Vitis **56**, 1–10 (2017) DOI: 10.5073/vitis.2017.56.1-10

Influence of grapevine canopy trimming and maturity variability within fruit population on the sensory properties of Pinot noir wine

B. Pineau[1)], C. Grose[2)], M. Beresford[1)], E. Sherman[1)], V. Raw[2)], A. K. Parker[3), *)], M. W. Wohlers[1)] and M. C. T. Trought[2)]

[1)] The New Zealand Institute for Plant & Food Research Limited, Mt Albert, Sandringham, Auckland, New Zealand
[2)] The New Zealand Institute for Plant & Food Research Limited, Marlborough, Marlborough Wine Research Centre, Blenheim, New Zealand
[3)] The New Zealand Institute for Plant & Food Research Limited, Lincoln, Christchurch, New Zealand

Summary

The effects of differences in Pinot noir fruit maturity on the sensory properties, overall complexity and typicality of 'Marlborough Pinot noir' wines was studied over two seasons. Trimming canopies to 100 (TT), 60 (MT), or 30 (ST) cm above the fruiting cordon produced fruit with high, moderate and low soluble solids at harvest respectively. To investigate the variability of fruit populations (*i.e.* homogeneous *v.* heterogeneous soluble solids concentrations) on wine sensory properties, each treatment was harvested on the same date and fermented both separately and after blending fruit to ratios of 10:80:10 and 30:40:30 of low, moderate, and high maturities respectively. Additional wines were created after fermentation by blending wines made from each trim treatment to the same ratio as used for the pre-fermentation fruit population blends. Moderate and high fruit maturities provided wines with similar sensory properties, complexity and typicality as 'Marlborough Pinot noir'. Low 'Pinot noir' fruit maturity resulted in less fruity, spicy, full-bodied characters, more green/vegetal, and overall less complex wines compared with moderate and high fruit maturity wines. Composite wines made by blending, post-fermentation, wines produced from low, moderate and high maturity fruit did not differ from the wines made from similar blends of fruit. Indeed, the four composite wines made from blending fruit or wines had organoleptic properties comparable to those of the wine made with a homogeneous fruit population of moderate maturity with the same mean soluble solids concentrations. We conclude that 'Pinot noir' wines made using fruit with a wide range of maturities do not have different sensory properties from those made with fruit with a narrow range of maturities, providing the mean soluble solids concentrations of the fruit populations are similar.

K e y w o r d s : canopy trimming, fruit variability, fruit blending, wine blends.

Introduction

It is widely accepted (both experimentally and from commercial experience) that differences in fruit maturity translate into perceptible differences in sensory properties of the corresponding wines. This was demonstrated in red wine grape varieties such as 'Cabernet Sauvignon' (Kontoudakis *et al.* 2011, Heymann *et al.* 2013) and 'Cabernet franc' (Cadot *et al.* 2012), and white wines (e.g. 'Sauvignon blanc' (Pineau *et al.* 2011)). While some of the differences in sensory properties may reflect the wine alcohol concentration, sensory differences remain even when sugar is added to juice at the start of fermentation (chaptalisation) to standardise the alcohol concentration (Pineau *et al.* 2011).

There is little knowledge on how fruit variability at harvest affects sensory properties. Sorting fruit, generally by density, has suggested that wine quality may reach an optimum at a soluble solids concentration lower than that generally used for commercial harvest (Singleton *et al.* 1966) and high variability at harvest has been considered to result in poor wine composition (Long 1987, Trought 1997, Barbagallo *et al.* 2011). It is recognised that blending relatively small volumes of wines into a bulk sample can have a significant influence on the blend's sensory properties, but there is little quantitative information on the influence of variation in fruit composition on wine organoleptic quality. A small proportion of unripe berries, particularly where they have a high green character resulting from secondary metabolites such as methoxypyrazines, may contribute to adverse sensory properties. However, a recent publication (Ward *et al.* 2015) suggests that an addition of up to 5 % of green berries had no influence on the aroma, taste or mouthfeel of 'Cabernet Sauvignon'.

In a previous paper (Parker *et al.* 2016) trimming 'Pinot noir' grapevines to 30 cm or 60 cm from the cane slowed fruit sugar (soluble solids) accumulation relative to vines with a full 100 cm canopy. However, it had less effect on titratable acidity (TA), while, Spring *et al.* (2011) reported that trimmed vines had higher yeast available nitrogen (YAN). These studies indicate that the changes in sugar

Correspondence to: Dr. M. C. T. Trought, The New Zealand Institute for Plant & Food Research Limited, Marlborough Wine Research Centre, 85 Budge Street, PO Box 845, Blenheim 7240, New Zealand. E-mail: mike.trought@plantandfood.co.nz
***** Current address: Lincoln University, P.O. Box 85084, Lincoln 7647, Christchurch, New Zealand.

© The author(s).
This is an Open Access article distributed under the terms of the Creative Commons Attribution Share-Alike License (http://creative-commons.org/licenses/by-sa/4.0/).

accumulation were desynchronised from the organic acids, YAN and possibly other fruit metabolites. The primary aim of this study was to investigate the influence of trimming and the consequent changes in fruit maturity on the composition and sensory properties of the resulting wines. A secondary objective was to compare the sensory properties of wines processed from homogeneous and heterogeneous fruit maturity populations. Fruit with a range of soluble solids concentrations were mixed pre-fermentation and compared with equivalent wines, blended post-fermentation, but made from the individual homogeneous wines. The hypotheses tested were: 1) that wines made from fruit with a wide range of maturities (*i.e.* heterogeneous fruit populations) would have different sensory properties from those made from fruit with a narrow range of maturities (*i.e.* homogeneous fruit populations), even when the mean soluble solids concentrations were similar, and 2) that blending fruit would result in wines of different organoleptic qualities from equivalent wines made by blending post-fermentaiton.

Material and Methods

Field experimentation: The field experiment is described in detail elsewhere (Parker *et al.* 2016). To summarise, 'Pinot noir' vines (clone 777, rootstock C3309, planted in 2007) were trimmed over two seasons, 2010-11 and 2011-12, hereafter referred to by the date of vintage 2011 and 2012 respectively. The field trial used a randomised block design of 10 replicates, with four vines in each plot and established on two adjacent rows of mature vines on a commercial vineyard in Marlborough, New Zealand (41°27' S, 173°54' E). The soil profile is classified as a Woodbourne soil (> 75 cm well drained, developed loamy alluvium), and seasonal rainfall (September to April) was similar in both growing seasons (425 and 430 mm respectively) although rainfall during ripening (February and March) in 2011 was half that of 2012 (39 and 99 mm respectively). Full details of the regional weather conditions are available on the Marlborough Research Centre web page (http://www.mrc.org.nz/category/weather-data/blenheim-weather-data/). Drip irrigation was undertaken by the grower. Two new rows were used in the second season of the trial to prevent any carryover effect of the treatments (e.g. differences in potential yield) between seasons. Vines were managed using Double Guyot, bilateral 12-node canes. Shortly after fruit set the canopy was trimmed to 30, 60 or 100 cm (the control) above the fruiting wire. Lateral shoots were removed at regular intervals to ensure each treatment maintained a constant leaf area.

At harvest, two bunches from a randomly selected shoot on two different vines within each vineyard plot were harvested for berry density segregation. A range of sucrose solutions (from 16 to 30 °Brix) were prepared in 2.5-L plastic containers. Berries were snipped off the rachis and sorted according to these densities (if they floated they were less than or equal to the density of the solution).

Winemaking protocol: At harvest (on 6 April 2011 and 15 April 2012), fruit from three field replicates of each treatment were combined, to give three fermentation replicates. Seven experimental 'Pinot noir' wines were made from experiments in each of the 2011 and 2012 vintages. The corresponding wines referred to as ST (short trim), MT (medium trim) and TT (tall trim) wines, correspond to homogeneous fruit populations of low, moderate and high maturities, respectively. Two additional wines were made from blends of the above-mentioned populations at ratios of 10:80:10 and 30:40:30 fruit of low, moderate, and high maturities, referred to as PreFB1 (pre-fermentation blend 1) and PreFB2respectively. Two further wines were created through post-fermentation blending of the ST, MT, and TT wines in the same proportions as used for the fruit blends, *i.e.* 10:80:10 and 30:40:30, referred to as PostFB 1 (post-fermentation blend 1) and PostFB 2, respectively.

Fruit were crushed and destemmed in an Enoitalia crusher/destemmer (Eno 1S, Italy). A standard sulphur dioxide (SO_2) addition (40 ppm) was added as potassium metabisulphite at crushing. Must was cold soaked for 3 d at 6 °C and then warmed to 18 °C and inoculated with RC212 yeast (Lallemand, Denmark) (rate 250 mg·L^{-1}). Grapes were fermented at 25 °C and di-ammonium phosphate (DAP) was added where yeast available nitrogen (YAN) concentrations were below 250 ppm. Ferments were plunged three times a day. Fermentation soluble solids concentrations (measured as °Brix) were monitored daily using a portable density meter (Anton-Paar DMA 35, Austria) and when residual sugar was less than 2.0 g·L^{-1} as determined by Clinitest® (Bayer, USA), ferments were given three days of post-fermentation maceration before pressing.

Ferments were pressed in a 20 kg hydro press (Marchisio, Italy) under a cover of carbon dioxide (CO_2). A pressing regime of two minutes at 1 Bar followed by another two minutes at 2 Bar was applied. Wine was settled for one week and then racked off yeast lees. If wine acidity was above pH 3.6, an addition of tartaric acid was made to retain pH below 3.6.

Wine was inoculated for malolactic fermentation using 0.6 mg·L^{-1} Viniflora® Oenos (CHR Hansen, Denmark) and fermented at 18°C. Malolactic fermentation was monitored and when malic acid concentration was below 0.1 g·L^{-1} an addition of 50 mg·L^{-1} SO_2 (as potassium metabisulphite) was made. Sulphur dioxide (SO_2) concentrations were monitored pre-bottling and adjusted to maintain a molecular SO_2 of approximately 0.5 mg·L^{-1}.

For sensory purposes, tartaric acid addition was made to wines with a pH of greater than 3.6. All wines were then filtered through a 1.2-µm diameter pre-filter and bottled in 750-mL bottles under screw cap using a nitrogen cover. Bottled wines were stored at 6 °C until required for sensory analysis.

Juice analysis: Juice samples were subjected to a range of primary metabolite analyses. Soluble solids concentrations (°Brix) were determined on an Atago refractometer PAL-1 (Atago Co. Ltd, Japan) and juice acidity (pH) analysed using a Metrohm 744 pH meter (Metrohm AG, Switzerland). Titratable acidities were determined on a Mettler-Toledo DL50 autotitrator (Mettler Toledo GmbH, Analytical, Switzerland) using an equivalence point titration of pH 8.2 with aqueous sodium hydroxide (0.1 M). Acid content was calculated in tartaric acid equivalents (g·L^{-1}). Juice ammonium concentration was quantified by enzymatic

assay (Vintessentials Laboratories, Victoria, Australia) and primary amino acids, in isoleucine (N) equivalents, by the nitrogen by o-phthaldialdehyde/N-acetyl-L-cysteine (NOPA) method (Dukes and Butzke 1998). The sum of both analyses gave the yeast available nitrogen concentration.

Wine analysis: Wine samples were analysed for pH and titratable acidity as for juice analysis. Alcohol was measured using an Anton Paar wine alcolyzer (Anton-Paar, Austria). All measurements were taken in duplicate from each of the three fermentation replicates and variation was < 0.02 v/v %. Total phenolics were quantified in gallic acid equivalents by the Folin-Ciocalteu method (Iland *et al.* 2000). Monomeric anthocyanins were quantified by the pH difference method (Lee *et al.* 2005).

Sensory analyses: Sensory investigations were conducted on the 2011 and 2012 sets of wines separately, using different expert panels but identical sensory methodologies. Evaluations were performed within two months of wine bottling, to ensure consistent wine storage period across the two years.

Expert panels: The wines were evaluated by panels of 28 or 27 wine industry professionals from Marlborough (winemakers, viticulturists, and wine scientists) over two days in November 2011 or December 2012, respectively. The 2011 panel comprised 17 males and 11 females; 70 % of participants were winemakers and 90 % had at least six years' experience working within the wine industry. Participants' ages were: 10 % within 18-30 years, 65 % within 31-45 years, and 25 % within the age range of 46-60 years. In 2012, the panel comprised 16 males and 11 females; 67 % of participants were winemakers and 89 % had at least six years' experience working within the wine industry. Participants' ages were: 11 % within 18-30 years, 74 % within 31-45 years, and 15 % within 46-60 years.

Sensory facility and sample preparation: Evaluations were conducted in booths with natural and white fluorescent lighting at the sensory facility of the Marlborough Wine Research Centre, Blenheim. To minimise the confounding effect of wine colour, the samples were served in black glasses of standard XL size, labelled with three-digit codes, and covered with watch glass lids. 30 mL samples were prepared 1 h prior to being evaluated and were served at room temperature (20 °C).

Descriptive sensory analysis: Wines were evaluated using descriptive sensory analysis as described in Lawless and Heymann (2010). A list of potential descriptors was first compiled through review of previous sensory research on 'Pinot noir' wine (Guinard and Cliff 1987, Cliff and Dever 1996, Campo *et al.* 2010). It was refined in preliminary bench-testing of the 2011 wines by sensory scientists to encompass the dominant sensory properties of the wines. The final list comprised eight flavour (red berry, dark berry, candied cherries/jammy, herbaceous/vegetal/rhubarb, woody/stalks, spicy, and earthy/fresh mushroom), three taste (acid, sweet, and bitter), and three mouth-feel (astringency, mid palate fruit weight/flesh, and body/viscosity) attributes. All attributes were familiar to the wine expert panels. Perceived intensities of all attributes and overall judgements on wines were rated *via* 100-mm, horizontal visual analogue scales, as per the procedure in Parr *et al.* 2007. For the flavour, taste and "Astringency" attributes, the scale had the word "absent" as an anchor on the left and "extreme" as an anchor on the right. "Poor" and "very good", respectively, were applied to scales of the other mouth-feel attributes.

For judgment of overall complexity, the scale was anchored with "poor" at the left end and "very good" at the right end. Typicality of 'Marlborough Pinot Noir' wine was assessed by adapting the method from Perrin and Pagès (2009) asking: "Imagine you are explaining to a friend what a Marlborough Pinot noir wine is like, for each wine: From your experience do you think that this is a good example or a poor example of a 'Marlborough-style' Pinot noir wine? Our interest is in your own view." Consequently, 'poor example' and 'very good example', respectively, were applied to the scale used to judge the wines' typicality. Each individual attribute or wine judgment were provided by placing a vertical mark across the line at the complexity or exemplarity points at which the wine was perceived to be.

Data collection: Each year, data collection took place over two days, with two sessions scheduled per day and each participant attending one of the sessions. Each session lasted about 60 min.

Before starting, the principle of the assessment was explained. Then, participants were presented a sample of each of the wines, laid out in a semicircle along with a warm-up wine sample (for which no data were collected). Participants were asked to smell and taste that warm-up sample before evaluating all wine samples in the order presented, from left to right. Participants were allowed to re-smell and re-taste the wines once they had evaluated them all in the order presented. Upon completing the evaluation, participants observed a break for at least ten minutes during which they were provided crackers and bread as palate cleansers. Then, they evaluated a second sample of each of the wines, in the exact same way as described above, except that they did not have a warm-up sample. The presentation order of samples followed a Latin square design balanced across participants and evaluation replications for first order and carry-over effects. Expectoration was compulsory.

Statistical analysis

Data from juice and wine analyses: Results from field trials were analysed by ANOVA using GenStat 14 (VSN International Ltd, Hemel Hempstead, United Kingdom). Comparison of means was determined post hoc by Fisher's unprotected Least Significant Difference (LSD) values at $\alpha = 0.05$. Kurtosis of the berry density data was determined using GenStat 14 and Gaussian Peak 3-parameter curves fitted using Sigma plot v12.5 (Systat Software, Inc. San Jose, CA, USA).

Data from descriptive sensory analysis and judgments on wine: Ratings to 100-mm visual analogue scales were averaged across the two evaluation replications and each vintage replicate was analysed separately. Further analyses were performed on combined data to compare the sensory findings across the 2011 and 2012 vintage replicates.

Analysis of data from each vintage replicate: Multivariate Analysis of Variance (MANO-

VA) using the Wilk's Lambda statistic was carried out on intensity scores for the thirteen sensory attributes to test for a difference in the wines' overall sensory profiles. Pair-wise comparisons of the wines' sensory profiles were further performed through additional two-sample MANOVAs, equivalent to Hotelling's T^2 tests, run separately for each possible combination of two wines.

Mean ratings scores were further analysed on an attribute-by-attribute basis through series of 1-way Analysis of Variance (1-way ANOVA) using 'fruit population/blend modality' as the single fixed factor and 'panellist' as a blocking effect. Post-hoc differences between means were determined using Fisher's unprotected Least Significant Difference (LSD) values at α=0.05.

Mean values for sensory attributes for which 1-way ANOVA resulted in *p*-values less than 0.20 were finally input to Principal Components Analysis (PCA) of the correlation matrix. Using an approach based on that of Husson *et al.* (2005), confidence ellipses (at the 95 % level) were derived, to obtain an indication of variability in wine positions in the PCA space obtained. Judgement data were submitted to 1-way ANOVAs following the method described above for the sensory attributes.

Analysis of data combined across the two vintage replicates: Multiple Factor Analysis (MFA) was used to investigate the degree of consistency between results from descriptive analysis of the 2011 and 2012 wines. The analysis was performed as described in Escofier and Pagès (1994). Briefly, for each of the 2011 and 2012 sets of wines, sensory attribute mean scores were input to PCA of the correlation matrix. Wines' mean scores were then normalised using the amount of variation explained by the first dimension of their respective PCA. The overall degree of correlation between the 2011 and 2012 sets of normalised mean scores was determined by calculating an RV coefficient. The normalised mean scores were further aggregated and submitted to PCA of the correlation matrix to obtain a consensus configuration, illustrating the degree of similarities in the patterns of variation among the 2011 and 2012 wines.

Results

Field results: As reported earlier (Parker *et al.* 2016), trimming resulted in juice with a lower soluble solids concentration at harvest ($P < 0.05$) (Tab. 1). In contrast, trimming had little effect on the titratable acidity or pH, while sugar and acid concentrations were desynchronized (see Fig. 5 in Parker *et al.* 2016), there were no significant trimming effects on the titratable acidity or pH of the juices used for winemaking in either year (Tab. 1). Juice primary amino acids (PAA), ammonium and as a consequence yeast available nitrogen (YAN) were generally higher where vines were trimmed ($P < 0.05$) (Tab. 1). Blended fruit produced juices with a mean composition similar to that of the juice from the medium trimmed treatment (Tab. 1). While trimming reduced the mean soluble solids concentration, the berry density distribution around the mean value of each treatment (the kurtosis) decreased from -0.56 to -1.21 in 2011 and -0.15 to -1.09 in 2012, indicating a greater variability in distribution compared with a normal distribution (Fig. 1).

Table 1

Influence of 'Pinot noir' grapevine canopy trimming and blending of harvested fruit on must composition at the start of fermentation (n = 3)

	Trimming treatments[1]			Fruit blending treatments[2]	
	ST	MT	TT	PreFB 1	PreFB 2
2011					
Soluble solids concentration (°Brix)	21.1^{a}	22.5^{b}	23.9^{c}	22.7^{b}	22.4^{b}
pH	3.56	3.56	3.57	3.55	3.57
TA (g·L^{-1})	6.63	6.34	6.14	6.32	6.25
Primary amino acids (mg·L^{-1})	297^{d}	255^{c}	205^{a}	245^{b}	242^{b}
Juice ammonium (mg·L^{-1})	111^{c}	87^{b}	70^{a}	87^{b}	89^{b}
Yeast available nitrogen (mg·L^{-1})	408^{c}	342^{b}	276^{a}	333^{b}	331^{b}
2012					
Soluble solids concentration (°Brix)	21.7^{a}	22.1^{a}	23.2^{b}	21.9^{a}	22.4^{a}
pH	3.60^{b}	3.53^{ab}	3.53^{ab}	3.50^{a}	3.54^{ab}
TA (g·L^{-1})	6.71^{abc}	6.91^{bc}	6.66^{ab}	6.95^{c}	6.51^{a}
Primary amino acids (mg·L^{-1})	90	89	86	89	92
Juice ammonium (mg·L^{-1})	69	63	53	56	64
Yeast available nitrogen (mg·L^{-1})	159^{b}	152^{ab}	139^{a}	145^{a}	155^{ab}

TA = titratable acidity (g·L^{-1} tartaric acid equivalent).

[1] Grapevine canopies trimmed shortly after fruit set to 30 (ST), 60 (MT), and 100 (TT) cm above the fruiting wire.

[2] Blends of fruit harvested from the different trimming treatments: PreFB 1 = 10:80:10 and PreFB 2 = 30:40:30 fruit from the ST, MT and TT grapevines respectively.

Values were separated using Fisher's unprotected LSD test (α = 0.05), where values in the same line with different superscript letters are statistically different from one another between treatments.

Wine Results: Wine alcohol concentrations reflected the soluble solids concentrations of the juice (Tab. 2). Wines from the TT treatments had greater anthocyanin concentrations in both seasons and in 2012 higher phenolic concentrations. In general, the fruit blending and wine blending treatments resulted in similar mean composition to the MT treatment, with the exception of the titratable acidities of the wine blending treatments, which were significantly lower than those of the other wines (Tab. 2).

Sensory properties

Descriptive sensory analysis: MANOVA of the descriptive sensory data revealed a significant effect of the various fruit populations/blend modalities used on the overall sensory profiles of the wines produced in 2011 (Wilk's Lambda = 0.700, approximate Fisher's test: $P < 0.001$) and in 2012 (Wilk's Lambda = 0.700, approximate Fisher's test: $P < 0.001$). ANOVA of the sensory attributes' mean scores is summarised in Tab. 3. Consistent across years, a difference in fruit populations/blend modalities was established for all the mouth-feel attributes (*i.e.* astringent, mid palate fruit weight/flesh and body/viscosity), as well as for two of the flavour attributes, dark berry and spicy (all *P*-values < 0.05). The intensities of herbaceous/vegetal/rhubarb flavour, were different in 2011 (*P*-value < 0.05), but not in 2012 (*P*-value < 0.1). In contrast, the fruit populations/blend modalities affected neither the taste properties of the

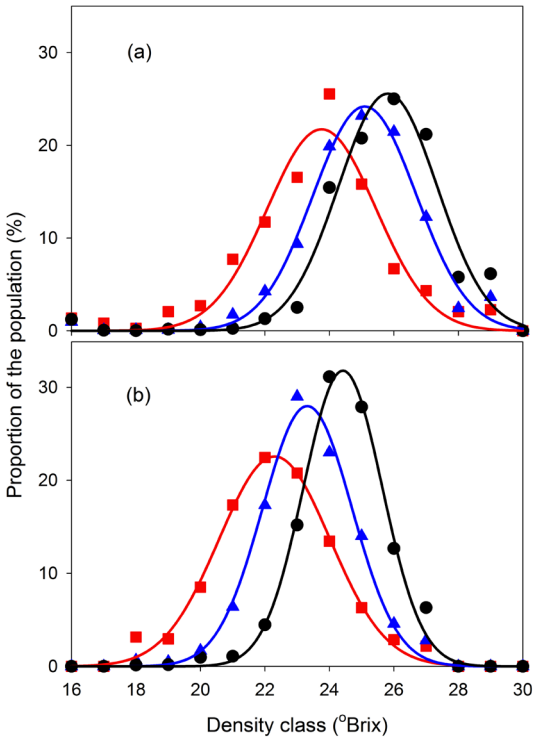

Fig. 1: Influence of 'Pinot noir' grapevine canopy trimming on berry density distribution. (**a**) 2011 harvest, (**b**) 2012 harvest. ■ ST, ▲ MT, ● TT. Gaussian Peak 3-parameter curves fitted using Sigma plot v12.5.

Table 2

Influence of 'Pinot noir' grapevine canopy trimming, pre-fermentation blending of harvested fruit, and post-fermentation blending of resulting wine on wine composition (n = 3)

	Trimming treatments[1]			Fruit blending treatments[2]		Wine blending treatments[3]	
	ST	MT	TT	PreFB 1	PreFB 2	PostFB 1	PostFB 2
2011							
Alcohol (% ABV)	11.5^{a}	12.6^{b}	13.9^{c}	12.9^{b}	12.6^{b}	12.8^{b}	12.8^{b}
[4] Pre-adjustment pH	3.91	3.91	3.93	3.90	3.92	nd	nd
[4] Pre-adjustment TA (g·L^{-1})	5.19^{a}	5.23^{a}	5.60^{c}	5.38^{b}	5.23^{a}	nd	nd
Phenolic conc. (mg·L^{-1} GAE)	1202	1277	1293	1241	1207	nd	nd
Monomeric anthocyanin (mg·L^{-1} M-3-G)	78.2^{a}	91.4^{b}	108.3^{c}	95.3^{b}	92.6^{b}	nd	nd
Post-adjustment pH	3.54	3.54	3.58	3.52	3.56	3.56	3.57
Post-adjustment TA (g·L^{-1})	5.64^{b}	5.65^{bc}	5.73^{c}	5.66^{c}	5.57^{b}	5.48^{a}	5.47^{a}
2012							
Alcohol (% ABV)	9.5^{a}	11.1^{b}	11.9^{c}	11.1^{b}	11.3^{bc}	11.1^{b}	10.9^{b}
[4] Pre-adjustment pH	3.08	3.74	3.73	3.73	3.78	nd	nd
[4] Pre-adjustment TA (g·L^{-1})	6.34^{ab}	6.29^{a}	6.61^{c}	6.49^{bc}	6.18^{a}	nd	nd
Phenolic conc. (mg·L^{-1} GAE)	960^{a}	1076^{b}	1397^{c}	1117^{b}	1093^{b}	nd	nd
Monomeric anthocyanin (mg·L^{-1} M-3-G)	77.6^{a}	92.7^{b}	127.0^{c}	96.4^{b}	100.0^{b}	nd	nd
Post-adjustment pH	3.72^{b}	3.65^{a}	3.64^{a}	3.64^{a}	3.69^{ab}	3.63^{a}	3.65^{a}
Post-adjustment TA (g·L^{-1})	6.53^{b}	6.70^{bc}	7.00^{d}	6.76^{c}	6.52^{b}	6.36^{ab}	6.23^{a}

ABV = Alcohol by Volume; TA = titratable acidity (g·L^{-1} tartaric acid equivalent); GAE = Gallic acid equivalent; M-3-G = Malvadin-3- glucoside; nd= not determined.

[1, 2] see legend Tabs 1 and 2.

[3] Wine blending treatments. Wines from the ST, MT and TT treatments were blended post-fermentation; PostFB 1 = 10:80:10 and PostFB 2 = 30:40:30 Short, Mid and Tall Trimmed wines respectively.

[4] pH and TA values at the end of malolactic fermentation. Acidity adjustments, to facilitate sensory evaluation, were made by the addition of tartaric acid to wines post-fermentation.

Values were separated using Fisher's unprotected LSD test (α = 0.05), where values in the same line with different superscript letter are statistically different from one another between treatments.

Table 3

Analyses of variance of significant sensory attribute mean and judgement scores for the seven 2011 and 2012 'Pinot noir' wines made using different fruit populations/blend modalities

Sensory attribute	2011 vintage							2012 vintage						
		Trimming			Pre-ferment	Post-ferment			Trimming			Pre-ferment		Post-ferment
	P-value	ST	MT	TT	Pre FB 1[1]	Pre FB 2[1]	Post FB 1	Post FB 2	*P*-value	ST	MT	TT	Pre FB 1[1]	Pre FB 2[1]	Post FB 1	Post FB 2
Sensory (flavour) attributes																
Dark berry	**0.001**	**48b**	**56ab**	**63a**	**57ab**	**57ab**	**58ab**	**60a**	**0.029**	**47ab**	**52ab**	**57a**	**54ab**	**53ab**	**53ab**	**46 b**
Herbaceous/ vegetal/rhubarb	**0.026**	**51a**	**47ab**	**50ab**	**45ab**	**44ab**	**51ab**	**41b**	0.070	44.6	38.4	36.3	33.7	36.3	39.8	39.5
Spicy	**0.003**	**46b**	**51ab**	**58a**	**51ab**	**51ab**	**53ab**	**49b**	**< 0.001**	**32b**	**43a**	**41ab**	**41a**	**45a**	**43a**	**39 ab**
Sensory (texture) attributes																
Astringent	**0.027**	**39b**	**45ab**	**50a**	**49ab**	**44ab**	**47ab**	**47ab**	**0.043**	**32ab**	**34ab**	**41a**	**33ab**	**32b**	**38ab**	**36ab**
Mid palate fruit weight/flesh	**< 0.001**	**39b**	**50a**	**55a**	**49a**	**51a**	**50a**	**51a**	**< 0.001**	**36b**	**48a**	**46a**	**41ab**	**50a**	**47a**	**43ab**
Body/viscosity	**< 0.001**	**36b**	**49a**	**55a**	**46a**	**49a**	**47a**	**50a**	**< 0.001**	**34b**	**46a**	**45a**	**40ab**	**48a**	**43ab**	**42ab**
Judgement scores																
Overall complexity	**0.001**	**41b**	**50ab**	**54a**	**48ab**	**48ab**	**49ab**	**54a**	**< 0.001**	**37b**	**49a**	**49a**	**47ab**	**51a**	**46ab**	**44ab**
Marlborough typicality	0.056	44.6	48.6	53.4	51.7	49.5	49.5	56.0	**< 0.001**	**39b**	**51a**	**52a**	**50a**	**55a**	**48ab**	**45ab**

Note: Intensities were measured on a scale anchored at 0 = absent/poor and 100 = extreme/very good. The 2011 and 2012 data were analysed separately. All pair-wise comparisons were adjusted for multiple testing using Fisher's unprotected LSD ($\alpha = 0.05$). Within each vintage and attribute, means followed by the same letter in the same row are not significantly different from one another. Significant effects are marked in bold.

Red berry, Candied cherries/jammy, woody/stalks, earth/fresh mushroom flavour attributes and acid, sweet and bitter texture attributes were non-significant ($P > 0.1$).

[1,2] see legend Tabs 1 and 2.

wines (*i.e.* acid, sweet, and bitter) nor their red berry, candied cherries/ jammy, woody/stalks, and earthy/ fresh mushroom flavour intensities ($P > 0.1$).

Further pair-wise comparisons of the wines' mean scores revealed that the perception of the mouth-feel attributes were generally greater with increased trim height ($P < 0.05$) (Tab. 3). Likewise, the perceived intensities of dark berry and spicy flavours also increased, while the perceived intensity of herbaceous/ vegetal/rhubarb flavour decreased, although not significantly so in 2012 ($P > 0.05$). Pre- and post-ferment blending appeared to result in wines of similar mouth-feel and flavour properties, closer to those of the MT and/or TT treatment wines than to those of the ST treatment wine.

To further illustrate the patterns of sensory variation among the wines in each vintage, the averaged sensory scores for the most significantly varied attributes were input to PCAs of the correlation matrices. The two-dimensional solutions obtained accounted for ~96 and 81 % of the total variance in the 2011 and 2012 data, respectively, of which ~76 and 59 % were accounted for by the first Principal Components (PCs) and ~20 and 22 % by the second PCs, respectively (Fig. 2).

The attributes loading plot for 2011 is presented in Fig. 2a. With very high positive loadings on PC1, the three mouth-feel attributes were positively correlated with one another and with the Dark berry and Spicy flavour attributes. They were correlated negatively with Herbaceous/vegetal/ rhubarb flavour, which was the only attribute loaded negatively on that first PC. Variation on PC2 was driven by the very high positive loadings of the herbaceous/vegetal/rhubarb and, to a lesser extent, spicy flavour attributes. Results were overall similar in 2012 (Fig. 2c). The only noticeable differences were the stronger negative loading of the herbaceous/vegetal/ rhubarb flavour attribute on PC1, and the very high positive loadings on PC2 of the astringent and bitter attributes, which were correlated positively with each other and, to a lesser extent, with the herbaceous/vegetal/

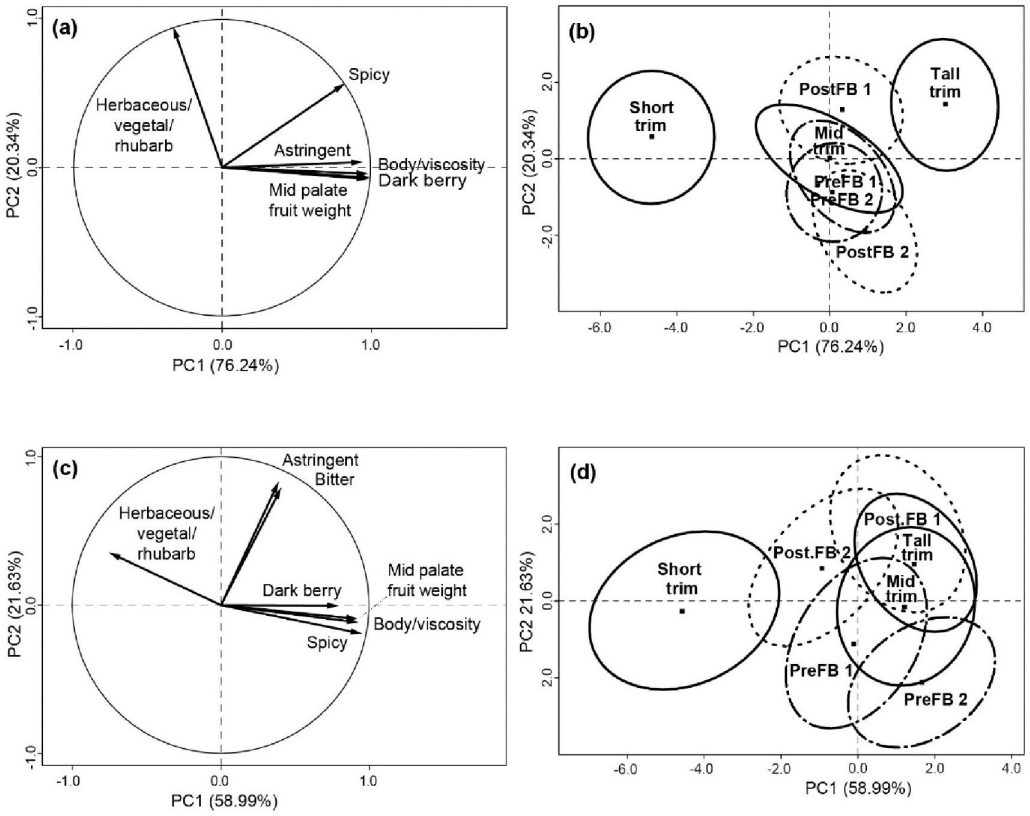

Fig. 2: Principal Components Analyses of the correlation matrix of the sensory attributes pertaining to differences among the seven 2011 (**a** and **b**) and 2012 (**c** and **d**) 'Pinot' wines resulting from different fruit populations/blend modalities: **a** and **c**: Variable factor maps showing the loading of the significantly varied sensory attributes; **b** and **d**: Wine factor maps showing the relative positioning of the seven wines in the two-dimensional space. Blends of fruit harvested from the different trimming treatments: PreFB 1 = 10:80:10 and PreFB 2 = 30:40:30 fruit from the ST, MT and TT grapevines respectively. Wine blending treatments: Wines from the blended post-fermentation; PostFB 1 = 10:80:10 and PostFB 2 = 30:40:30 ST, MT and TT wines respectively.

rhubarb flavour attribute. Overall, the attributes loading plots showed that wines in both seasons differed primarily in their mouth-feel properties, spiciness and dark berry-like fruitiness rather than, as could have been expected, in their herbaceous characters (Fig. 2a and 2c).

The relative positioning of the wines in the two-dimensional spaces are shown in Fig. 2b and d. In 2011, the ST treatment wine was isolated on the negative side of PC1, illustrating its significantly lower astringency and lighter mid palate fruit weight and body compared with the other six wines (Fig. 2b and Tab. 3). The TT treatment wine had the highest positive loading on PC1, illustrating its high mid palate fruit weight, body, astringency and intense dark berry and spicy flavour characters. The other five wines were clustered around the origin on PC1, meaning that they had sensory properties intermediate to those exhibited by the ST and TT treatment wines. The small degree of variation in their relative positioning alongside PC2 illustrated the variation in herbaceous/vegetal/rhubarb and spicy flavour intensities, and especially the trend for the PostFB 1 wine to exhibit higher intensities of those flavour attributes than the PostFB 2 wine (Tab. 3).

In 2012, the ST treatment wine was, again, isolated on the negative side of PC1 (Fig. 2d). As was the case in 2011, this illustrated the lighter mid palate fruit weight and body of that wine compared with the other six wines (Tab. 2). However, the TT treatment wine was not separated from the other wines, as was the case in 2011. Instead, it shared with the MT, PreFB 2, and PostFB 1 treatment wines the highest relative positioning on PC1, reflecting that all four wines had similarly high scores for all of the attributes loaded positively on PC1 (Fig. 2d and Tab. 3). The remaining two wines, PreFB 1 and PostFB 2, were located close to the origin on PC1, illustrating their intermediate sensory properties. Finally, the non-significant trend for the PostFB 1 wine to be more astringent and less full-bodied than the PreFB 2 wine was illustrated by the high and low relative positioning of these wines on PC2, respectively.

Therefore, the PCA analyses showed that, in 2011, the ST and TT treatment wines had the most different sensory properties and were separated from the other wines, which shared intermediate sensory characteristics. In 2012, the ST treatment wine remained different from the other wines, while the Tall Trim treatment wine was no longer distinctively different from wines from the other treatments with which it overall shared similar sensory properties.

Overall judgments on wines: Mean judgment scores are summarised in Tab. 3. Consistent across years, the berry fruit populations/blend modalities used affected the overall complexity of the final wines produced significantly ($P < 0.05$). Their effect on the perceived typicality of the wines as 'Marlborough Pinot noir' was marginally significant in 2011 ($P < 0.1$) and significant in 2012 ($P < 0.05$).

In 2011, the ST treatment wine was judged to be significantly less complex than both the TT and the PostFB 2 treatment wines (Tab. 3). The other four wines were of intermediate complexity. In 2012, the MT, TT and PreFB 2 treatment wines were perceived as significantly more complex than the ST treatment wine, and the other three wines had intermediate complexity.

Mean typicality scores showed a non-significant trend for the ST treatment wine to be perceived less typical as a 'Marlborough Pinot noir' than the TT treatment wine in 2011 (Tab. 3). In 2012, the ST treatment wine was judged to be significantly less typical as a 'Marlborough Pinot noir' than the MT, TT, and the two wines resulting from pre-fermentation fruit blends (*i.e.* PreFB 1 and PreFB 2 wines), with the post-ferment blended wines (*i.e.* PostFB 1 and PostFB 2 treatment wines) receiving intermediate typicality scores.

Comparison of sensory results between vintage replicates: Because sensory evaluation of wines in the two vintage replicates of the study were performed by different panels, a MFA method was used to investigate the degree of consistency between results from descriptive analysis of the 2011 and 2012 wines.

The analysis provided an RV coefficient of 0.719, on a scale varying from 0 = no correlation to 1 = perfect correlation. The significant associated *P*-value of 0.047 indicated that the patterns of sensory similarities/differences among the wines were consistent across the two vintages.

This is illustrated in the wine consensus configuration presented in Fig. 3, in which, for each fruit population/blend modality tested, the relative positioning of the 2011 and 2012 wines is shown at the end of the plain and dotted lines, respectively. Overall, the two-dimensional configuration explains ~63 % of the total variance in the aggregated data, most of which (~47 %) is accounted for by PC1. That is, the patterns of sensory similarities/differences among the wines are primarily represented by similarity/difference in their relative positioning alongside PC1. Therefore, Fig. 3 shows that, of all seven berry populations/blend modalities tested, the ST and TT treatments consistently resulted in wines with the most different sensory properties. Wines corresponding to the other five berry populations/blend modalities consistently shared very similar sensory profiles, intermediate to those exhibited by the two extremes although much more similar to that of the TT treatment wine than to the ST treatment wine.

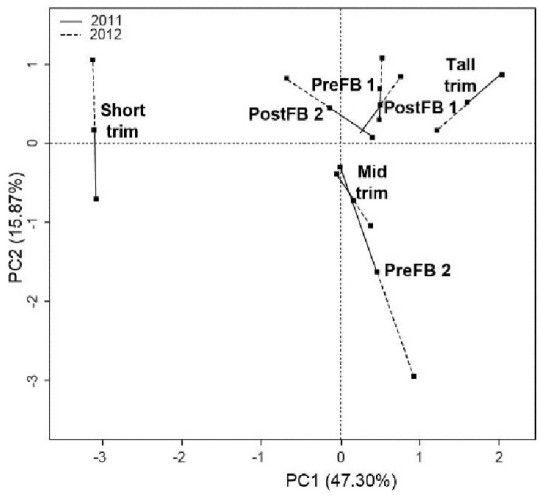

Fig. 3: Wine consensus configuration resulting from Multiple Factor Analysis of descriptive sensory data collected for the 2011 and 2012 replicates of the seven experimental 'Pinot noir' wines made using different fruit populations/blend modalities. For treatment details, see legend Fig. 2.

Discussion

Trimming post-fruit set slowed soluble solids accumulation in 'Pinot noir' fruit (Parker 2016), but had little effect on titratable acidity or pH (Tab. 1). Trimming increased the yeast available nitrogen (amino acids and ammonium), similar to that observed elsewhere (Spring *et al.* 2011). The changes in the rates of soluble solids accumulation resulted in marked differences in the range of fruit soluble solids concentration (as measured by density) at harvest (Fig. 1). The effects of trimming treatments on fruit composition at harvest were reflected in wine composition (Tab. 2) and in the sensory properties of the wine (Tab. 3).

Consistent across the two vintage replications of the study, descriptive sensory analysis (Tab. 3) revealed a significant impact of the fruit populations/blend modalities tested on the overall sensory properties and overall complexity of the resulting wines. Also, the nature of the sensory differences was remarkably consistent across vintage replicates, with significant differences being observed in the mouth-feel characteristics as well as in the dark berry and spicy flavour intensities of the wines, but not in their taste properties nor in the intensities of red berry, candied cherries/jammy, woody/stalks and earthy/fresh mushroom flavours they exhibited. In addition, significant differences were observed in the herbaceous/vegetal/rhubarb flavour intensity of wines from the 2011 vintage, whereas the differences were marginally significant for the 2012 wines. The opposite was true of the wines' typicality as 'Marlborough Pinot noir', with marginally significant and significant differences being found among wines from the 2011 and 2012 vintages, respectively (Tab. 3). The two specific objectives of the study, *i.e.* 1) to determine the effect of variation in 'Pinot noir' fruit maturity and 2) to determine the effect of variation in 'Pinot noir' fruit composition, i.e. fruit population of homogeneous *vs.* heterogeneous maturity, on the sensory characteristics of the resulting wines, resulted in contrasted findings, summarised and discussed below.

Short trim, MT and TT treatment wines corresponded to fruit populations of low, moderate and high maturities, respectively. Consistent across the two vintage replications of the study, low fruit maturity resulted in wine (ST wine) with an overall sensory profile significantly different from those of wines made with fruit of moderate and high maturities (MT and TT treatment wines). Specifically, the wine made with fruit of low maturity was consistently perceived as having significantly lighter mid-palate fruit weight and body/viscosity than its two counterparts. The wine was also scored as less astringent, and exhibited less intense dark berry, spicy and more intense herbaceous/vegetal/rhubarb flavour characters than wines made with fruit of higher

maturity, although the differences were either significant or marginally significant depending on the vintage (Tab. 3 and Fig. 2). In addition, low fruit maturity negatively affected the overall complexity and typicality as 'Marlborough Pinot noir' of the final wine produced, although the effect on this was significant only in the 2012 vintage replication of the study. Conversely, moderate and high fruit maturities resulted in wines of similar sensory properties, overall complexity and typicality as 'Marlborough Pinot noir'. Those results are consistent with findings by Kontoudakis *et al.* (2011) for 'Cabernet Sauvignon' wine and suggest that only a noticeably low fruit maturity at harvest will affect the style of the wine produced negatively. Harvesting fruit at about 22.3 ºBrix (Tab. 1) resulted in wines with equivalent organoleptic qualities to wines produced from fruit harvested at a higher soluble solids concentration, but with a lower alcohol concentration. However, further research is needed to investigate the extent to which wines made from fruit from trimmed vines, harvested at the same soluble solids concentration, but on different dates, would be affected by an extended "hang time".

With regards to the second objective of the research, we started with the premise that variability in fruit composition would result in poorer wines (Long 1987, Trought 1997, Barbagallo *et al.* 2011). The hypothesis was that increasing heterogeneity in fruit composition would result in wine with sensory characteristics less desirable than wines from homogeneous fruit, but with the same mean soluble solids concentration. The four wines corresponding to fruit populations of heterogeneous maturities, i.e. resulting either from pre-fermentation fruit blend (PreFB 1 and PreFB 2 wines) or post-fermentation wine blends (PostFB 1 and PostFB 2 wines) consistently showed similar sensory properties, overall complexity and typicality as 'Marlborough Pinot noir' to wines made from homogenous fruit populations with a similar mean soluble solids concentration (Tab. 3 and 4). This means that: 1) the two blending modalities tested (*i.e.* pre-fermentation fruit blending and post-fermentation wine blending), and 2) the two blend proportions tested (*i.e.* 10 %, 80 %, and 10 % fruit populations of low, moderate and high maturities, respectively, and 30 %, 40 %, and 30 % fruit populations of low, moderate and high maturities, respectively) produced equivalent sensory properties in the resulting wines. Therefore, this study provides consistent evidence that, at an experimental scale, 'Pinot noir' wines blended from a range of compositions do not differ from single wines made from blends of a range of fruit populations.

Furthermore, the sensory properties, overall complexity and typicality as 'Marlborough Pinot Noir' of the four wines corresponding to the heterogeneous fruit composition (*i.e.* PreFB 1, PreFB 2, PostFB 1, and PostFB 2 wines) were consistently perceived as being similar to those of wines made using homogeneous berry populations of either moderate or high maturity (*i.e.* MT or TT wines, respectively) and significantly different from those of the wine resulting from fermentation of low maturity fruit (*i.e.* ST wine). That finding suggests that heterogeneous 'Pinot noir' fruit maturity is not perceptible in the sensory properties of the resulting wine, as long as the proportion of berries of low maturity in the harvested fruit blend is counterbalanced by a similar proportion of berries of high maturity. In other words, when the mean soluble solids concentrations of the harvested fruit are similar, 'Pinot noir' wines made using fruit with a wide range of maturities do not have different sensory properties from those made with fruit with a narrow range of maturities. Therefore, the results do not support intuitive expectations that heterogeneity, as opposed to homogeneity, in 'Pinot noir' fruit maturity at harvest would affect the sensory properties of the resulting wines.

Conclusion

This study conducted across the 2011 and 2012 vintages investigated the effects of variation in 'Pinot noir' fruit maturity, *i.e.* low, moderate and high fruit maturities, and variation in 'Pinot noir' fruit composition, *i.e.* fruit populations of homogeneous v. heterogeneous maturity, on the sensory properties, overall complexity and typicality as 'Marlborough Pinot noir' wines.

Wine from moderate and high fruit maturities had similar sensory properties, complexity and typicality as 'Marlborough Pinot noir' in both seasons. Compared against those benchmarks, low fruit maturity resulted in less fruity, spicy, full-bodied, more green/vegetal, and overall less complex wines. We conclude that low fruit maturity at harvest predominantly affects the organoleptic properties of 'Marlborough Pinot noir' wine, when assessed using rigorous sensory analysis protocols.

Practically, this could provide the wine industry with flexibility, once moderate fruit maturity is reached, to integrate other parameters, such as weather forecast, staff resources, etc., into harvest decision-making, and to produce wines of lower alcohol concentration reliably. Alternatively, trimming vines desynchronises soluble solids accumulation from some other metabolites in the fruit and may enable growers with the ability to give fruit greater "hang time" without causing an unacceptable increase in wine alcohol concentration.

This study also provided evidence that, 'Pinot noir' wines blended from fruit with a heterogeneous range of compositions did not differ from a homogeneous sample of the same mean soluble solids. Indeed, the four wines corresponding to fruit populations of heterogeneous maturities, either through pre-fermentation fruit blends or post-fermentation wine blends, had similar sensory properties, overall complexity and typicality as 'Marlborough Pinot noir'. This suggests that 'Pinot noir' wines made using fruit with a wide range of maturities do not have different sensory properties from those made with fruit with a narrow range of maturities providing the mean soluble solids is similar.

Acknowledgements

This work was part of the New Zealand Grape and Wine Research programme, a joint investment by The New Zealand Institute for Plant & Food Research Limited and New Zealand Winegrowers. Funding was provided by the New Zealand Foundation for Research Science and Technology (Designer Grapevines

CO6X0707). We appreciate the support of R. Rose for the use of his vineyard in the trial and his vineyard management. We also acknowledge the assistance of field and laboratory staff at Plant & Food Research, Marlborough, and the industry people that undertook the sensory analysis of the wines. The comments on the draft manuscript by R. Harker, A. Gunson and A. Friend (Plant & Food Research) are appreciated.

References

Barbagallo, M. G.; Guidoni, S.; Hunter, J. J.; 2011: Berry size and qualitative characteristics of *Vitis vinifera* L. cv. Syrah. S. Afr. J. Enol. Vitic. **32**, 129-136.

Cadot, Y.; Caillé, S.; Samson, A.; Barbeau, G.; Cheynier, V.; 2012: Sensory representation of typicality of Cabernet franc wines related to phenolic composition: Impact of ripening stage and maceration time. Anal. Chim. Acta **732**, 91-99.

Campo, E.; Ballester, J.; Langlois, J.; Dacremont, C.; Valentin, D.; 2010: Comparison of conventional descriptive analysis and a citation frequency-based descriptive method for odor profiling: An application to Burgundy Pinot noir wines. Food Qual. Pref. **21**, 44-55.

Cliff, M. A.; Dever, M. C.; 1996: Sensory and compositional profiles of British Columbia Chardonnay and Pinot noir wines. Food Res. Int. **29**, 317-323.

Dukes, B. C.; Butzke, C. E.; 1998: Rapid determination of primary amino acids in grape juice using an o-phthaldialdehyde/N-acetyl-L-cysteine spectrophotometric assay. Am. J. Enol. Vitic. **49**, 125-134.

Escofier, B.; Pagès, J.; 1994: Multiple factor-analysis (afmult package). Comput. Stat. Data Anal. **18**, 121-140.

Guinard, J. X.; Cliff, M.; 1987: Descriptive analysis of Pinot-noir wines from Carneros, Napa, and Sonoma. Am. J. Enol. Vitic. **38**, 211-215.

Heymann, H.; Licalzi, M.; Conversano, M. R.; Bauer, A.; Skogerson, K.; Matthews, M.; 2013: Effects of extended grape ripening with or without must and wine alcohol manipulations on Cabernet Sauvignon wine sensory characteristics. S. Afr. J. Enol. Vitic. **34**, 86-99.

Husson, F.; Le, S.; Pagès, J.; 2005: Confidence ellipse for the sensory profiles obtained by principal component analysis. Food Qual. Pref. **16**, 245-250.

Iland, P.; Ewart, A.; Sitters, J.; Markides, A.; Bruer, N.; 2000: Techniques for Chemical Aanalysis and Quality Monitoring during Winemaking. Patrick Iland Wine Promotions, Campbelltown, South Australia.

Kontoudakis, N.; Esteruelas, M.; Fort, F.; Canals, J. M.; Zamora, F.; 2011: Use of unripe grapes harvested during cluster thinning as a method for reducing alcohol content and pH of wine. Aust. J. Grape Wine Res. **17**, 230-238.

Lawless, H. T.; Heymann, H.; 2010: Sensory Evaluation of Food, 2nd ed. Springer, New York.

Lee, J.; Durst, R. W.; Wrolstad, R. E.; 2005: Determination of total monomeric anthocyanin pigment content of fruit juices, beverages, natural colorants, and wines by the pH differential method: Collaborative study. J. AOAC Int. 88, 1269-1278.

Long, Z. R.; 1987: Manipulation of grape flavour in the vineyard: California, North Coast region, 82-88. In: T. H. Lee (Ed.): 6th Aust. Wine Indust. Conf., Adelaide.

Parker, A. K.; Raw, V.; Martin, D.; Haycock, S.; Sherman, E.; Trought, M. C. T.; 2016: Reduced grapevine canopy size post-flowering *via* mechanical trimming alters ripening and yield of 'Pinot noir'. Vitis **55**, 1-9.

Parr, W. V.; Green, J. A.; Whie, K. G.; Sherlock, R. R.; 2007: The distinctive flavour of New Zealand Sauvignon blanc: Sensory characterisation by wine professionals. Food Qual. Pref. **18**, 849-861.

Perrin, L.; Pagès, J.; 2009: A methodology for the analysis of sensory typicality judgments. J. Sens. Stud. **24**, 749-773.

Pineau, B.; Trought, M. C. T.; Stronge, K.; Beresford, M. K.; Wohlers, M. W.; Jaeger, S. R.; 2011: Influence of fruit ripeness and juice chaptalisation on the sensory properties and degree of typicality expressed by Sauvignon Blanc wines from Marlborough, New Zealand. Aust. J. Grape Wine Res. **17**, 358-367.

Singleton, V. L.; Ough, C. S.; Nelson, K. E.; 1966: Density separations of wine grape berries and ripeness distribution. Am. J. Enol. Vitic. **17**, 95-105.

Spring, J. L.; Verdenal, T.; Zufferey, V.; Viret, O.; 2012: Nitrogen dilution in excessive canopies of Chasselas and Pinot noir cvs. J. Int. Sci. Vigne Vin **46**, 233-240.

Trought, M. C. T.; 1997: The New Zealand Terroir: Sources of variation in fruit composition in New Zealand vineyards, I-23-I-27. Proc. 4th Int. Symp. Cool Clim. Vitic. Enol., 16-20 July 1996. Rochester, New York, USA.

Ward, S. C.; Petrie, P. R.; Johnson, T. E.; Boss, P. K.; Bastian, S. E. P.; 2015: Unripe berries and petioles in *Vitis vinifera* cv. Cabernet Sauvignon fermentations affect sensory and chemical profiles. Am. J. Enol. Vitic. **66**, 435-443.

Received May 9, 2016
Accepted October 6, 2016