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UNDERSTANDING REGIONALITY AND TERROIR IN AUSTRALIAN PINOT NOIR

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Abstract

Aims: This study aimed to (1) characterise colour and phenolic profiles of commercial Australian Pinot noir wines, (2) understand regional drivers of sensory and volatile profiles of commercial Australian Pinot noir wines, and (3) generate a deeper understanding of where Australian Pinot noir wines profiles sit in an international context.

Methods and Results: A broad set of commercial wines was sourced from 10 Australian Pinot noir producing wine regions (n=102) from two vintages (2015 and 2016). The modified Somers method was used for preliminary colour and phenolic analysis of the wines. Noticeable colour and phenolic profile differences were observed amongst the regions. For example, wines from Southern Tasmania were found to have consistently higher anthocyanin levels.
A sub-set of the broad group of Australian samples (n=80) was selected for grape-derived and fermentative volatile analysis (solid phase micro extraction coupled with gas chromatography–mass spectrometry) in addition to colour and phenolic analyses. Vintage was found to have a greater effect on aroma compounds than region.
A narrower set of commercial wines (n=15) was sourced from 5 Australian Pinot noir producing wine regions for in-depth sensory (Pivot© Profile) and grape-derived and fermentative volatile analysis (solid phase micro extraction coupled with gas chromatography–mass spectrometry). The sensory assessment results showed that wines from the Mornington Peninsula, and to a lesser extent two from Northern Tasmania were associated with 'red fruits' aroma, while the majority of wines from Adelaide Hills, Southern Tasmania, and Yarra Valley, were associated with the attributes 'floral' and 'oaky' aroma.

Conclusions: Wine colour and phenolic analyses revealed demonstrable differences between Australian regions, and between the 2015 and 2016 vintages. Further investigation of volatile composition and sensory attributes of 2018 vintage wines showed regional sensory trends when it comes to Australia's Pinot noir producing regions, with the Yarra Valley, Adelaide Hills and Mornington Peninsula showing similarities in their sensory profiles. However, from a sensory perspective Tasmanian Pinot noir tends to incorporate elements of all those regions into its sensory profiles, potentially reflecting the larger geographical size of the Tasmanian regions and greater terroir diversity in a single region.

Significance and Impact of the Study: The growing popularity of Pinot noir with Australian wine consumers underpins a need for better understanding the variety and its performance across varied terroirs. Many viticulturists and winemakers base agronomical and oenological practices on the colour and palate attributes of final wines. It is therefore important for the Australian wine industry to better understand the effect of regional compositional characteristics which potentially impact sensory attributes. These findings have the potential to support decision making for winemakers and viticulturists to achieve desired quality and stylistic outcomes and require further in-depth analysis of characteristics of the terroir. To the authors' knowledge, this is the first study attempting to compare sensory and volatile profiles of Australian Pinot noir wines. Further studies including a greater number of samples and wine regions would provide more conclusive results, as would a comparative study using standardised winemaking protocols for fruit from a range of regions.

Keywords: Australian Pinot noir, regionality, aroma, Pivot© Profile

Pinot noir (*Vitis vinifera* cultivar)

Pinot noir is a popular red winegrape cultivar which is well suited to a range of regions that have a similar climate to that of the *Côte d'Or* appellation in Burgundy, France where Pinot noir produces some of the finest and most expensive wines in the world (Shaw, 2012). One aspect contributing to this quality is Burgundy is one of the coolest climatic regions based on the degree-day index (heat summation Apr-Oct <2500-degree days) (Amerine and Winkler, 1944). Other high quality Pinot noir producing regions usually also fall into this climatic category, however may differ according to other indices such as growing season temperature, Huglin index, cool nights and dryness (Jones *et al.,* 2009). Climate is thought to be a key driver of high quality Pinot noir wines, thus concerning some producers in the face of the changing climate.

Pinot noir plantings account for over 112,000 ha globally. It is cultivated in many European countries such as France, Germany (Spätburgunder) and Italy (Pinot Nero), as well as in many New World regions such as California (US), Australia, South Africa, Canada, Argentina, and Chile. Pinot noir is also the most cultivated red winegrape in New Zealand (NZ), with plantings covering a total area of ~5,550 ha, equivalent to the 14.7% of the total NZ vineyard area (New Zealand Winegrowers, 2016). Pinot noir also dominates plantings in Oregon (US), where it accounts for >60% of wine grape cultivation area (Olen and Skinkis, 2018). A summary of Pinot noir plantings in selected countries is provided in Table 1.

Table 1. Area planted to Pinot noir and as a proportion of total vineyard area in selected countries. Adapted from Longo *et al.* (2020a).

Country	Area planted of Pinot noir (ha)	% of total vineyard area
France	32,000	4
USA	26,000	6
Germany	11,787	12
New Zealand	5,573	15
Australia	5,000	4
China	1,000	0.1

Pinot noir was introduced into Australia in 1817 by John McArthur, and in the 1830s by James Busby, but wasn't commonly planted until the 1970s, when CSIRO released the MV6 (mothervine) clone (Wine Australia, 2020). Today, Pinot noir accounts for ~5,000 ha of vineyards in Australia and is the 6th most planted variety in the country (Wine Australia, 2019b). Australian Pinot noir is enjoying market growth, particularly in the domestic market (Wine Australia, 2019a) and generally produces wines with light red colour and low astringency due to the relatively low anthocyanin content and a low skin-to-seed tannin ratio (Agati *et al.,* 2007). From a sensory point of view, the wines are generally associated with a wide range of aromas ranging from 'strawberry', 'cherry', and 'floral' to more complex, developed attributes such as 'spicy', 'prune' and 'toasty' (Longo *et al.*, 2020b; Cantu *et al.,* 2021; Campo *et al.,* 2010).

Site selection is crucial for producing high-quality wines, and Pinot noir is no exception (Longo *et al.,* 2020a). Soils similar to the signature Burgundian calcareous soils derived from limestone bedrock (Shaw, 2012) are preferred, however in the absence of these soils, Pinot noir is most successfully grown in well-drained soils. The importance of soil type was suggested by Roullier-Gall *et al.* (2014) who showed that Pinot noir wines produced from grapes grown in a similar way, in the same vintage, but harvested from two different neighbouring villages in the *Côte de Nuits* appellation, can exhibit distinctive chemical fingerprints independently from the vintage.

Several studies have dealt with the terroir effects on Pinot noir, as reviewed by Longo et al. (2020a). However, finding clear evidence of a link between wine composition, sensory attributes and grape geographical origin remains a challenge. Duley et al. (2021) used nuclear magnetic resonance (NMR) spectroscopy and inductively coupled plasma mass spectrometry (ICP-MS) to discriminate several commercial Australian and Central Otago (NZ) wines on the basis of their geographical origin. However, they were unable to draw any specific correlation between a vineyard site and the wine metabolomic component (such as amino acids, sugars, acids, alcohols). A better degree of regional discrimination was obtained using ICP-MS to measure inorganic anions (e.g. light metals, heavy metals, rare earth elements). Along the same lines, Cantu *et al.* (2021) used chemical and sensory analyses to discriminate wines made from one clone of Pinot noir at twelve different vineyard sites along the US West Coast. Interestingly, they found that the vineyard location (i.e. latitude and longitude) was one of the main factors

describing the chemical and sensorial differences between the wines, while other details such as soil pH and rootstock type may have an effect on the ageing features of the wine.

Despite the fickle reputation of Pinot noir, findings are increasingly being reported of chemical parameters (Longo *et al.,* 2020b; Cantu *et al.,* 2021), elemental composition (Duley *et al.,* 2021; Grainger *et al.,* 2021) and/or sensory characters (Longo *et al.,* 2020b; Cantu *et al.,* 2021) that are able to discriminate the region in which the grapes were grown. The primary contributors to this regionality are not yet clear but are reported to be a combination of soil (Duley *et al.,* 2021; Roullier-Gall *et al.,* 2014; Grainger *et al.,* 2021) and climatic factors (Roullier-Gall *et al.,* 2014).

Australian geography is very heterogenous and Pinot noir is grown in many cool Australia regions including: Mornington Peninsula and Yarra Valley in Victoria, Adelaide Hills and Fleurieu Peninsula in South Australia, and the Tamar and Huon Valleys in Tasmania. This paper summarises a number of experiments carried out on regional Australian Pinot noir wines by the University of Tasmania research group over the last three years and funded by Wine Australia, with support from the University of Tasmania, WineTQ, Shaw + Smith, Hill-Smith Family Vineyards, the Australian Wine Research Institute and a large number of other Pinot noir producers across Australia.

Chromatic and Colour Structure of Pinot noir Wines: Understanding Australia

To establish an understanding of the variation between Australian Pinot noir wines with regards to their colour structure and chromatic features, a total of 102 Australian commercial wines (54 and 48 wines from the 2015 and 2016 vintages, respectively) were sourced and analysed. One of the requirements for wine submission was that the fruit for the wine was sourced from a single vineyard in order to minimise the confounding impact of blending components from other vineyards. Where commercially available, the same wines were selected for both vintages and analysed 12 months apart so that bottle age was comparable. The Modified Somers method was used for colour and phenolic composition and the tannin concentration was measured using the methyl cellulose precipitable (MCP) tannin assay (Mercurio *et al.,* 2007). Results were collated into graphs such as Figure 1, and then shared with participating producers to provide them with benchmarking data within their own and other regions.

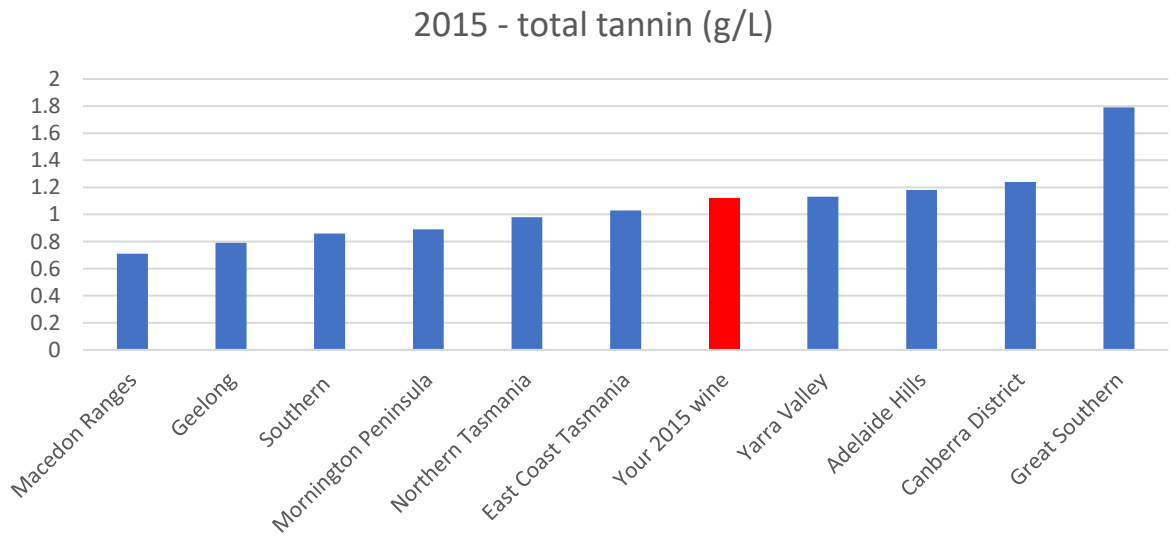

Figure 1: An example of MCP tannin assay wine analysis data supplied to producers.

As a general outcome, seven of the 11 measures showed significant differences between regions for the 2015 wines: colour density ($p<0.001$), total anthocyanins ($p<0.001$), % non-bleachable pigment ($p<0.01$), chemical age 2 ($p<0.01$), total pigments ($p<0.001$), pigmented tannins ($p<0.001$) and free anthocyanins ($p<0.001$). All 11 measures were significantly different between the regions for the 2016 wines: colour density ($p<0.05$), hue ($p<0.001$), chemical age 1 ($p<0.05$), chemical age 2 ($p<0.05$), total anthocyanins ($p<0.05$), % non-bleachable pigment ($p<0.05$), total tannins ($p<0.05$), total pigments ($p<0.05$), total phenolics ($p<0.05$), pigmented tannins ($p<0.05$) and free anthocyanins ($p<0.05$). This suggested regional trends for Australian Pinot noir that could

potentially be linked to the vineyard's terroir characteristics, rather than winemaking techniques or grape maturity at harvest given the substantial sample size of 102 samples across the two vintages. This preliminary work gave cause to further investigate the regionality of Australian Pinot noir wines, which included the addition of the analysis of volatile compounds and also including non-Australian Pinot noir wines for international references.

A 2-year Volatile and Colour Study of Pinot noir Wines from Australian and Non-Australian Regions

To better understand regional drivers of Pinot noir wine chemical composition, 80 single-vineyard samples (2015 and 2016 vintages) from Australian and non-Australian regions were analysed for important volatile compounds, as well as colour and phenolic measures. The wines were sourced from five Australian and five non-Australian regions: Adelaide Hills, Yarra Valley, Mornington Peninsula, Southern Tasmania, Northern Tasmania, Burgundy (France), Willamette Valley (Oregon, USA), Central Otago and Marlborough (NZ), and Niagara Peninsula (Ontario, Canada).

Principal component analysis (PCA) of the colour and phenolic data revealed around 88% of the variation in the data could be accounted for by the first two principal components (PCs) (Longo *et al.,* under review). Northern Tasmania, Southern Tasmania, Adelaide Hills, Yarra Valley, Mornington Peninsula, Willamette Valley and Niagara Peninsula all clustered in similar regions of the biplot, irrespective of the vintage of the wine. In contrast only 49% of the variation in the volatile compositional data was described by PC1 and PC2, and clustering was more strongly driven by vintage than by region (Longo *et al.,* under review).

Discriminant analysis (DA) of PCA scores was used to interrogate the data and provide evidence on how well the regions could be classified. The volatile compounds analysed showed clear discrimination of region with only 6% of samples misclassified by region, compared with 13% of samples misclassified when using colour data (Longo *et al.,* under review). All non-Australian regions were classified correctly from their volatile compounds, except one Oregon sample that was classified as originating from Adelaide Hills. For the Australian samples, the model correctly predicted all the samples from the Southern Tasmania and Mornington Peninsula regions. DA using PCA scores prepared from the volatile compositional data performed best for vintage classification, with 100% of the samples predicted correctly, as compared to 73% when using colour and chromatic measures.

This volatile data was also sent back to the producers, as in Figure 1, to further deepen the benchmarking of the project participants around potential drivers of Pinot noir wine aroma. The research team then further explored these results with an additional, single vintage, study which included sensory evaluation.

Chemical and Sensory Study with Australian Pinot noir

To evaluate associations between sensory and chemical analyses, 11 wine professionals (eight males and three females, aged 35-55 years) participated in sensory analysis of 15 single-vineyard, 2018 Pinot noir wines from five Australian wine growing regions (Adelaide Hills, Yarra Valley, Mornington Peninsula, Northern Tasmania and Southern Tasmania) (Longo *et al.,* 2020b). The Pivot© Profile method was used given its rapid application and suitability for use with product category experts, such as winemakers or wine judges (Pearson *et al.,* 2020). A HS-SPME-GC-MS method was used to quantify multiple volatile compounds, while the Modified Somers method was used for colour structure and chromatic component characterisation.

From the GC-MS analysis, ethyl decanoate, ethyl 2-methylpropanoate, ethyl 2-methylbutanoate, and decanoic acid differed significantly between regions (p<0.05) and were proposed as potential regional markers for Australian Pinot noir wines (Longo et al., 2020b). It has previously been shown that the concentration of esters is strictly associated with specific grape juice nitrogen composition and lipid metabolism, which are affected either by the ripening level of grapes at harvest or nitrogen management in the vineyard or the winery (Antalick *et al.,* 2015) wine. Hence, inherent grape nitrogen composition and concentration attributable to region can influence fermentation health and kinetics.

Some similarities were also apparent in terms of chromatic components and colour structure, in particular for the Adelaide Hills samples, which appeared to age more quickly than other regions, having significantly higher hue values than the wines from the other regions. Some sensory similarities among wines from the same region were observed despite wines likely being produced using different winemaking techniques. The biplot combining all the most important descriptors from the appearance, aroma, and palate dimensions can be seen in Figure 2. In particular, wines from the Mornington Peninsula (MP), and to a lesser extent two from Northern Tasmania

(NT) were associated with 'red fruits' aroma, and 'acidic', and 'astringent' palate descriptors, while the majority of wines from Adelaide Hills (AH), Southern Tasmania (ST), and Yarra Valley (YV) was associated with the attributes 'brown' appearance, 'floral' and 'oaky' aroma, and 'complex' and 'soft' palate.

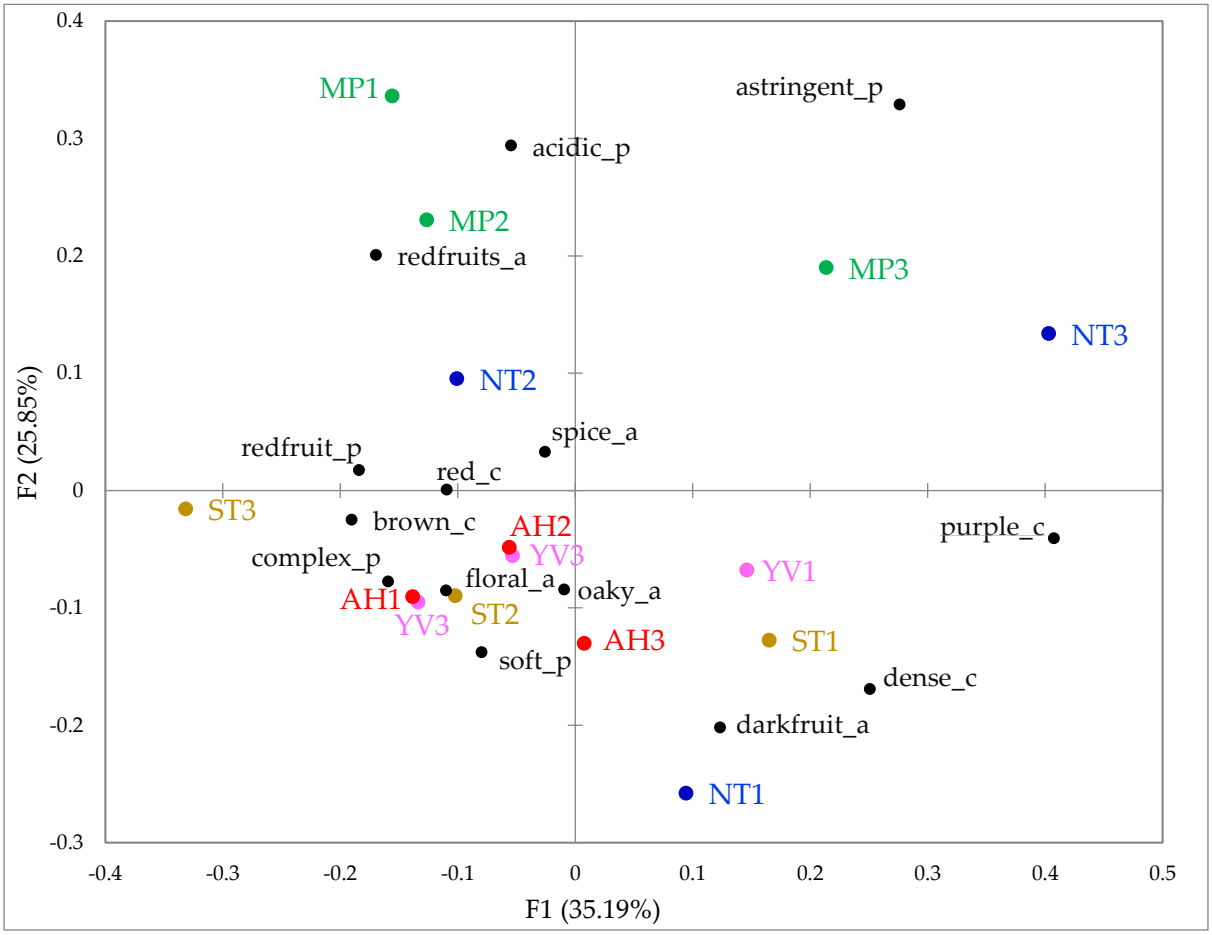

Figure 2: Correspondence analysis biplot of the 15 Pinot noir wines characterised using the Pivot© Profile sensory method. Regional samples designated as follows: AH - Adelaide Hills; MP - Mornington Peninsula; YV - Yarra Valley; ST - Southern Tasmania; NT - Northern Tasmania. Sensory attributes designated as c - colour; a – aroma and p - palate. From Longo *et al.* (2020b).

Importance of Understanding Terroir for Industry

Understanding terroir assists producers to understand the inherent capacity of their own site and the wines which could potentially be produced. Our investigation of regional wine composition aimed to find components which persists despite differing winemaking techniques to not only understand how to reach a desired wine style, but also to underpin marketing and education efforts. This work intended to provide an evidence base on which to make wine flavour and aroma claims from a regional perspective, such as on the Wine Australia website (Wine Australia, 2020).

Based on our preliminary findings, regional trends in the colour, phenolic and volatile profiles of commercial wines were observed. To summarise, the volatile compound profile was able to correctly classify 94% of wines correctly to their region, whereas the colour and phenolic profile only correctly attributed 86%. The Pivot© Profile sensory analysis revealed some regional differences and similarities, such as wines tasted from the Mornington Peninsula (MP) were associated with 'red fruits' aroma, and 'acidic', and 'astringent' palate descriptors, while the majority of wines from Adelaide Hills (AH), Southern Tasmania (ST), and Yarra Valley (YV) were associated with the attributes 'floral' and 'oaky' aroma, and 'complex' and 'soft' palate.

The findings from this study have the potential to support decision making for winemakers and viticulturists to achieve desired quality and stylistic outcomes, and require further in-depth analysis of characteristics of the terroir with greater control over confounding variables such as winemaking practices.

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