 / 57.9	41.0 / 49.7	1.1 / 1.1	190.2 / 232.5	21.1 / 22.2
595	146.3 / 144.8	134.2 / 134.6	130.7 / 102.5	1.1 / 1.3	359.3 / 411.9	39.1 / 26.1
596	113.1 / 85.4	99.3 / 80.5	102.0 / 77.4	1.0 / 1.1	325.1 / 358.8	33.6 / 22.7
598	138.2 / 134.3	131.0 / 131.1	88.6 / 104.2	1.4 / 1.3	335.7 / 344.5	29.4 / 30.4
711	116.7 / 114.6	109 / 107.3	75.6 / 84.8	1.5 / 1.1	127.0 / 229.9	60.5 / 42.0
712	40.7 / 67.5	37.8 / 62.7	34.7 / 57.7	1.0 / 1.1	138.5 / 180.7	25.3 / 30.2
713	86.8 / 88.9	81.4 / 81.6	52.4 / 66.1	1.6 / 1.2	118.3 / 153.9	52.9 / 42.8
714	79.8 / 83.6	73.7 / 76.8	55.3 / 72.0	1.3 / 1.0	230.8 / 255.6	24.4 / 34.4
715	40.6 / 63.8	37.2 / 58.1	30.9 / 58.6	1.1 / 1.0	232.9 / 246.3	13.1 / 24.8

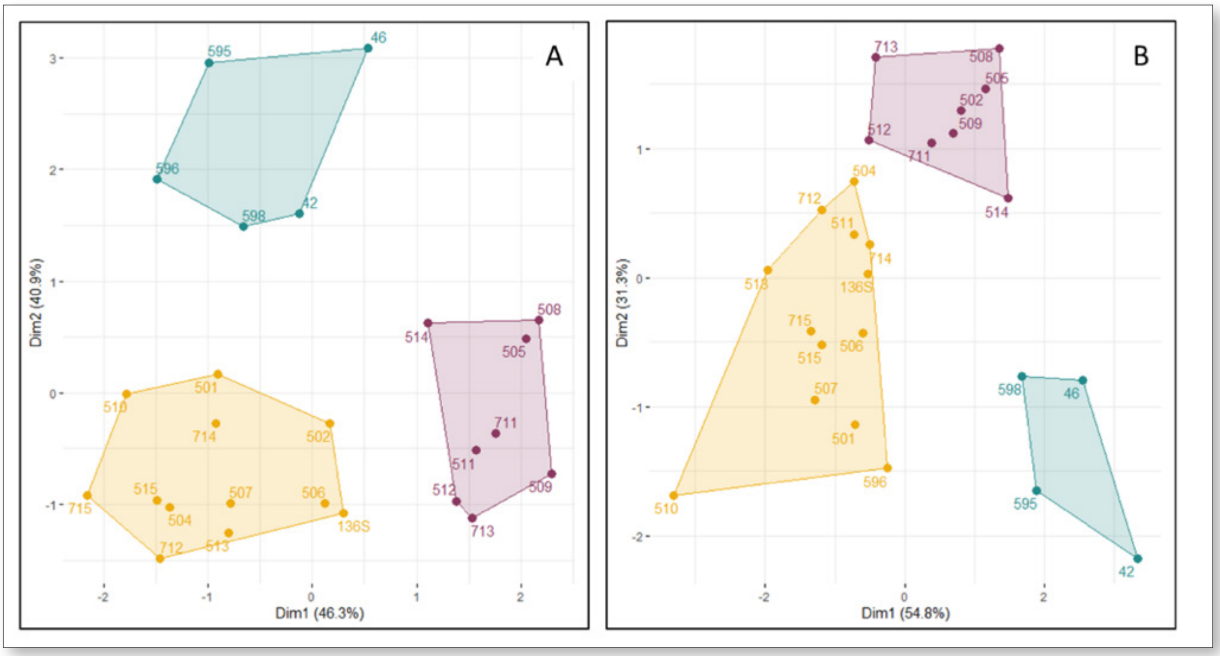

Figure 1. Clustering results of 25 clonal selections of cv. Malbec based on six fruit-set related traits obtained in 2022 (A) and 2023 (B).

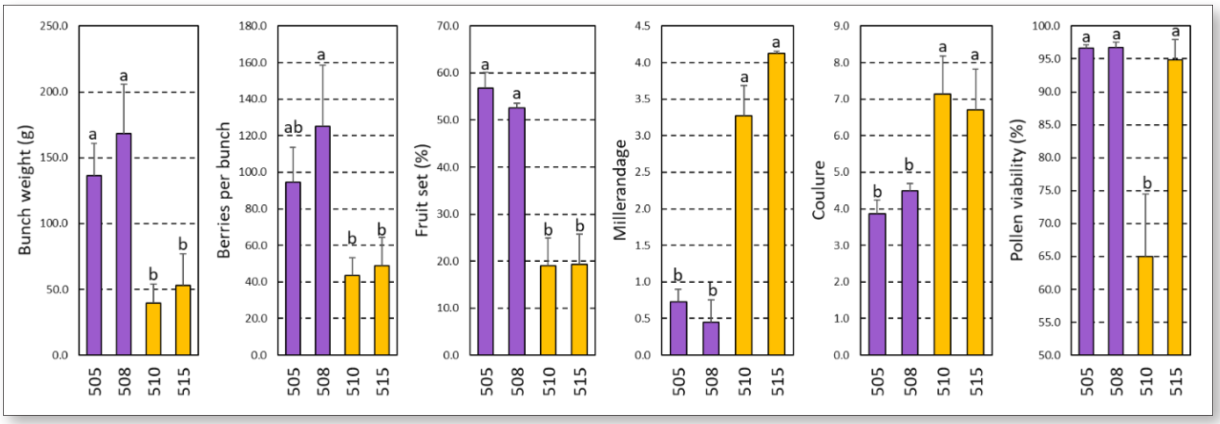

Figure 2. Reproductive performance of four clonal selections of cv. Malbec (505, 508, 510, and 515)

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NOV 20, 2024 | 16.30 PM | SCIENTIFIC SESSION: **MALBEC II - FLASH ORAL**

Malbec growth, fruit, and wine characteristics from the Umpqua valley of Oregon

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Keywords: **Malbec, Phenology, Climate, Pacific Northwest.**

ABSTRACT

Observations for Malbec come from Abacela Vineyards and Winery, established in 1995 the Umpqua Valley American Viticultural Area (AVA) of Oregon. Abacela has been a pioneer in establishing numerous varieties for the first time in Oregon and the Pacific Northwest (PNW). Malbec was first planted at Abacela in 1995, with the first wines made in 1997, the first 100% varietal Malbec wine produced in the PNW.

Abacela consists of approximately 190 ha of oak savannah with mixed madrone and conifer forested areas with 33 ha of vineyards. Abacela vineyard blocks average 190m in elevation, ranging from a low of 150m to 250m. Aspects average 200° (SSW) mostly ranging from 115° (ESE) to 270° (W) over slopes that average 10-15% but are as steep as 25-45%. Vineyards are planted across five soil types, which vary from silt-clay loams to sandy-silty loams.

The grape growing climate at Abacela averages 16.8°C during the growing season (April through October) and accumulates 1675 (C° units) growing degree days on average. The diurnal temperature range during the growing season averages 18.5°C, and 20.0°C during the ripening months of August and September. Abacela averages 850mm of precipitation annually with less than 25% coming during the growing season.

Abacela has Malbec Clone 4 and Clone 9, totalling 3 ha planted to four different rootstocks, which is cane pruned, on a VSP trellis with mostly 1.5 x 3 m spacing. Budbreak averages 9 April, flowering 9 June, véraison 14 August, and harvest 8 October. At harvest, Malbec fruit at Abacela has averaged 23.5 °Brix, 3.51 pH, and 6.2 TA (g/L) with yields averaging 6.4 tons per ha. Finished Malbec wines have averaged 13.9% vol with vintage variations from 12.5% to 15.2% vol over the last 25 years. Malbec production over the last ten years has averaged 500-1000 cases.

NOV 20, 2024 | 16.35 PM | SCIENTIFIC SESSION: **MALBEC II - FLASH ORAL**

Characterization of Malbec grapes and wines from the geographical indication (GI) Paraje Altamira (Mendoza, Argentina)

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Keywords: **variability, geographical indication, phenolic composition, sensory attributes, Malbec.**

ABSTRACT

The global commercialization of Argentine wines faces a disadvantageous international competition with Old World producing countries in terms of prices, due to centuries of history and knowledge. Currently, Malbec wines from Paraje Altamira have reached high levels of quality and have been recognized as one of the most important wine regions in Argentina. Recently, studies have been carried out on the characterization of soil and climate. The aim of this study was to improve the knowledge of Paraje Altamirá s wines and support the opinion of expert technicians with scientific data. Nine representative Malbec vineyards located in the GI Paraje Altamira were evaluated (ME, CR, Z, LP, B, GA, Y, LC1, LC2). Three replicates composed of 20 to 30 homogeneous vigour plants, were analysed. The vineyards were managed according to the regioń s usual viticultural practices. Grapes were harvested at 24 ±1°Brix, and processed following a standardized protocol to obtain 27 experimental wines. Stabilized wines were characterized by alcohol, pH, titratable acidity, total phenols, tannins, anthocyanins, polymeric pigments, color attributes (CIELAB parameters), and anthocyanin profile (HPLC-DAD). In general, wines from different vineyards had a similar chemical composition. A PCA analysis showed that only Y wines were significantly different from the rest, characterized by a higher tannin content, a greater proportion of polymeric pigments, and more alcohol, probably due to a higher degree of grape maturity. The B wines revealed higher levels of anthocyanins, color saturation (>C*ab), and titratable acidity; while the rest revealed comparable and lower levels of each parameter evaluated. It is interesting to observe that the Y wines coming from vineyards with the highest yields (>3.5 kg/plant), indicated good balance and high phenolic potential. To a better understanding of the zone, these results were complemented by a descriptive wine sensory analysis conducted by a trained panel of judges.

NOV 20, 2024 | 16.40 PM | SCIENTIFIC SESSION: **MALBEC II - FLASH ORAL**

Evolution of maturation of cv. Malbec subjected to double pruning

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Keywords: **Malbec, double-pruning, physical chemistry, subtropical climate, maturation curve.**

ABSTRACT

The Brazilian viticulture presents great potential due to its vast territorial extension and climatic diversity, which provide the development of regions suitable for wine production. Within this scenario, among the various cultivars explored, the Malbec variety *(Vitis vinifera)* stands out. A management practice that has been increasingly spreading in the southeastern Brazilian viticulture is the double pruning technique, which directly impacts the chemical composition of grape must, such as increasing levels of soluble solids. The objective was to evaluate the maturation curve of the Malbec variety under double pruning management in a subtropical condition. After the onset of maturation, in weekly berry samples, soluble solids, pH, titratable acidity, and maturation index were evaluated. The results obtained revealed that 'Malbec' reached 20°Brix values in the grape must, showing the cultivation potential of this variety to produce quality grapes for winemaking.

Introduction:
Brazilian viticulture stands out not only for its productivity but also for the diversity of management due to the edaphoclimatic differences in the producing regions. In 2021, the area dedicated to grapevine cultivation was 75 thousand hectares, representing a 0.24% increase compared to the previous year. The state of Rio Grande do Sul stands out as the largest national producer, with 62.41% of the total production, followed by Pernambuco. São Paulo ranks third, with a total of 8,022 hectares of vineyards and production of 147,359 tons (Mello, Machado, 2021).

Among the various cultivars produced in Brazil, Malbec has stood out for its agronomic and oenological characteristics. Malbec presents small, globose, and intensely pigmented berries, with average levels of 19.7° Brix and 0.7% titratable acidity of tartaric acid (Leão et al., 2021).
The double pruning technique consists of reversing the vine's cycle, shifting the harvest from the rainy summer period to the winter in the Brazilian southeast, characterized by low precipitation and thermal

amplitude, favoring the phenolic maturation of grapes and the maintenance of acidity (Souza et al., 2020).

Monitoring the evolution of grape maturation in the field under double pruning management allows establishing the ideal harvest time based on the chemical aspects of grape must (Guerra, 2002).

In this context, the objective of the present study was to evaluate the maturation curve of 'Malbec' grapes under double pruning management in a subtropical climate region in Southeast Brazil.

Materials and Methods:

The vineyard is located in the municipality of Mineiros do Tietê, in the state of São Paulo, situated at 22°32'25'' S, 48°24'13'' W, at an altitude of 580 meters. Based on the Köppen-Geiger geographical classification, this region has a Cfa climate type (subtropical, with hot summers, temperatures higher than 22°C, and precipitation greater than 30 mm in the driest period). Climatic data were obtained through a meteorological station installed on the property, for the year 2023 (Figure 1).

In the experimental vineyard, the grapevines were spaced 3.0 m between rows and 1.0 m between plants, grafted onto the Paulsen 1103 rootstock, and trained in a trellis system. Following the double pruning management, shoot training pruning was performed in August 2022, with the removal of inflorescences in September. Production pruning was carried out on March 12, 2023, and harvest took place in mid-June. The average minimum temperature during the production year was 16.0°C, the maximum average was 20.5°C, and the annual average was around 17.6°C throughout the cycle. Regarding rainfall, January had the highest rainfall index (374.5 mm), and July had the lowest (2.9 mm).

During berry ripening, the average minimum temperature was 13.3°C. The maximum temperature was 25.3°C. The accumulated precipitation during this period in the cycle was 201.1 mm (Figure 2).

From the beginning of berry ripening, chemical aspects of the 'Malbec' grape must were determined in berry samples taken weekly. Thus, at (0, 7, 14, 21, 28, 35, and 42 days after the onset of ripening), in 5 samples, 10 berries per block were collected. The samples were placed in plastic bags and sent to the laboratory for determination of soluble solids content (SS), titratable acidity (TA), pH, and maturation index.

Using a refractometer (Reichter, model r2i300, USA) for quantification of °Brix (SS); a titrator, for the neutralization reaction between the acid (TA) present in the berry with the base (0.1N NaOH, at the equivalence point at pH=8.2), with results expressed as a percentage of tartaric acid (%); and a pH meter (Tecnal potentiometer - Tec-10, Piracicaba, Brazil) for pH evolution. For the calculation of the maturation index, the ratio between SS and TA is calculated.

The results of the chemical analyses were subjected to regression analysis using the statistical software Sisvar, version 5.6 (Lavras, MG, Brazil).

Result and discussion:

There was a quadratic increase in the soluble solids content in the grape must, with the maximum point of the function reached at 42 days after the onset of berry softening, obtaining a value of 20°Brix (Figure 3). This value was higher than that obtained by Leão et al. (2021), who, working with the Malbec cultivar in a semi-arid climate condition, obtained a soluble solids content of 19.5°Brix. According to Brazilian legislation, Normative Instruction 1/2002 (04/02/2002), the minimum value for grape harvesting is 15°Brix (Choudhury et al., 2004).

There was also a quadratic increase in pH value and maturation index in the grape must and a reduction in titratable acidity (Figure 3).

It is noted that there was a stabilization in the grape must value from 28 days after the onset of berry softening. Regarding titratable acidity, from 35 days after the onset of berry softening, the values remained constant. Regarding the maturation index, the maximum value of 20 was obtained at 42 days after the onset of berry softening.

According to Leão et al. (2021), the soluble solids content for harvesting the Malbec cultivar is 19.5°Brix. Although the present study evaluated only one production cycle, this value was exceeded already at 21 days after the onset of maturation, providing superior quality compared to what is found in the literature, thus positioning the region as potential for the production of this cultivar.

Conclusion:

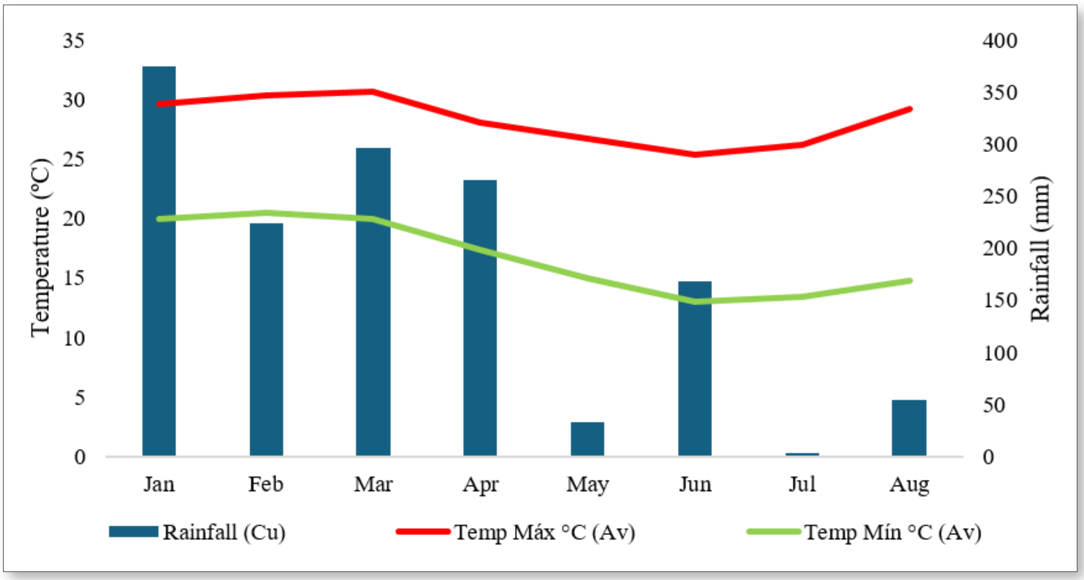
The 'Malbec' cultivar, under double pruning management in a subtropical condition, showed enological potential for wine production in the 2023 harvest.

Soluble solids content in the grape must reached 20°Brix at 42 days after the onset of berry softening.

The cultivation potential of the Malbec cultivar for the production of quality grapes for winemaking was evident.

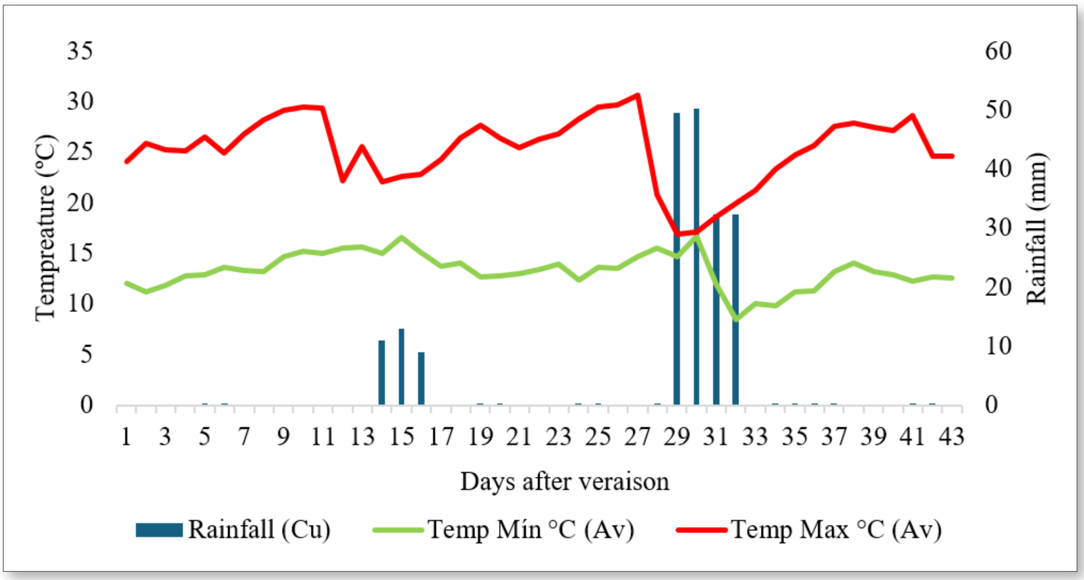
However, more production cycles are necessary for a comprehensive evaluation under these conditions, in order to suggest its adoption as an alternative cultivar for viticulturists, aiming to turn it into a variety with enological potential under the double pruning method. It is important to emphasize that the practice of double pruning requires more rigorous phytosanitary management, especially from the post-pruning period until flowering, which may result in additional costs for crop management.

Figure 1. Climate data (temperature and cumulative rainfall) from the experimental site in 2023 in Fazenda Santa Lúcia, Mineiros do Tietê – São Paulo.



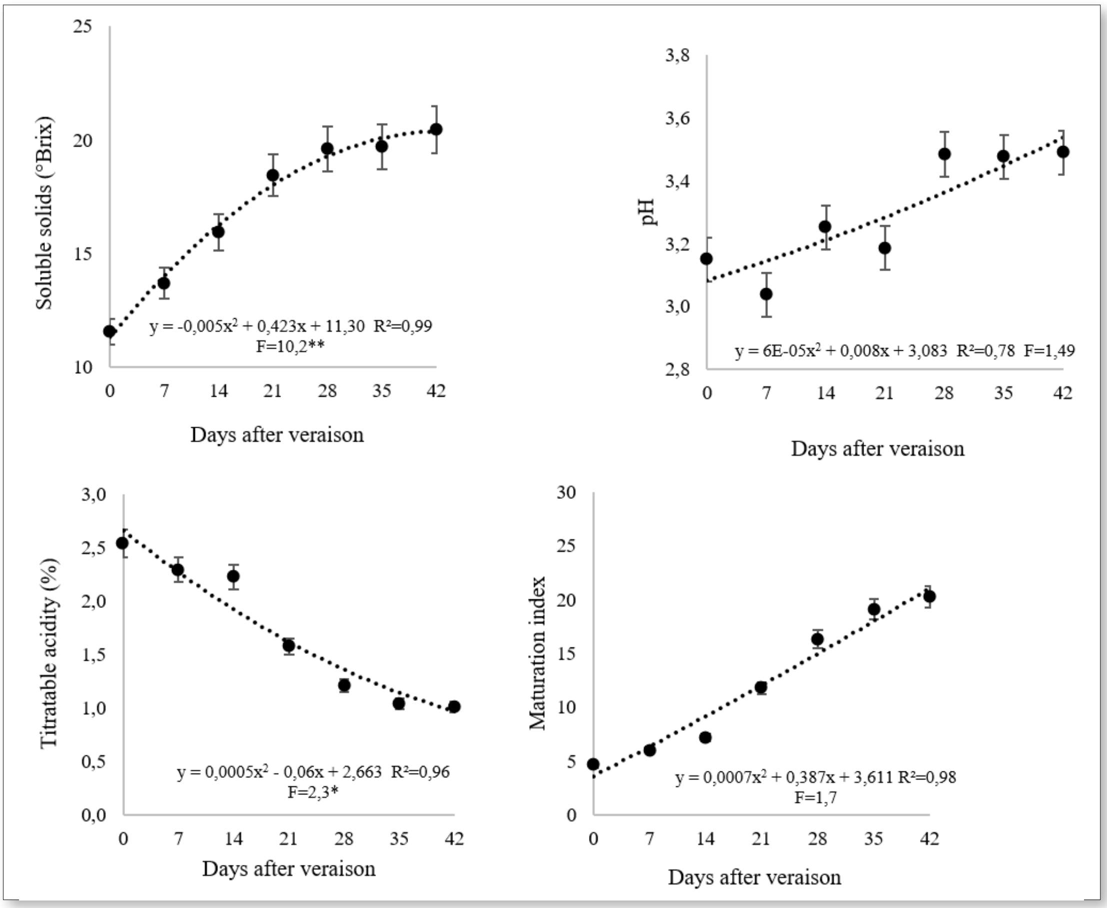
*Productive period. The bars represent the total amount of rain while the lines represent the minimum (green) and maximum temperatures (red).

Figure 2. Climate data (temperature and cumulative rainfall) from the experimental site during the ripening of 'Malbec' grapevine in 2023. Mineiros do Tietê, State of São Paulo, Brazil.



The average maximum temperatures are represented by solid lines, and the average minimum temperatures are represented by dashed lines. The bars represent the total amount of rain while the lines represent the minimum and maximum temperatures.

Figure 3. The evolution of soluble solids, pH, titratable acidity, and maturation index of Malbec under double pruning management in a subtropical condition.
*** p > 0.01 ** p > 0.05. Barras de erro com 95% de IC.**



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NOV 20, 2024 | 16.45 PM | SCIENTIFIC SESSION: **MALBEC II - FLASH ORAL**

Effects of plant material and rootstock on the productivity and quality of Malbec cultivar

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Keywords: **rootstock, plant material, productivity, Malbec.**

ABSTRACT

During 2023 and 2024 seasons, we evaluated the effect of two Malbec plant materials grafted on 3 different rootstocks on the vegetative growth, productivity and berry quality. To achieve so, a small parcel was planted in 2018 with the combination of two Malbec plant materials: a commercial clone (INTA N°18) and a material derived from a massal selection (Selección Perdriel). In turn, those materials were grafted with three different rootstocks: 101-14, 1103 Paulsen and own-rooted; the six combinations were planted randomly with ten replicates of three plants. Despite of its many quality attributes, some Malbec materials, show low productivity due to the phenomenon of shatter. Shatter is characterized by the presence of bunches with a low number of berries, due to the absence of fertilization, death of the ovary or abscission of the fruit. The causes of shatter seem to be multiple and concurrent and largely related to the plant material, although other factors like adverse weather conditions and the availability of carbohydrates for flowers and young fruits have a strong influence as well. Different rootstocks behave differently in the same agronomic conditions, affecting plant development and growing. Previous studies have shown that certain scion/rootstock combinations can modify source/sink relationships by influencing vegetative expression, vigor, yield and quality.

The results of this research show that, over two years, there was an effect of rootstock on the vegetative growth of the plants, independent of the plant material. 101-14 rootstock decreased shoot length, leaf area and total vigor compared to 1103 Paulsen and own-rooted. In turn, 1103 Paulsen decreased some yield components, such as fruit set and the number of berries per bunch, and increased shatter. The Malbec clonal material was found to be the most productive on its own roots, while 101-14 decreased Malbec productivity independent of the plant material. Both plant material and rootstock affected berry quality components in different ways.

Evaluation of different alternatives to modulate the balance of Malbec vineyards in La Pampa (Argentina): shoot and cluster thinning

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Keywords: **shoot thinning, cluster thinning, Malbec, La Pampa, phenolics compounds.**

ABSTRACT

Canopy management makes it possible to modulate the balance of the vines to improve their microclimate and grape quality. Shoot and cluster thinning would allow for modification of the source-to-sink ratio for this purpose. This work aimed to evaluate the impact of both techniques on the chemical composition of Malbec grapes and wines from La Pampa, over two vintages and two locations (25 de Mayo and Casa de Piedra). In 25 de Mayo, three treatments were assessed: a control (T: 30 shoots/m) (without canopy interventions) and two levels of shoot thinning (ST1: 20 shoots/m and ST2: 15 shoots/m). In Casa de Piedra, two treatments were applied: a 25 % thinning of clusters (CT) at the beginning of veraison, with the respective control (C). Yield decreased as a consequence of both strategies due to fewer clusters/plant. The effect on vine balance depended on the vintage. In 2022 (more productive vintage), ST2 and CT determined more balanced vines (Ravaz index near 10). As the number of shoots decreased, the shoot weight increased. As expected, shoot weights did not differ significantly in CT. Concerning grape composition, in 2021, ST1 and ST2 did not influence phenolic composition. On the contrary, in 2022, ST2 showed higher levels of total phenols, tannins, and anthocyanins. However, in wines, ST2 revealed more phenolic potential with higher tannins and colour, compared to T, in both vintages. On the other hand, the CT grapes accumulated more sugar only in 2022, generating wines with higher alcohol content. Likewise, the CT wines showed higher levels of tannins, anthocyanins, and polymeric pigments than the control. Although the impact of these techniques depended on the vintage, they improved the balance of the plants, favouring the accumulation of phenolic compounds in the berries and their expression in the wines.

SCIENTIFIC SESSION: **MALBEC - POSTER**

Chemical and sensory variability of Malbec wines from three geographical indications (GI) of Mendoza (Argentina): Las Compuertas, Altamira and Los Chacayes

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Keywords: **variability, geographical indication, phenolic composition, sensory attributes, Malbec.**

ABSTRACT

The characterization of wines originated from different Argentine's GI (Geographical Indications) is of great interest for their regional identity, traceability, and international and local promotion. The variability among wines from a specific region is a critical factor for research studies as both, chemical composition and sensory properties, are influenced by multiple factors. This study aimed to evaluate the chemical and sensory variability of Malbec wines from reputed Mendoza's GIs. Three repetitions of the following 7 vineyards were analyzed: Las Compuertas (CO1, CO2, CO3), Altamira (ALT1, ALT2, ALT3), and Los Chacayes (CH1). Each one was composed of 15 homogeneous and well-balanced plants. Grapes were harvested at 24 ± 1°Brix, and processed following a standardized protocol. The stabilized wines were characterized by alcohol, pH, titratable acidity, total phenols, tannins, anthocyanins, polymeric pigments, and color attributes (CIELAB parameters). A PCA analysis showed that CH1 wines were significantly different from the rest, characterized by a higher content of total phenols, a greater proportion of polymeric pigments, and an intense red hue (h_{ab} = 5.25). ALT2 wines revealed higher levels of tannins, anthocyanins, color saturation (>C^*_{ab}), and ethanol, probably due to a higher degree of grape maturity. ALT1, ALT3, and CO3 wines revealed lower contents of the different phenolic parameters and a higher proportion of violet hue (<h_{ab}). Finally, CO1 and CO2 wines exhibited the lowest color intensity (<C*ab) and higher pH levels. Finally, the CIELAB color differences (ΔE*ab) between wines from different origins were greater than 3, indicating differences visually perceptible. These results were complemented by a descriptive wine sensory analysis conducted by a trained panel of judges. A better understanding of the distinctive chemical and sensory characteristics of Malbec wines, according to the origin, are key elements to contribute to the GI's identity and competitiveness and it is useful information for regional experts' communication.

SCIENTIFIC SESSION: **MALBEC - POSTER**

Influence of organoleptic characteristics in Malbec wines obtained by Flash-Expansion and the addition of vegetable proteins and tannins.

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Keywords: **vegetal protein; tannin; thermoflash; phenolic compounds.**

ABSTRACT

In the last decade, the market demanded the absence of allergenic substances in wine production. In this context, clarifying agents from vegetal origin, mainly peas and potatoes, have begun to be commonly used. Additionally, in warmer areas such as the East of Mendoza, where sugar ripeness occurs before phenolic ripeness, is more and more requested fast extraction techniques as flash-expansion. This extraction system involves heating the crushed and destemmed grapes above 80°C, then subjecting them to a vacuum. A rupture of the skin's intracellular walls, due to the vacuum and the decrease in the boiling point, liberates their colour allowing the juice fermentation with very low tannins concentration. In this context, a fermentation without skins and seeds produces unstable wines in terms of colour. They require tannins addition, the use of micro-oxygenation, and the use of clarifying agents to reduce the bitterness and roughness in the result wines. In this experiment, Malbec grapes from the Rivadavia department of Mendoza were processed by flash-expansion, separated from their solids by decantation, and then centrifuged to 400 NTU. Fermentation occurred under controlled conditions, and the treatments were: different doses of vegetal proteins from peas and/or potatoes, with and without tannins. The resulting wines were cold stabilized at 2°C for 10 days and adjusted with SO_2 to 35 ± 5 mg/L, and bottled under controlled conditions (750 mL + synthetic cork). They were analyzed by physicochemical parameters (alcohol, reducing sugars, total acidity, volatile acidity, pH, malic acid, lactic acid), global phenolic parameters (IPT, NIC, hue, and intensity), tannins, anthocyanins, polymeric pigments color attributes (CIELAB parameters). This experiment was complemented by a wine sensory analysis conducted by a trained panel of judges, after 3 months of bottling. The results obtained showed significant differences in the analyzed physicochemical parameters.

SCIENTIFIC SESSION: **MALBEC - POSTER**

Biodiversity of the mycobiota associated with the surface of Malbec grapes from the southern oasis of Mendoza (Argentina) viticulture region approached by high-throughput sequencing

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Keywords: **southers oasis of Mendoza viticulture region, Malbec grapes, metagenomics, fungi, yeasts**

ABSTRACT

The use of high-throughput sequencing (HTS) technologies is a powerful tool to study the microbial communities of an ecosystem and to explain how the environment influences the composition of microorganisms present in such an ecosystem. This work aimed at characterising the fungal biodiversity on the surface of Malbec grapes from four subregions of the Southern Oasis of Mendoza viticulture region. Fungal biodiversity was studied by mass sequencing of ITS2 amplicons from DNA samples obtained by washing the surface of intact Malbec grapes collected during the 2023 vintage from vineyards located in four subregions of the Southern Oasis of Mendoza (Rama Caída, Las Paredes, Villa Atuel and Cuadro Nacional). The DNA extraction method was optimised using the DNeasy PowerSoil Pro kit (QIAGEN). DNA extraction and concentration were verified by agarose gel electrophoresis. The ITS2 region of the fungal genome was amplified using primers FITS7 and ITS4. Sequencing was performed on an Illumina MiSeq ultra-sequencer at the Genomics and Bioinformatics Platform of the Centro de Investigación Biomédica de La Rioja (CIBIR), in Logroño (Spain). The bioinformatic analysis was performed using the QUIIME2 software. In all the subregions studied, there was a predominance of fungi belonging to the subdivision of the kingdom Fungi Ascomycota, with relative abundances ranging from 86.06 to 99.49%, with Dothideomycetes as the predominant class. The most abundant genera and species were *Aureobasidium thailandense* (16.48 to 61.23%), *Cladosporium herbarum* (4.33 to 50.27%), and *Curvularia* spp. (23.92 to 35.28%) for all subregions. No significant differences in alpha diversity were observed between the subregions analysed in any of the calculated indices. According to the beta diversity indices, significant differences in fungal taxa were observed between the subregions, suggesting the existence of different fungal microbiomes in the terroir studied.

SCIENTIFIC SESSION: **MALBEC - POSTER**

Ozonation strategies in vineyards to improve the physicochemical quality of wine

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ABSTRACT

The viticulture industry faces constant challenges to improve its processes year after year. The goal is not only to produce the best wine, but also to ensure that it is obtained through sustainable, economical, and environmentally friendly processes. Current technologies, such as the use of ozone applied to vines, help us to enhance certain processes and improve grape quality. One strategy researched in several wine-producing regions is the use of ozonated water in vineyards to control fungal diseases, taking advantage of the oxidizing properties of ozone and its fast decomposition without leaving toxic residues. A study was conducted to evaluate the effectiveness and impact of this technique on the physicochemical parameters in grape musts treated with different ozone concentrations and application methods. Ozonated water with a concentration of 1.25 ppm was applied in vineyards with the Ramet training system using three methods: foliar application, application through the irrigation system, and endotherapy. Applications were carried out at key moments of the vine vegetative cycle: after veraison and before harvest. The treated grapes were vinified for 10 days at 20°C, and the resulting wines were analyzed for physicochemical parameters such as total polyphenol index (TPI), color, anthocyanins, and tannins. The results indicated a tendency to reduce ethanol content in wines obtained from grapes treated with foliar-applied ozonated water, increasing polyphenol contents and color indices by 10 to 12%. These preliminary findings suggest that the use of ozonated water in vineyards, especially through foliar application, could be a promising strategy to mitigate the effects of climate change on wine production. However, further research and additional studies are needed to fully understand the effects of this technique and to determine its feasibility on a large scale under different viticultural conditions.

SCIENTIFIC SESSION: **MALBEC - POSTER**

Characterization of Malbec clones in different agroecological zones of Argentina

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Keywords: **characterization, Malbec, clones, agroecological zones, chemical composition, sensory analysis.**

ABSTRACT

A series of studies of Malbec clones were carried out to evaluated the chemical and sensory composition of wines in: (1) different clones located in six different regions of Argentina were evaluated for their fertility capacity and oenological quality parameters, (2) different clones implanted in one region, and (3) single clone implanted on three different regions. The clonal material used for the study was selected by the Tempus Alba winery based on phenological characteristics. The regions studied in trial (1) were: Agrelo, Anchoris, Gualtallary and Vista Flores in Mendoza; San Pedro de Yacochuya and Animaná in Salta; Villa Soto in Córdoba. The clonal material studied in trial (2) (clones 24, 14, 22, 18 and 15) was implanted in Anchoris (Mendoza). Finally, trial (3) evaluated the behaviour of clone 24 in Ugarteche, Anchoris and Vista Flores (Mendoza). A tendency to increase the concentration of polymeric pigments was observed in the Yacochuya and Gualtallary areas, suggesting a greater colour intensity in these wines. On the other hand, the Vistaflores and Animana areas presented higher levels of floral and fruity aromatic notes than the rest of the regions. Clones 24 and 18 presented more tannins and anthocyanins, standing out for their balsamic and floral aroma. The evaluation of clone 24 in three different areas showed that Vista Flores presented higher content of phenolic compounds, spicy aromas, and violet nuances. In the analysis of Malbec wines from different areas of Argentina, significant patterns have been observed in the parameters of colour, chemical composition and sensory analysis. Our results indicate that all regions present unique characteristics in their wines, that the clones studied present differences, as does a single clone planted in different agroecological zones. The diversity of clones and regions studied allows for a better understanding on how agroecological and genetic factors influence the wine composition and flavour.

Oenological behaviour of autochthonous biocontrol yeasts from Malbec wine grapes of the Southern Oasis of Mendoza (Argentina) winemaking region

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Keywords: **oenological behaviour, autochthonous biocontrol yeasts, Malbec wine grapes, winemaking region of San Rafael.**

ABSTRACT

The Southern Oasis of Mendoza winemaking region, located in the west-centre of Argentina, harbours a tradition of high-quality wines derived from its valuable terroir. Autochthonous yeasts from Malbec grapes from the San Rafael winemaking region, selected for their ability to biocontrol *Alternaria* on grapes, were previously evaluated *in vitro* for oenological compatibility potential, but their behaviour during winemaking should be assessed. Therefore, *Metschnikowia* sp. yeasts (LP128.2, LP131.2, LP132.1), which showed no potential for wine spoilage (acetic acid production or odour defects) and no competence with *S. cerevisiae* (<0.9 Niche Overlap Index), were further evaluated in laboratory-scale winemaking trials with Malbec must (1 L). The trials were carried out by sequential inoculation (48 h before at 10ºC) of biocontrol yeasts (106 cells/mL) followed by inoculation with commercial *S. cerevisiae* (IOC 18-2007, Institut Œnologique de Champagne, France) (106 cells/mL) at 25ºC. As a result, the 3 strains of *Metschnikowia* sp. were able to grow and remain viable during the first 5 days of co-culture with *S. cerevisiae* and did not modify the growth of the commercial *S. cerevisiae* yeast or its fermentation kinetics. With regard to the finished wines, the physicochemical parameters of all the wines were similar, 2 of the *Metschnikowia* sp. strains (LP131.2 and LP132.1) stood out for having better chromatic parameters (copigmented anthocyanins) in the colour analysis of the wines, and very good colour intensity and tonality in the descriptive sensory analysis carried out by a trained tasting panel. Therefore, the autochthonous biocontrol yeasts from Malbec wine grapes of the Southern Oasis of Mendoza (Argentina) winemaking region not only showed a compatible oenological behaviour, but also the ability to impart desirable characteristics to the wine, which in turn could add value to the biocontrol proposal.

SCIENTIFIC SESSION: **MALBEC - POSTER**

Chemical and sensory identity of Malbec wines from the main producing regions of Argentina

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Keywords: **chemical composition, sensory attributes, winegrowing areas, typicity, Malbec.**

ABSTRACT

The concept of typicity refers to the degree to which the characteristics of wine represent or reflect a delimited geographical area of origin. In "New World" wine-producing countries, such as Argentina, the concept of regionality from the consumer's point of view is based on brand valuation and price as indicators of wine quality. In our country, the origin of wines is directly linked to and represented by the concept of Geographical Indication. In this context, more than 78% of the wine is produced in the province of Mendoza, followed by San Juan, La Rioja, and Salta. As is well known, Malbec is Argentina's emblematic cultivar. Although some studies on the chemical characterization and sensory profile of its wines have been reported, they have only explored the diversity existing in different geographical areas of Mendoza. This study seeks to identify chemical parameters and distinctive sensory attributes that characterize Malbec wines from different zones of Mendoza, San Juan, La Rioja, and Salta; to relate edaphic and environmental variables with the indicated parameters; and to generate a digital tool that allows access to the "Sensory Footprint" of the wines. More than 200 monovarietal commercial wines from representative wineries in each zone were selected, considering a range of 3 vintages as a limit. The wines were bottled and stored under controlled conditions (15°C, 50-60%RH, darkness) until analysis. Characterization was carried out in terms of general parameters, phenolic compounds, odorant compounds, elemental profile, MIR/NIR spectra, and sensory attributes (QDA). In the first stage, an ANOVA was applied for the chemical and sensory variables separately, and, to estimate the representative parameters of each geographic zone, a partial least squares discriminant analysis was performed. Some identifying characteristics were observed in specific zones that will allow producers to define communication and/or commercial strategies to favor their competitiveness in the market.

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