EFFECT OF TWO CONTRASTING SOILS ON GRAPE AND WINE SENSORY ATTRIBUTES IN SHIRAZ

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Abstract

Aims: Berry composition and wine sensory characteristics reflect the origin of grape production and seasonal climatic conditions. The aim of this study was to compare berry and wine sensory characteristics from two contrasting soil types where the vineyard climate, geography, topography, vine and management factors were not different.

Methods and Results: Two adjoining blocks of Shiraz with similar vine age (+/-1 year), identical clone (1654), row orientation (NW, SE) and cordon height were selected for this study. All irrigation, spray and midrow management treatments were identical. Both sites have soils that are texture contrast or duplex brown chromosols. The main distinguishing feature between the two sites being the presence of 10% to 50% ironstone gravel, mainly in the bleached topsoil "E" (or A2) horizon for the "Ironstone" block which is in contrast to the "Sand over clay" block.
Berry sensory attributes were evaluated using the accepted method of berry sensory assessment (BSA). The method allows for the identification and quantification of berry sensory attributes against standard sensory references by a trained panel. The evaluation of wine sensory attributes was performed using a quantitative descriptive analysis (QDA). Both methods were performed to assess sensory differences in grapes and wine from the two soil types. Berries from the "Ironstone" soil had more intense green/grassy flavour, a higher perception of acidity and greater astringency. This was in contrast to berry samples from the sand over clay soil, which were described as having more intense dried fruit/jammy flavour, a higher perceived sweetness and an elevated toasted flavour. Wines made from fruit from the "Ironstone" soil were found to have more intense red fruit characters, tannin quality and astringency in contrast to the dark fruit, higher colour intensity and confectionary characteristics of the wines made from fruit from "Sand over clay" soils. Fifty-six soil mineral elements were analysed from each soil horizon, leaf blades, must and wine samples. Results obtained from inductively couple plasma atomic emission spectroscopy (ICP-OES) analysis identified elements some of which were unique to each soil type and some which were in higher concentrations. The differences in the two soils elemental status was translated to leaves, berries and wine from those soils.

Conclusions: Differences were observed in berry and wine sensory characteristics when comparing the fruit harvested from two contrasting soils in close proximity. Soils displayed very similar physical characteristics. Both soils were observed to be texture contrast or duplex brown chromosols. They shared common features of sandy or loamy topsoils ("A" horizons) over brown light clay (LC) to light medium (LMC) "B" horizons with or without highly weathered sandstone in the subsoil or "C" horizon. There was no soil carbonate present at any site and topsoil pH was neutral (pH 6.5-7.5) and decreased slightly to 6.0 in the "B" and "C" horizons. Root zones, both predicted and observed were not significantly different.
Slight differences were observed between the soils with measures of readily available water (RAW), topsoil depth and a unique layer of gravel in the ironstone soil all of which have been associated in previous research with water movement and plant water availability in soils. Analysis of the chemical composition and concentration of soils, vines, grapes, musts and wines demonstrated distinct differences in the chemical characteristics between the two soil sites. This study was able to investigate soils with different soil chemistries and sensory characteristics for berries and wine in isolation from other known influences including viticultural, environmental, many other soil, and winemaking factors.
The application of elements to vines in a controlled environment in future work may provide a link between soil chemistry and grape and wine sensory attributes.

Significance and Impact of the Study: Soil elemental composition is a contentious aspect of terroir especially in relation to the relative importance afforded to climate and soil physical characteristics in previous research. This trial was able to isolate soil for analysis to observe unique elemental compositions in varying concentrations in relation to differences in berry and wine sensory outcomes. The mechanisms by which soil elements might influence sensory outcomes of wines is not widely understood and future research could lead to soils and wines being paired for desired sensory outcomes.

Keywords: Elemental composition, fruit quality, wine quality, soil chemistry

Introduction

The sensory properties of wines are known to reflect the geographical origins of winegrape production (Cugnetto, 2014; Fischer and Bauer, 2006; Tomasi, 2013; Vilanova *et al*., 2007; Wittendal, 2004). In Australia, the variety Shiraz constitutes 30% of all plantings and contributes to 29% of Australian wine exports (Wine Australia, 2020). Shiraz is grown in many regions in Australia and the its sensory profiles have been shown to represent the place where they are grown (Pearson, 2019). The sensory components of wines which define its "quality" are influenced by many factors (Jackson, 1993).

The assessment of individual factors of terroir in isolation and their influence on grape and wine sensory qualities has proven to be very difficult (Fischer *et al*., 1999; Seguin, 1986). Climate, soil and cultivar were examined simultaneously by (van Leeuwen *et al*., 2004) who concluded that the influence of climate was greatest on most parameters followed by soil and cultivar. It is widely accepted that the main influence of soil as a component of terroir on wine sensory qualities is due to its physical characteristics and the effect it has on water movement and availability, root growth as well as nutrient availability for physiological vine growth (Seguin, 1986; van Leeuwen *et al*., 2004). In comparison, soil chemistry and in particular, soil elemental composition is one factor often overlooked or deemed too difficult to isolate or too indirect with its influence in relation to other components of terroir (Matthews, 2015).

Previous studies have demonstrated a link between grape and wine composition and elemental composition, which allowed their geographical origin to be identified (Bertoldi *et al*., 2011; Coetzee, 2005; Gambetta, 2014; Gonzálvez, 2009; Greenough, 1997; Hopfer, 2015; Marengo, 2003). The elemental composition of grapes and wines are derived almost entirely from the soils on which they are grown and their unique parent geological profile (Ortiz-Villajos *et al*., 2015) although their uptake varies according to bioaccumulation behaviour (Kabata-Pendias, 2011). The correlation between soil elemental composition, grapes, wine and vine physiological growth is well understood. What is less understood is the relationship between soil elemental composition and its influence on wine sensory properties (Gladstones, 2011; Imre *et al*., 2012; Maltman, 2013; White *et al*., 2007).

The objective of this study was to assess the effect of two soils differentiated mainly by their elemental status on berry and wine sensory properties of Shiraz in isolation where other known agronomical factors of influence such as climate, vine age, clone, rootstock, management practices, and vintage were excluded.

Materials and Methods

Experimental Trial Site

The location for the trial site was Yangarra Park Vineyard, Kangarilla Road, McLaren Vale, South Australia. Two adjacent blocks of Shiraz with similar soil texture, pH and contrasting elemental composition were selected for the trial. Both blocks had the same orientation (North-South), vine clone (1654), average trunk circumference (210mm^2), planting density (1785 vines/Ha), row width (2.85m) and vine spacing (2.0m). All other aspects were identical for canopy, irrigation, pest and disease, nutrition, midrow, undervine weed and pruning management.

Table 1: Vineyard details for each experimental site.

Measured variable	**Units**	**Ironstone - Iron**	**Sand over clay - SOC**
Elevation	metres above sea level	181	200
Planted	year	1999	1998
Soil general description	General	Ironstone	Clay/Sand
Soil description	(McDonald, 2009)	Ironstone gravel in A1 and A2 (E) horizons	A1 horizon non-gravelly
Depth of rootzone	centimetres	60-95	65-85
RAW	kilopascals	30-42	26-53
pH	$-\log_{10} c$	6-8	6-7.5
Topsoil depth	centimetres	15-35	20-40

Soil Measurements

Soil pits were dug using a backhoe in the midrows alongside the sample vine panels to an average depth of 1.0m. A detailed soil survey was conducted with the assistance of soil scientist, and experienced vineyard soil surveyor. Soil identification, classification and geology of the soil profiles was performed using the CSIRO Australian Soil and Land Survey Field Handbook McDonald (2009) and The Australian Soil Classification Isbell (1993). **S**oil colour used to describe soil profile descriptions was based on moist soil colour using a Munsell Soil Colour Chart (Munsell Colour 1988). Soil horizon depths were measured, and depths recorded. Each soil horizon was tested for physical and chemical properties in the field and samples were taken from each horizon for soil mineral elemental composition analysis by inductively coupled plasma atomic emission spectrometry (ICP-OES). Soil texture was determined by hand in the field by adding water to the soil matrix, mixing and then ribboning it through first index finger and thumb. Soil pH was tested using a colorimetric field kit. Soil carbonate class was assessed in field using the following method (Chaney, 1982). Soil pedology was recorded based on the observation of aggregates and degree of aggregation of soil. Topsoil depth (equivalent to the A horizon) was measured with a measuring tape. Soil moisture content was assessed by visual inspection and classified according to McDonald (2009). Readily available water (RAW) was assessed using the method according to McDonald (2009). Root growth was measured by visual assessment and rating of the presence of roots in each horizon in a 100mm^2 on a cleaned exposure face and graded according to McDonald (2009).

Soil Characteristics

Both soils are texture contrast or duplex brown chromosols. The common features are sandy or loamy topsoils ("A" horizons) over brown light clay (LC) to light medium (LMC) "B" horizons with or without highly weathered sandstone in the subsoil or "C" horizon. There was no soil carbonate present at any site and topsoil pH is neutral (pH 6.5-7.5) and decreases slightly to 6.0 in the "B" and "C" horizons. Root zones, both predicted and observed were not significantly different.

The main distinguishing feature is the presence of 10% to 50% ironstone gravel mainly in the bleached topsoil "E" (or A2) horizon at Iron soil sites (Figure 1). Other differences observed were a slightly higher mean RAW value and deeper topsoil for the SoC (Table 2).

Table 2: Comparison of soil characteristics for two blocks of Shiraz vines.

Measurement variable	Mean Iron	Mean SoC
RAW kpa	36.89	43.85
Topsoil depth cm	25.63	35.00
Predicted Rootzone cm	75.63	80.00
Observed Rootzone cm	78.75	73.75

Images were taken of the soil pits for visual assessment of soil profile differences (Figure 1).

Figure 1: Iron soil (left) and SoC soil (right) profile images.

Elemental Analysis

Soil elemental status was tested by collecting soil samples at each profile depth. The concentrations of fifty-six elements were analysed by ICP-OES. Vine elemental status was analysed by sampling leaf blades at E-L stage 35 (veraison)(Coombe, 2000). Twenty-five leaves were collected from three vines at approximately node position 5 using gloves to avoid contamination. Leaf blades were separated from petioles, placed in brown paper bags and oven-dried at 60℃ for 48 hours. Dried leaves were analysed by ICP-OES. Must samples were collected at the crusher for pre-ferment elemental analysis by ICP-OES. Primary amino acid nitrogen in grape juice was also measured using a Vinessential Laboratories kit as per kit instructions and procedures (Dukes and Butzke, 1998). Wine samples (100mL) were analysed using ICP-OES for the elemental status of each wine post ferment.

Berry Sensory Assessment (BSA)

Berry sensory assessment was performed as outlined in (Lohitnavy *et al*., 2010). The panel consisted of 11 members (5 females and 6 males, 20 to 48 years of age), all with previous experience in formal sensory assessment. Panellists were trained over two sessions, which consisted of identifying standards, determining variations in sugar, acid, astringency and bitterness, as well as generating attributes and descriptors. Solutions and standards as well as the attributes and their low and high anchors were developed for reference training. The panellists formally assessed the samples on two separate occasions. Each panellist made their assessments in individual booths under fluorescent light with a light temperature of 6500°K. All the grape samples were given a unique 3-digit code and on formal sessions panellists saw each sample in duplicate, tasting three randomly selected berries per sample. The tasting order was randomised to minimise sample order interactions within the data collected. The three digit codes and randomisation were generated using Excel (Microsoft Corporation, Excel 2011). Panellists ranked their perception of attributes on a 15-point scale. Panellists were required to take a 1-minute break between samples and a 5-minute break every three samples to prevent palate fatigue. Panellists were also required to rinse with a citrus pectin (2 g/L, Sigma-Aldrich) and water solution between samples and eat 1 water cracker every 3 samples to avoid palate fatigue (Plain Water Cracker) (Stone *et al*., 2008).

Winemaking

Grapes were harvested separately from sample sites on the day of commercial harvest. Eight-kilogram lots of Shiraz grapes per replicate block within each vineyard were harvested by hand and then crushed and destemmed with a manual crusher. Grapes were fermented in open 3L polypropylene buckets (Amber Plastics Pty Ltd) in the controlled environment room. Each ferment was inoculated with a neutral yeast strain PDM (Maurivin) at an addition rate of 25g/hL. Wines were maintained at 20°C ±2°C during fermentation. Diammonium phosphate (DAP) was added at the start of fermentation as a 50g/L solution of diammonium phosphate and reverse osmosis water. During crushing a 50mg/L sulphur addition was added to the ferments for microbial stability. After initial primary fermentation was underway and a skins cap formed, the ferments were co-inoculated with lactic acid VP41 bacteria (Lallemand Inc.) at 0.1g/10L to induce malolactic fermentation (MLF). Ferment caps were kept moist and were plunged daily. Total soluble solids (TSS) were measured daily with a hydrometer to record the rate of fermentation.

All wines were then pressed off skins on the same day once the majority of samples had reached approximately 2° Baumé (Be). Pressings were collected in a measuring cylinder and then transferred onto glass flagons with a breathable lid. Finished wines were assessed for malolactic fermentation using a Vintessential Laboratories L-Malic Acid Enzymatic Kit (Vinessential Laboratories Australia). Residual sugars were determined using the Rebelein method. Once wines were confirmed to have less than 0.1g/L malic acid and less than 1g/L of residual sugar, they were given a sulphur dioxide addition using potassium metabisulphite powder (PMS) to make up to 60mg/L total sulphur. The wines were then allowed to settle for a period of two weeks and then syphoned into 330ml beer bottles and sealed under crown seal caps. Wines were fined with copper sulphate stock solution (4g/L) at a rate of 1ml/L the night before the wine sensory evaluation or quantitative descriptive analysis (QDA).

Wine Sensory Analysis – Quantitative Descriptive Analysis (QDA)

Descriptive analysis was conducted as outlined in Stone *et al*. (2008) to ascertain sensory differences between samples. An experienced panel of 12 consisting of 6 males and 6 females aged between 19 to 55 years of age was used for the study. Panellists were trained in two sessions and involved tasting all wines, ranking wines based on compositional analysis and generating attributes and specific descriptors. Panellists examined the wines over two sessions as described in BSA. Panellists were also required to alleviate palate fatigue as with BSA (Stone *et al*., 2008).

Results

Berry Sensory Assessment (BSA)

Differences in berry sensory attributes assessed were observed between the Shiraz berries from the two soil types (Table 3). Berries from the Iron soil had more intense green/grassy pulp, detachment of pulp from skin, acidity and astringency of seeds whilst berries from the SoC soil was associated with sweeter berries that were more intense in dried fruit/jammy flavour (Figure 2).

Table 3. The effect of soil type on the Berry Sensory Assessment (BSA) of Shiraz SoC and Iron grapes.

Measurable Variable	Iron Mean	SOC Mean	P-value
Pulp			
Dark fruit flavour	8.62	8.95	0.18
Red fruit flavour	7.56	7.37	0.32
Dried fruit/Jammy flavour	5.88	6.78	0.01
Green/grassy flavour	3.01	2.36	0.04
Flavour intensity/complexity	10.25	10.31	0.27
Detachment of pulp from skin	4.90	4.26	0.10
Juiciness of pulp	8.82	9.02	0.30
Sweetness	10.16	10.79	0.01
Acidity	6.46	5.62	0.03
Skins			
Disintegration	6.07	5.82	0.22
Acidity	3.67	3.98	0.25
Dark fruit flavour	6.24	6.54	0.13
Red fruit flavour	2.91	2.72	0.24
Dried fruit/jammy flavour	3.75	4..2	0.05
Green flavour	3.47	3.26	0.32
Bitterness	2.68	2.52	0.22
Astringency	6.65	6.73	0.40
Grain size of tannins	6.66	6.17	0.07
Seeds			
Colour	9.71	10.29	0.11
Crushability	9.52	10.04	0.08
Toasted flavour	6.96	10.04	0.00
Herbaceous flavour	3.32	2.96	0.25
Bitterness	4.77	3.68	0.08
Astringency	7.84	6.63	0.03
Likeability	8.71	9.0	0.08

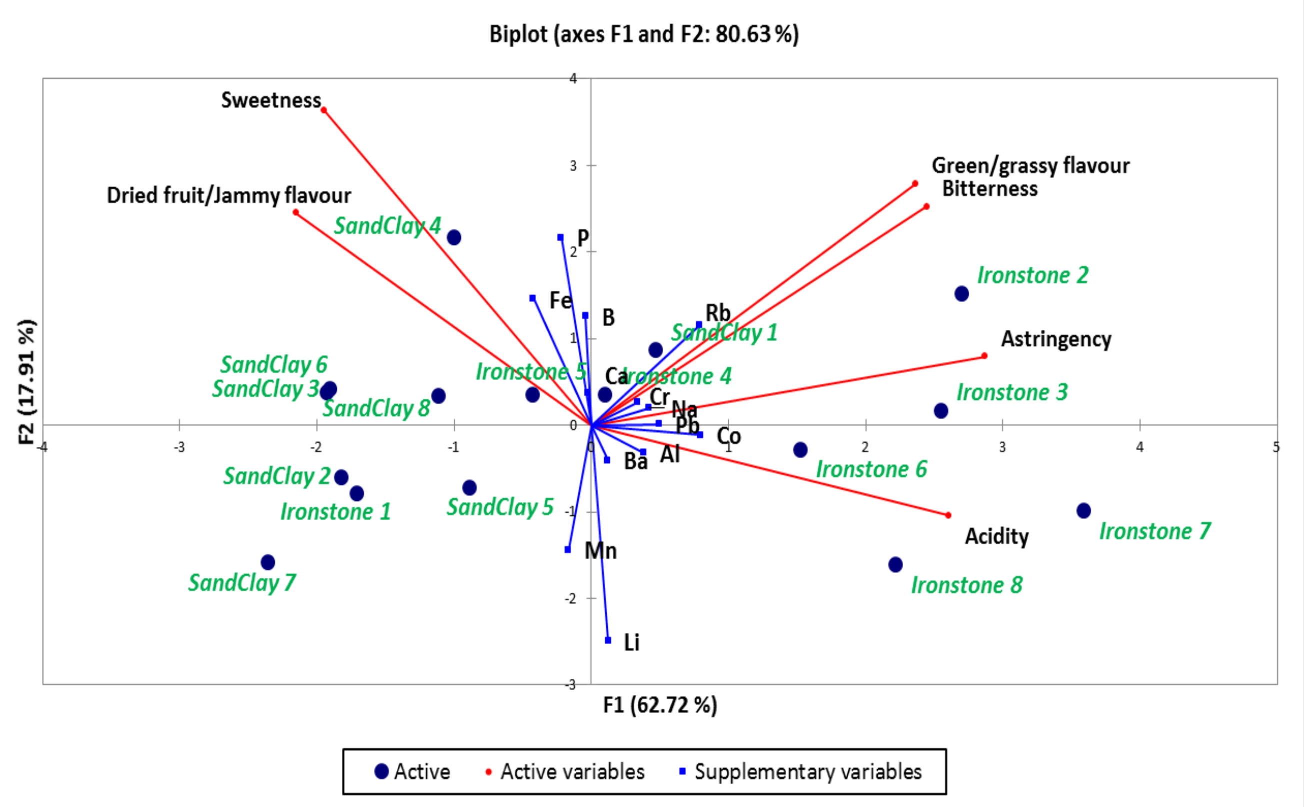

Figure 2: PCA biplot of grape berry samples generated from correlation mineral analysis and berry sensory attributes. Sensory attributes (red), Grape chemical elements (blue), Soil treatments (green). sodium (Na), phosphorus (P), titanium (Ti), rubidium (Rb), barium (Ba), scandium (Sc), manganese (Mn), potassium (K), zinc (Zn), magnesium (Mg).

Wine Sensory Analysis – Quantitative Descriptive Analysis (QDA)

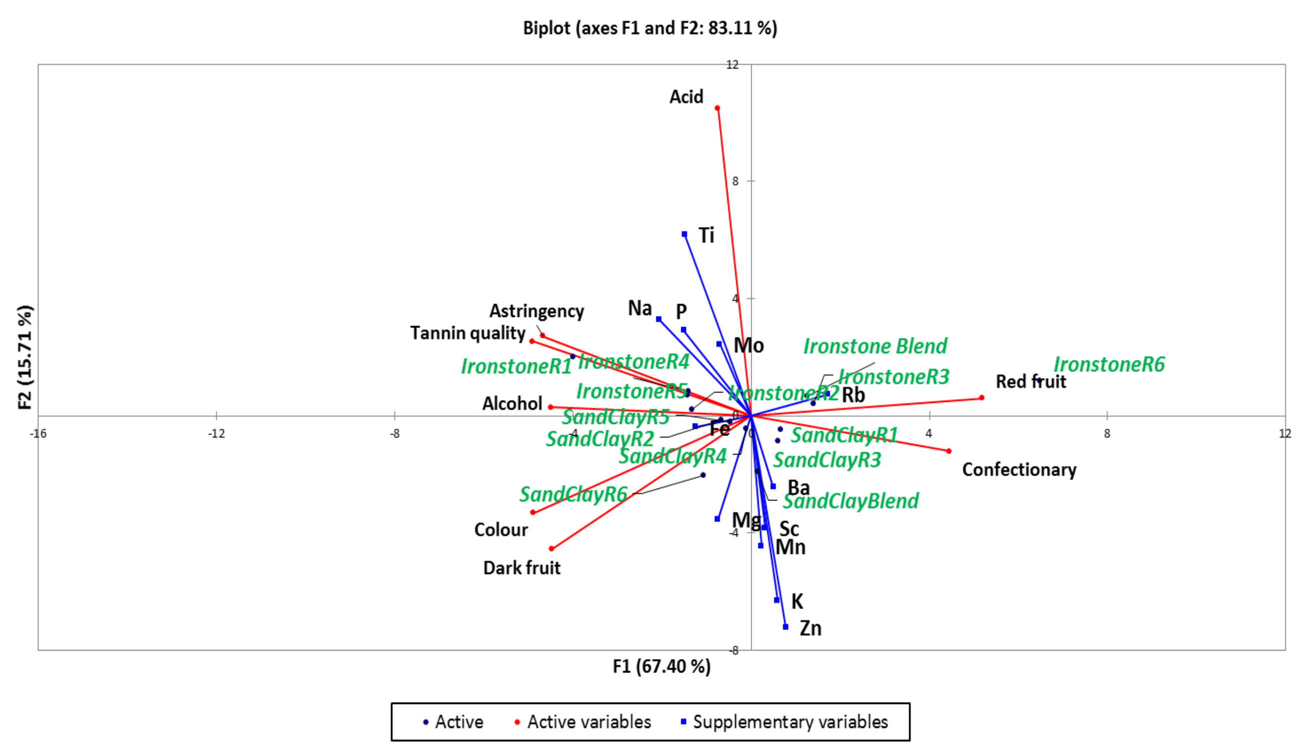

Figure 3: PCA biplot of red wine samples generated from correlation with replicates of two soil types and sensory attributes. Sensory attributes (red), Wine chemical elements (blue), Soil treatments (green). sodium (Na),

phosphorus (P), titanium (Ti), rubidium (Rb), barium (Ba), scandium (Sc), manganese (Mn), potassium (K),zinc (Zn), magnesium (Mg).

Wines made from fruit from the Iron soil were found to have more intense in red fruit characters, tannin quality and astringency in contrast to the dark fruit, higher colour intensity and confectionary characteristics of the wines made from fruit from SoC soil (Figure 3).

Discussion

This research trial was able to successfully isolate and analyse grape, wine and soil elemental composition of two soils with contrasting elemental profiles in close proximity and without significant differences in vineyard management, vine factors (cultivar, vine age, rootstock), macro climate, topography and aspect. Physical characteristics of the soils were largely similar, however there were some differences observed in RAW, topsoil depth observed and predicted rootzone with a layer of gravel also present in the iron soil. Differences in physical characteristics of vineyard soils has been shown to influence the sensory outcomes of wines (C. van Leeuwen, Roby, J., de Rességuier, L., 2018). Isolating any one of the many components of terroir for investigating its influence on wine sensory profiles has proven difficult, especially vineyards that have the same agronomical characteristics and differ only in soil type (de Andrés-de Prado *et al.*, 2007).

Whilst the identification of geographical origins of grapes and wine using elemental analysis is widely acknowledged to be an accurate tool (Di Paola-Naranjo *et al.*, 2011; Đurđic *et al.*, 2017) an association of elemental ions and unique sensory characters of wines is yet to be fully understood (Gladstones, 2011; Hopfer, 2015; Maltman, 2013). Manipulating soil chemistry using additions of limestone and oyster shells has previously resulted in a significant change in anthocyanin composition in Cabernet Sauvignon skins compared with the ‘native soil” (Yokotsuka *et al.*, 1999). It was also postulated that differences between two Burgundy classified vineyards, only metres apart with similar aspects could also be due to soil differences (Iland and Fetzmann, 2000) which aligned with the results of this trial which had were separated by a distance of only 328 metres. A greater understanding of the role of soil elements on biochemical processes influencing the sensory profiles of wine could lead to manipulation in the vineyard to achieve greater certainty of sensory outcomes despite seasonal climate conditions.

Conclusions

The results of this trial showed the two sites had significant differences in both berry sensory (BSA) and wine sensory (QDA) results whilst their replicates had common sensory attributes for both sensory analyses (PCA biplots). The different Shiraz wine sensory wine profiles aligning to different soils in this trial were also seen with the variety Grenache in Spain where the wine sensory evaluation results were unique to different soils and did not change significantly between Vintages (de Andrés-de Prado *et al.*, 2007). Both sites displayed distinctive sensory qualities for both grapes and wine with a significant difference between elemental compositions in grapes, leaves, wine and soil profiles. There is a gap in research to directly relate the elemental composition of vineyard soils to the composition of wines (Hopfer, 2015) with the role of elemental ions and soil chemistry traditionally being thought to only exert an influence on vine physiology, phenology and grape composition through a nutritive effect (Hansch and Mendel, 2009; White *et al.*, 2007). What has been largely overlooked in preference for other terroir components, principally climate and soil physical factors, is the influence of elemental ions from soil on the biochemical processes influencing grape composition. This is despite the understanding of the importance of metallic ions on biochemical processes such as flavanol development through forming complexes in red grape varieties (Downey *et al*., 2006). The relative importance of soil chemistry versus soil physical characteristics in relation to wine sensory properties needs to be investigated further.

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