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AN EXPLORATION OF SOUTH TYROLEAN PINOT BLANC WINES AND THEIR QUALITY POTENTIAL IN VINEYARD SITES ACROSS A RANGE OF ALTITUDES

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Aim: Pinot Blanc is the third most planted white wine grape in northern Italy's region of South Tyrol, where small-scale viticultural production permits the examination of the wine's diverse expressive potential in a small area across a wide range of climatic variables. This study aimed to explore the qualitative potential of Pinot Blanc across a range of climatic variation leading to site-specific terroir expression in a cool climate region.

Methods and Results: Eight Pinot Blanc vineyards with individually unique terroir along the Adige Valley were chosen and monitored over the course of three years and resulting wines underwent chemical and sensory analysis. Selected quality-defining parameters were compared to four defined temperature classes and multiple harvest dates. Temperature class had a mild effect on aromatic expression of Pinot Blanc wines, with organoleptic perception of cooler sites being characterized by higher acidity and citrus aromas, while warmer sites had more prominent pear and banana aromas. Different harvest dates had a stronger impact on cooler sites, while warmer temperature classes showed little difference between time of harvest.

Conclusions: Vineyard site temperature is less of a principle driver of wine expression in Pinot Blanc than time of harvest, which has a stronger impact on cooler vineyard sites, where achieving a certain technical ripeness is paramount to producing high quality, typical wines. To mitigate the effects of climate change, it may be beneficial for warmer wine producing regions with narrowly defined typicity and limited climactic variation to employ earlier harvest protocols.

Significance and Impact of the Study: Mountainous regions provide the opportunity for agricultural activity at higher altitudes, where cooler conditions and earlier harvest dates could potentially mitigate the deleterious effects of rising temperatures on grapevines and preserve the typical organoleptic qualities associated with wines from these regions.

Keywords: Pinot Blanc, climate change, terroir, typicity, sensory profiling

Introduction

Pinot Blanc is one of the cornerstone varieties of wine production in South Tyrol, composing 564 of the almost 5,500 hectares of the region's vineyard surface, making it the fourth most planted variety in the region (CCB, 2020). The small-scale viticulture production typical to South Tyrol, characterized by geographically and altitudinally diverse vineyard locations, permits the examination of Pinot Blanc's varying expressive potential across a range of climactically heterogenous vineyard sites. A study of this nature can provide insight into how large of a role temperature plays in quality determination of resulting wines, as well as important components from a sensorial and chemical aspect that define typicity of Pinot Blanc in South Tyrol.

Within the scope of climate change, the rise of global temperatures is one of the greatest threats to viticultural regions worldwide. While climate change does indeed pose a threat to all sectors of agriculture, certain crops, such as the grapevine, are constricted to narrower climatic zones than other more cosmopolitan crops (Jones and Webb, 2010). Increased ambient temperatures have been shown to affect multiple aspects of the grapevine, including vine metabolism, which can lead to potential alteration of wine aroma and color (Orduña, 2010). Higher mean temperatures can also lead to unbalanced ripening, in which sugar levels accumulate faster, organic acid levels experience more rapid declines, all the while flavor development is still underway; the result being high alcohol, low acid grapes with underdeveloped aromatics (Jones, 2004).

Across the Alps, average annual temperatures have increased by approximately 2°C over the past century; almost twice as much as the global average (Auer *et al*., 2007; EEA, 2009). This more rapid increase in temperature may put Alpine viticultural regions at a more imminent risk of altered grape and wine quality, which can ultimately threaten the terroir and typicity of these regions' long-established wine cultures. Mountainous regions provide the opportunity for agricultural activity at higher altitudes, where cooler conditions could potentially mitigate the effects of rising temperatures and preserve the typical organoleptic qualities associated with these regions' respective wines. Over the past decade there has been a trend in South Tyrol towards planting new vineyard sites at higher altitudes of up to 1300 meters (Egarter Vigl *et al.,* 2018), but the exploitation of these higher altitude areas and the quality of grapes and wines yielded from them has been little studied until now.

The current study aimed to provide a deeper understanding of how different climates during the vegetative cycle of the grapevine affect organoleptic and chemical characteristics of Pinot Blanc in a mountainous region. A further goal of this research was to characterize the unique expression of the Pinot Blanc variety in South Tyrol through a comprehensive scope, integrating viticultural, sensorial and chemical data in order to valorize site and wine quality.

Materials and Methods

Research trials began in the vineyard, with the management and harvest of the 2017-2019 production of eight Pinot Blanc vineyard sites along the Adige River in South Tyrol, ranging from 223 to 730 meters above sea level. Each site was equipped with its own weather station which monitored hourly ambient temperature at two meters above the ground surface. Grapes were harvested for the 2017 and 2018 vintages on two separate harvest dates; the first harvest occurring at a technical ripening goal of approximately 18°Babo and the second harvest at approximately 20°Babo. The 2019 vintage was carried out in a single harvest with approximately 20°Babo as a technical ripening goal.

The intended number of total fermentation trials per vintage was 48. Due to several partial or full losses of yield, 2017 and 2018 had 45 and 42 fermentation trials, respectively. We processed and fermented all grapes following a strict singular protocol for all wines, with each trial having three fermentation replicates. Thus, for each of the eight sites, there were 16 wines, which had three fermentation replicates in the cellar, for a total of 48 (eight sites * two treatments * three replicates) wines.

The sensory panel consisted of local wine production professionals, male and female, between the ages of 26 and 59. Prior to the tasting sessions each year, panelists participated in two training sessions that focused on individual aroma identification and characteristics of Pinot Blanc wines. During the first year of training session, the panel also selected and agreed upon the sensory attributes that would be used for the duration of the study. Sensory evaluation by quantitative descriptive analysis on 15 olfactory parameters and seven gustatory parameters was carried out across three sessions for each vintage. In a single session, panelists (minimum 12 per session) blind tasted through the entire series of a single microvinification replicate (i.e. 15, 14 and 16 unique wines for the 2017, 2018 and 2019 vintages, respectively). Wines were labeled with random three-digit numbers,

in a randomized order, with data for each of the assessed parameters collected by FIZZ Sensory Analysis Software (version 2.61, Biosystèmes, Couternon, France).

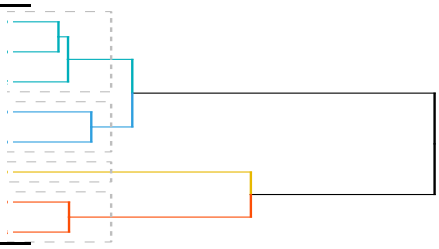
For each value per parameter judged for each wine, the median score was calculated to yield a single value. To determine temperature classes for the eight vineyard sites, we took into consideration average and cumulative minimum and maximum temperatures, mean and range temperatures, potential radiation, growing season rainfall (GSR), and growing degree days (GDD) calculated according to Winkler *et al.* (1974). With these values, we used an agglomerative hierarchical cluster analysis (HCA) to classify the vineyard sites into groups according to their similarity. Values used for the HCA were expressed as the median of each parameter taken into consideration. We carried out permutational analysis of variance (pANOVA) on sensory attributes with temperature class and moment of harvest as predictors, using pairwise permutation tests (PPT) for post-hoc analysis. To determine any correlation of typicity of the wines with sensory and chemical parameters, we performed a simple correlation. All statistical analyses were carried out in R (R Core Team, 2020). The HCA was performed using the *factoextra* package (Kassambara and Mundt, 2016). Statistical analysis of sensory data was performed with a seed set at 4518; pANOVAs were performed with the *permuco* package (Frossard and Renaud, 2019) and pairwise permutation tests were performed using the *rcompanion* package (Mangiafico, 2020). Linear regressions were performed using the regression-based modelling package *corrr* (Kuhn *et al.,* 2020).

Results and Discussion

Four temperature classes (TC) were determined from the HCA based on temperature indices, agroclimatic indices and potential radiation. From coolest to warmest classification, TC 1 consisted of three sites at 569, 650 and 542 m asl, TC 2 consisted of two sites at 670 and 730 m asl, TC 3 consisted of one site at 419 m asl, and TC 4 consisted of two sites at 279 and 223 m asl (Table 1).

Table 1: Classification of temperature classes alongside their cluster dendrogram of eight vineyard sites that were the focus of the study, including each site's altitude in meters above sea level (meters above sea level), potential solar radiation (Watts/m^2), growing degree days (GDD), and the standard deviation (SD) of the calculated GDD.

Site	Temperature Class	Altitude (m asl)	Potential Solar Radiation (W/m^2)	GDD	SD
Eppan Lower	1	542	124,893	1653	+/-116
Eppan Upper	1	569	126,015	1641	+/-136
Nals Upper	1	650	114,782	1612	+/-130
Terlan Upper	2	670	122,911	1631	+/-149
Tramin Upper	2	730	122,232	1603	+/-153
Nals Lower	3	419	139,877	1872	+/-136
Terlan Lower	4	279	123,906	1971	+/-121
Tramin Lower	4	223	136,627	1941	+/-108



The sensory panel, composed of winemakers, winery owners and sommeliers, decided on 15 aromatic attributes and 7 gustatory attributes that are both representative and important in determination of Pinot Blanc quality in South Tyrol. Aromatic parameters chosen were: apple, pear, quince, pineapple, banana, lemon, grapefruit, peach, walnut, linden blossom, hawthorn blossom, hay, honey, mushroom and green aromas. Gustatory parameters selected were: complexity, fullness, typicity, length and perceived acidity. Overall scores of sensory parameters for wines across all three years and all four temperature classes showed that aromatic expression played a minor role in comparison to gustatory attributes, which, other than bitterness, were consistently scored higher than aromatics by the tasting panel (Figure 1).

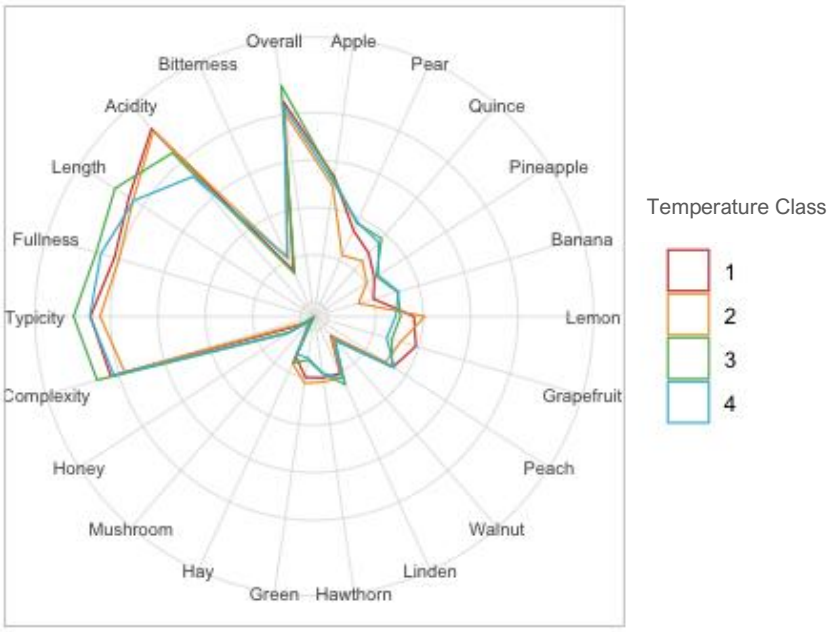


Figure 1: Radar chart of mean sensory attribute scores for all 22 parameters, with individual color-coded plots comparing organoleptic expression by temperature class, with temperature class 1 being the coolest and 4 the warmest.

We found four of the 15 aromatic sensory attributes to have significant results with temperature class as a predictor (Table 2a, Figure 2). Citrus aromas were more prominent in cooler sites; lemon had significantly higher intensity in three comparisons between cooler sites and their warmer counterparts (Table 3), while grapefruit was more aromatically intense in TC 1 than TC 4 (DM = 3.141, p = 0.01). Banana and pear aromas, which have been found to be strongly correlated (Pedri and Pertoll, 2013), were overall more expressive in warmer sites. Pear aroma became more expressive in warmer temperature classes, except when comparing the two coolest temperature classes, where it was less expressive in the warmer of the two classes. Temperature class did not have a strong apparent effect on most of the gustatory attributes, with no noticeable difference between classes for typicity, fullness, length, bitterness or overall impression. Perceived acidity was consistently higher in cooler temperature classes, although no significant difference was found between the two coolest TC's.

Table 2: Significant results (α = 0.05) of individual two-way permutation ANOVAs with sensory attributes as response variables, and temperature class (a) and time of harvest within each temperature class (b) as predictors.

	(a) Temperature Class		(b) Harvest in TC 1		Harvest in TC 2		Harvest in TC 3		Harvest in TC 4	
	$F_{3,131}$	p	$F_{1,31}$	p	$F_{1,16}$	p	$F_{1,10}$	p	$F_{1,22}$	p
Pear	4.008	0.012	4.499	0.0431						
Banana	5.636	0.001	14.13	< 0.001	5.85	0.033				
Lemon	5.124	0.002								
Grapefruit	4.087	0.010								
Honey			8.565	0.006					4.261	0.005
Typicity			9.574	0.004			5.791	0.043		
Fullness			13.28	0.001					5.961	0.026
Length			8.216	0.007						
Complexity	2.669	0.049	13.66	0.001			6.096	0.026		
Perceived Acidity	21.77	< 0.001	7.609	0.010	9.71	0.006	8.178	0.025	20.21	< 0.001
Overall Quality Impression			15.07	< 0.001			18.200	0.002		

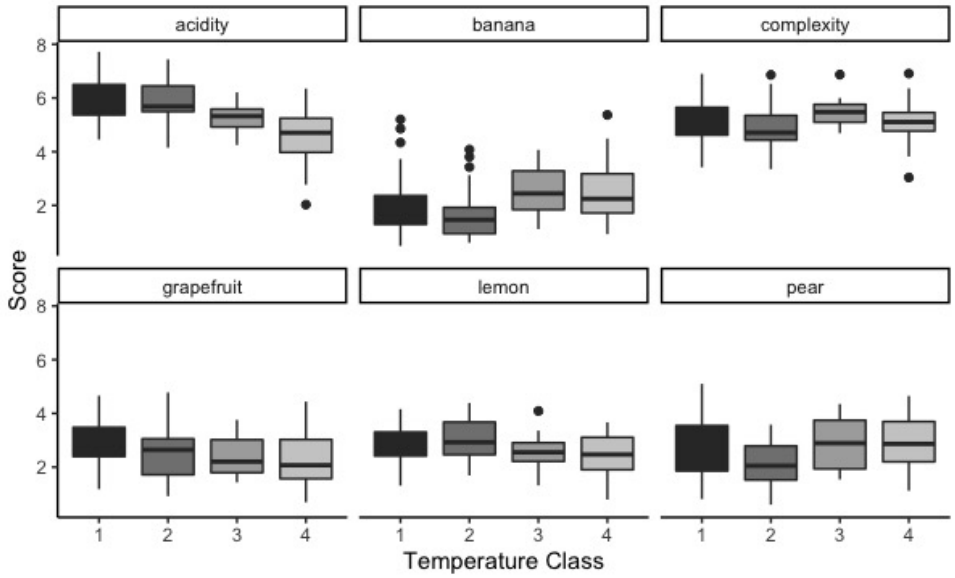


Figure 2: Box plots of mean scores of sensory attributes that were significantly ($p \leq 0.05$) influenced by temperature class.

Warmer viticultural zones are under heightened pressure as global temperatures continue to rise, and particularly so in extremely hot vintages. Harvesting grapes at 18°Babo rather than at the common technical ripening goal of 20°Babo could be a solution to preserving the fresh qualities sought in white wines. We compared wines from two different harvests which took place at 18°Babo and 20°Babo, and upon analysis found that the coolest temperature class was most affected by ripening in terms of number of parameters that responded significantly to the difference in harvest date (Table 2b). Post-hoc pairwise permutations showed that all significant sensory attributes (apart from perceived acidity), both aromatic and gustatory, were considered less prominent in the first harvest than the second (Table 4). Of particular importance is the decrease in typicity and overall quality impression of wines from the earlier harvest. These results highlight the importance for grapevines in the coolest sites of the region to reach the 20°Babo technical ripening goal in order to produce wines of equal quality to warmer, lower altitude sites.

Temperature classes 2 and 4 had few differences between the earlier and later harvests (Table 4), and apart from a decreased fullness in the early harvest wines of the warmest temperature class (TC 4, DM = -2.214, $p = 0.027$), there were no significant differences in gustatory parameters that could affect quality, particularly no difference in overall impression of quality. This could be seen as a potential avenue for wine producers to, in warmer vintages, perform an earlier harvest that could preserve the typical qualities of South Tyrolean Pinot Blanc without sacrificing its typical organoleptic characteristics or quality.

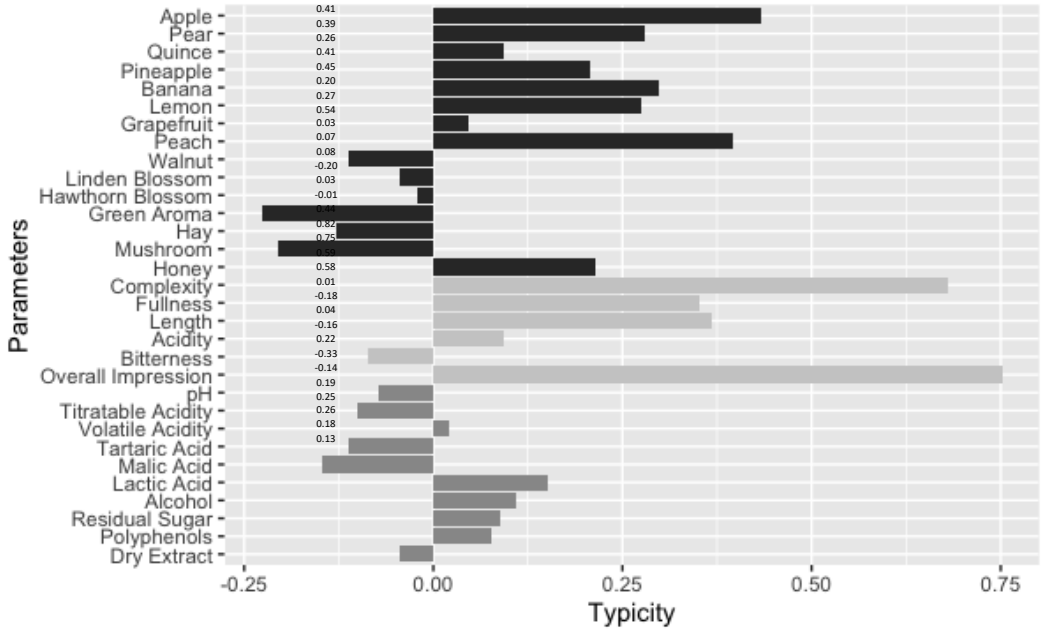


Figure 3: Bar plot of correlations between typicity (x axis) and the various aromatic (black) and gustatory (light grey) attributes as scored by panelists, as well as chemical parameters measured in the laboratory (dark grey). R values for each correlation are listed next to each parameter.

Perceived acidity was the only gustatory attribute that was consistently higher across all temperature classes (Table 4) in wines from the earlier harvest, as would be expected by the higher acidity levels in an earlier harvest. However, considering that acidity was found to be either minimally (with regard to perceived acidity) or negatively (regarding titratable and tartaric acidity) correlated with typicity (Figure 3), the perceived acidity differences between the first and the second vintages (Table 4) may well be negligible in considering whether an earlier harvest is appropriate in a vintage characterized by higher temperatures.

Table 3: Significant pairwise permutation post-hoc results of permutation ANOVAs with temperature class as a predictor. The direction of the difference of the means (DM) is based on the first variable on the left side being considered the measurement variable, and that on the right used as the grouping variable. In other words, when the DM is positive, the temperature class (TC) mean on the left in each TC comparison is larger than the TC mean on the right.

	Temperature Class Comparisons											
	TC1 - TC2		TC1 - TC3		TC1 - TC4		TC2 - TC3		TC2 - TC4		TC3 - TC4	
	DM	adj. *p*	DM	adj. *p*	DM	adj. *p*	DM	adj. *p*	DM	adj. *p*	DM	adj. *p*
Pear	2.474	0.027					-2.67	0.023	-3.15	0.010		
Banana					-2.399	0.033	-2.89	0.012	-3.32	0.005		
Lemon					2.504	0.037	2.331	0.039	3.218	0.008		
Grapefruit					3.141	0.01						
Perceived Acidity			3.209	0.003	5.690	< 0.001	2.571	0.013	4.622	< 0.001	2.553	0.001

Table 4: Significant pairwise permutation post-hoc results of permutation ANOVAs with harvest by temperature class as a predictor. The direction of the difference of the means (DM) is based on the first variable on the left side being considered the measurement variable, and that on the right used as the grouping variable. In other words, when the DM is positive, the mean of Harvest 1 (left), which occurred at approximately 18°Babo, was larger than the mean of Harvest 2 (right), which occurred at approximately 20°Babo.

	Temperature Class 1		Temperature Class 2		Temperature Class 3		Temperature Class 4	
	Harvest 1 - Harvest 2		Harvest 1 - Harvest 2		Harvest 1 - Harvest 2		Harvest 1 - Harvest 2	
	DM	adj. *p*	DM	adj. *p*	DM	adj. *p*	DM	adj. *p*
Pear	-2.014	0.044						
Banana	-3.166	0.002	-2.133	0.033				
Honey	-2.632	0.008						
Complexity	-3.128	0.002			-2.041	0.041		
Typicity	-2.748	0.006			-2.009	0.045		
Fullness	-3.098	0.002					-2.214	0.027
Length	-2.589	0.009						
Perceived Acidity	2.511	0.012	2.534	0.011	2.225	0.026	3.318	< 0.001
Overall Quality Impression	-3.235	0.001			-2.664	0.008		

Due to its aromatically neutral nature, non-aromatic organoleptic properties (e.g. acidity and freshness) are of heightened importance regarding Pinot Blanc wine quality, for which they play a major role in South Tyrol Pinot Blanc (Figure 1). Apart from acidity, all temperature classes in which Pinot Blanc grapes are being grown in the South Tyrol region have been defined by this study as yielding wines that are similarly typical, complex and full, with high scores for overall impression of quality.

Further advantageous avenues to support the findings of this study would include the incorporation of volatile organic compound data on the wines in question in order to determine which compounds are responsible for the perceived notes in the wines, as well as to differentiate any unique biochemical characteristics of temperature classes and different moments of harvest.

Conclusions

Pinot Blanc wines produced from a range of climactically diverse sites were found to differ slightly in their aromatic and gustatory attributes, but with no significant differences in their typicity and overall quality. Harvest dates and technical ripening parameters play a much more prominent role in quality determination of the wines, with the coolest vineyard sites being the most susceptible to decreased quality in the case that they are unable to arrive to these ripening goals.

Given the heterogeneous range of climates across the region of South Tyrol, typicity is also broadly defined and therefore the effects of climate change may be minimal in comparison to regions that are more climactically restricted. Wine producing regions that err on the warmer side may benefit from the employment of earlier harvest protocols where increased annual temperature has been seen to adversely affect wine quality.

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