A comparative analysis of regions worldwide with Pinot noir

Une analyse comparative du Pinot noir planté dans différentes régions du monde

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Abstract

This study examines the growing season climates of selected wine regions worldwide that have significant areas under Pinot noir. It uses the normalized climatic data for the 1971-2000 period to analyze those climatic factors that are influential on the production of quality wines in cool climate regions and provides a comparison with those of Burgundy. The results show that the regions fall into broad groups based on various combinations of climatic criteria, but principally those that pertain to the daytime maximum temperature, precipitation totals, the diurnal temperature range and the mean temperature during the ripening period.

Key Words: Pinot noir, climates, regions

Introduction

Often described as problematic, Pinot noir is grown in many areas of the world where aspiring wine makers attempt to identify the climatic and soil attributes that may closely resemble those of the *Côte de Nuits* communes in the *Côte d'Or* appellation where this variety thrives and has its origin (Gerbaux et al. 1998; Cliff and Dever 1998). It is generally recognized that the best climate for Pinot noir for the commercial production of still table wines appears to occur at the cultivable limit of red wine production. It is coarsely defined as the transitional zone between a cold continental and a cool maritime climate situated between the geographic limits of quality white and quality red wine production. This zone is exemplified by the climate of Burgundy, which is traditionally upheld as the benchmark against which most other Pinot noir regions are compared. Outside of Burgundy, several New World regions such as the cooler coastal areas of California, the Pacific North-west, Canada's Niagara Peninsula and the Okanagan Valley, South Island New Zealand, Australia's Yarra Valley, Tasmania, Chile's Casablanca Valley, to name a few, appear to exhibit growing season temperatures that fall broadly into this climatic zone.

This study examines several aspects of the climates of selected wine regions worldwide that have significant areas under Pinot Noir, or have comparatively small areas in production but have achieved international recognition for quality Pinot noir wine. It examines a number of climatic parameters during the growing season that are commonly recognized as crucial to the production of quality wines in cool climate regions and provides a comparative analysis with those of Burgundy. Ultimately, the study sought to understand what climatic differences and similarities these wine regions possess and how this information might be useful to emerging areas where this variety is being evaluated.

Materials and Methods

Sources of Climatic Data

This study used mean monthly temperature, precipitation and bright sunshine values based on the 1971-2000 normal period. Data were retrieved from sources that include: (i) The United States National Climate Data Center (NCDC), (ii) Environment Canada Online Data Source, (iii) the French Meteorological Service, (iv) the German Meteorological Service, (v) Federal Office of Meteorology and Climatology

MeteoSwiss (vi) National Climate Centre - Australian Bureau of Meteorology, (vii) New Zealand's National Institute of Water and Atmosphere, and (viii) the South African Meteorological Service. In each viticulture area, a standard meteorological station was chosen so to represent the macroclimate of the area. It was understood that a single climatic station may not fully exemplify the climates of a larger area or one with complex topographic features in light of the possible existence of sharp meso climate differences (Smart and Dry 1995; Tonietto and Carbonneau 2004). In keeping with the objective of the study, the macro or regional scale was the appropriate spatial scale of analysis.
Data for standard climatic variables included mean, maximum and minimum temperatures, mean monthly precipitation, frequency of days with precipitation, mean monthly bright sunshine hours. In some cases, it was necessary to estimate the heat units using mean monthly values above the 10^{o} C (50^{o} F) threshold. A graphical method (Gladstones 1992) was used to estimate the values for the transitional months of April and October with mean temperatures <10^{o} C.

Climatic Criteria

(i) Mean growing season precipitation total from April to October (Northern Hemisphere) or October to April (Southern Hemisphere and mean value for the ripening period and harvest (the fruit maturation period) from August to September (Northern Hemisphere) or February to March (Southern Hemisphere)
(ii) Total number of days with precipitation and mean value for the ripening and harvest period
(iii) Total number of growing season bright sunshine hours and mean value for the ripening month and harvest period
(iv) The accumulated total growing degree days (base 10^{o} C) normally used as a measure of the ripening potential; values between 1100-1150 are considered acceptable for dry or semi-dry table wines (Gladstones 1992)
(v) Mean monthly growing season temperature, accumulated total growing season mean temperature and mean temperature of the ripening and harvesting period
(vi) Mean monthly growing season maximum temperature, the accumulated total growing season maximum temperature and the mean values for the ripening and harvest period
(vii) Mean monthly growing season minimum temperature, accumulated total growing season minimum temperature and mean minimum temperature of the ripening and harvest period
(viii) Mean monthly growing season diurnal temperature range, accumulated growing season total and mean values for the ripening period and harvest

Results

Statistical Analysis

The statistical values for the mean, minimum, maximum temperatures and the standard deviations were extracted from the monthly data using SPSS software. Principal Component Extraction Analysis using varimax rotation was performed on the standardized climatic variables that are related to wine quality in order to determine the similarities and differences among the regions and the significant variables that differentiate the regions one from another. Sixteen principal components were calculated for the correlation matrix, but only the first three principal components with eigen values greater than 1 were retained for analysis. The first two components explained 78% of the variance, while the third explained 10% of the variance. Factor 1, which explained 58% of the variance, contained all the correlated variables that were related to the moisture attributes of Pinot noir regions, while Factor 2 contained all the correlated variables that were related to the thermal attributes and bright sunshine hours of the regions. With the exception of the variables related to the total growing season and ripening period minimum temperatures, an inverse correlation occurred between the precipitation variables and those related thermal attributes, as shown in the biplot (Figure 1). Principal component analysis also provided a suggestion that the 26 regions clustered into three broad groups. Not shown here are broad groupings of the regions based on bivariate scatter plots of the diurnal temperature range, mean monthly temperature, the maximum temperature and precipitation variables. Aside from a few outliers, the regions have more in common with respect to variables related to growing degree days and minimum temperatures, while three distinct groups emerged respect to the precipitation and diurnal temperature range.

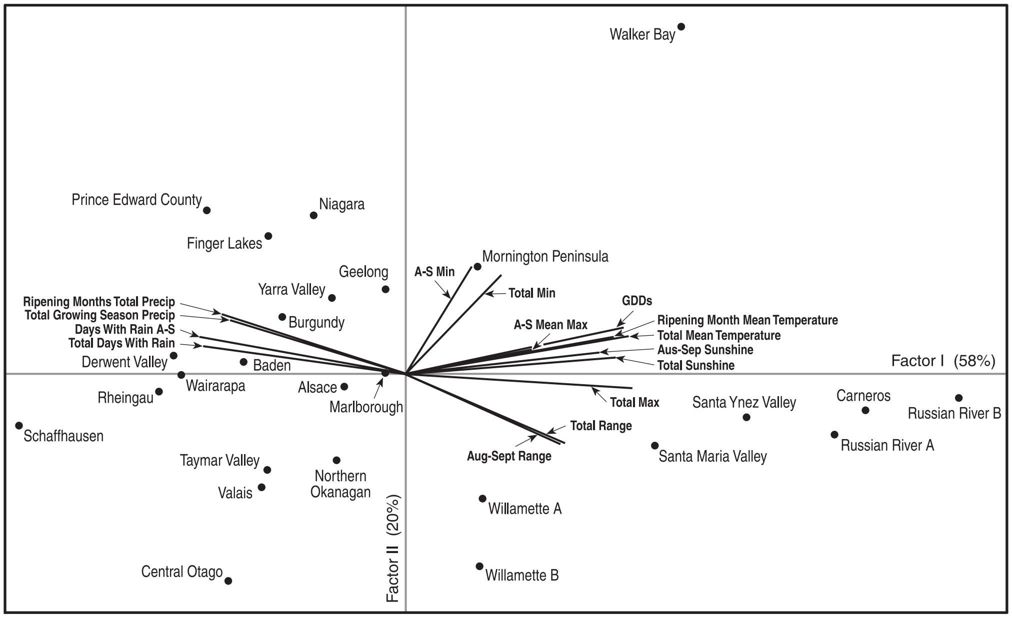

Figure 1 Principal component analysis of wine regions based on temperature and precipitation variables estimated for the growing season and the ripening period.

Precipitation Characteristics

Broadly described as cool climate regions, the wines regions growing Pinot noir fell into three broad precipitation patterns: (i) Coastal Mediterranean with >80% of the precipitation concentrated in the late fall and winter and an almost rainless summer with potential evapo-transpiration rates persistently greater than precipitation, necessitating deep soils and or supplemental irrigation, e.g. Coastal California, Willamette Valley, Chile's Casablanca Valley and the South Africa's Western Cape; (ii) moist continental climates with long cool to warm summers with precipitation fairly well distributed throughout the year and requiring supplemental irrigation in July and August only in abnormally dry years, e.g. Niagara Peninsula, and Wairarapa, Yarra Valley, Geelong, Valais, Burgundy, Baden and Rheingau and (iii) semi-dry continental climates, with low precipitation totals well distributed throughout the year but with warm to hot summers in which potential evapo-transpiration rates are persistently greater than precipitation, requiring supplemental irrigation due to pronounced rain shadow effects, e.g. the Okanagan Valley and Central Otago.

An examination of Table 1 shows that total precipitation during the ripening months range from a low of 7.4 mm for Santa Ynez to a high of 173 mm for the Finger Lakes. Three groups can be identified based on the total growing season precipitation versus the ripening period total precipitation. Group 1 with the highest precipitation values includes the Ontario wine regions, Finger Lakes, Burgundy, Schaffhausen, Pfalz, Yarra Valley and Wairarapa that are generally considered cool moist regions. Not surprisingly, this group also has the highest number of days with rainfall>1.0 mm during the ripening period. Burgundy averages 17.2 days while the values for the other regions range from 17 to 25 days. Group 2 with moderate values includes Alsace, Rheingau, Baden, Valais, Derwent Valley, Taymar Valley, Mornington Peninsula, Geelong, Marlborough, Northern Okanagan, Willamette Valley and Walker Bay. With the exception of Rheingau, these regions experience less number of days with rains that are likely to adversely affect the ripening period; average values range from 9 to 18 days. Group 3 includes Russian River, Carneros, Santa Ynez Valley and Santa Maria Valley and has less than three days with rains during the ripening period.

Growing Degree Days (GDDs) and Mean Monthly Temperature

A comparison of the total number of GDDs accumulated at the end of the growing season shows significant differences among the regions. There was also a noticeable marked variation in the seasonal distribution and during the veraison to ripening period. Total GDDs (base temperature of 10^{o} C) ranged from a low of 842 degree-days at Schaffhausen to a high of 2028 in the warmer area of the Russian River Valley. It was possible to distinguish three broad groups of regions based on the rate of warming in the spring and cooling in the fall. Group one regions has a short season that warms up slowly in the spring beginning in April, reach a peak in July and cool rapidly by the end of September (Niagara, Prince Edward County, Northern Okanagan, Finger Lakes, Willamette Valley, Burgundy, Alsace, Rheingau, Baden, Valais, Schaffhausen and Central Otago).

		Precipitation (mm)			Days with Rain			Growing Degree Days		Mean Monthly Air Temperature		Mean Monthly Maximum Temperature		Mean Monthly Minimum Temperature		Mean Monthly Temperature Range	
NORTHERN HEMISPHERE																	
Country	**Region**	**Aug - Sep**	**Apr - Oct**	**Year**	**Aug - Sep**	**Apr - Oct**	**Year**	**Aug - Sep**	**Apr - Oct**	**Aug - Sep**	**Apr - Oct**	**Aug - Sep**	**Apr - Oct**	**Aug - Sep**	**Apr - Oct**	**Aug - Sep**	**Apr - Oct**
Canada	Niagara	164	543	876	20.0	76.0	149.0	547	1392	18.7	109.0	23.7	145.0	13.7	73.0	10.1	72.8
	Prince Edward County	164	542	966	22.0	68.0	139.0	496	1230	18.1	103.0	22.2	134.0	13.8	72.0	8.4	61.8
	Northern Okanagan	69	260	415	17.0	74.0	135.0	468	1189	17.7	105.0	24.3	148.0	11.0	61.0	13.3	87.2
U.S.A	Finger Lakes	173	547	849	24.0	87.0	150.0	520	1378	18.2	107.0	23.5	144.0	12.9	70.0	10.6	73.0
	Willamette Valley A	64	302	1118	11.8	61.0	154.0	506	1227	18.9	112.0	27.1	163.0	10.7	60.0	16.3	103.8
	Willamette Valley B	48	284	1059	9.0	50.0	132.0	499	1209	18.6	108.0	26.5	159.0	9.7	55.0	16.8	104.3
	Russian River A	15	131	788	2.8	19.0	75.2	588	1689	19.9	126.0	27.8	179.0	11.6	72.0	16.2	108.0
	Russian River B	17	161	1070	2.8	20.0	73.2	683	2028	21.0	135.0	29.3	195.0	12.0	75.0	17.3	120.0
	Carneros	13	111	671	2.3	17.0	68.0	623	1812	20.0	128.0	27.8	181.0	12.1	74.0	15.7	107.0
	Santa Maria Valley	9	54	356	1.9	11.0	46.8	482	1342	17.8	113.0	23.6	156.0	12.0	70.0	11.7	86.0
	Santa Ynez Valley	7	53	403	1.3	9.8	43.6	519	1498	18.7	120.0	25.1	166.0	12.3	74.0	12.9	91.0
France	Burgundy	132	441	732	16.2	63.0	115.0	462	1164	17.6	107.0	22.9	142.0	12.3	72.0	10.6	71.0
	Alsace	102	354	496	13.5	44.0	68.0	450	1186	17.5	109.0	23.1	146.0	11.4	75.0	11.7	81.0
Germany	Rheingau	94	300	547	22.0	78.0	140.0	400	1042	16.6	103.0	21.4	134.0	11.6	64.0	9.8	64.0
	Baden	93	320	687	16.2	55.0	86.0	416	1092	16.8	104.0	21.1	136.0	12.1	71.0	9.2	66.0
Switzerland	Valais	93	320	599	14.0	55.0	83.0	383	1025	16.3	101.0	22.6	146.0	10.5	61.0	11.8	84.0
	Schaffhausen	160	551	883	20.0	73.0	125.0	334	842	15.5	94.0	21.1	131.0	10.8	63.0	10.3	74.0
SOUTHERN HEMISPHERE																	
Country	**Region**	**Feb - Mar**	**Oct - Apr**	**Year**	**Feb - Mar**	**Oct - Apr**	**Year**	**Feb - Mar**	**Oct - Apr**	**Feb - Mar**	**Oct - Apr**	**Feb - Mar**	**Oct - Apr**	**Feb - Mar**	**Oct - Apr**	**Feb - Mar**	**Oct - Apr**
South Africa	Walker Bay	83	295	667	10.0	44.0	104.0	565	1876	19.6	132.0	23.2	157.0	16.1	108.0	8.3	53.3
New Zealand	Wairarapa	143	499	979	17.0	66.0	131.0	379	1075	16.5	106.0	22.9	147.0	10.9	67.0	9.4	69.0
	Marlborough	81	359	655	10.0	46.0	87.0	428	1235	17.3	111.0	22.8	149.0	11.8	73.0	10.6	75.3
	Central Otago	62	235	370	11.0	43.0	68.0	356	1010	16.1	102.0	22.7	146.0	9.6	58.0	12.0	80.2
Tasmania	Taymar Valley	64	320	683	14.7	66.0	135.0	417	1159	15.8	99.0	22.1	141.0	9.6	57.0	9.4	67.0
	Derwent Valley	86	361	621	17.9	77.0	142.0	368	1075	16.1	104.0	20.9	136.0	11.4	71.0	8.2	55.2
Australia	Yarra Valley	132	566	1023	14.9	69.0	144.0	476	1347	18.2	115.0	25.2	160.0	11.1	70.0	9.2	65.0
	Mornington Peninsula	93	384	737	9.0	40.0	140.0	524	1466	19.2	119.0	24.6	154.0	12.6	75.0	8.7	61.2
	Geelong	80	301		13.0	59.0		474	1330	18.2	114.0	23.8	153.0	11.5	83.0	8.3	57.2
Mean		86.2	330		12.8	52.7		331	1304	17.8	111.0	23.9	152.0	11.7	70.0	11.4	78.4
Standard Deviation		50.5	152		6.7	22.3		85	285	1.4	10.2	2.2	15.5	1.3	10.1	2.9	18.1
Minimum		7	53		1.3	9.8		334	842	15.5	94.0	20.9	131.0	9.6	55.0	8.2	53.3
Maximum		173	566		24.0	87.0		683	2028	2.01	135.0	29.3	195.0	16.1	108.0	17.3	120.0

Values are based on the data for the 1971 - 2000 normal period.

Table 1 Summary statistics of temperature and precipitation variables for the growing season and the ripening period

In addition, the heat accumulation in October for the regions in this group is low and mean monthly temperature averages less than 10^{o} C. These climatic regions allow Pinot noir to ripen under relatively cool conditions and thus help to preserve the acidity and structure of the wines. Average number of heat units in September/March ripening period ranges from 150 for Rheingau to 208 for Niagara, while the mean temperature during this same period ranged from a low of 13.9^{o} C for Schaffhausen to a high of 17.4 ^{o} C for Willamette Valley. By comparison, Burgundy records 183 heat units for September and average temperature of 16.1^{o} C. Group two regions experienced rapid warming in the spring, peaked gradually in July/January followed by gradual decline into the fall but remains warm (>10^{o} C) well beyond end of March harvest dates (Wairarapa, Marlborough, Taymar Valley, Derwent Valley, Yarra Valley, Mornington Peninsula and Geelong). The average ripening period temperature in March ranges from 14.9^{o} C for the Taymar Valley to 18.9^{o} C for Mornington Peninsula, while the mean monthly heat units range from 171 for Wairarapa to 261 for the Mornington Peninsula.

Although Regions in group three (Carneros, Santa Maria Valley, Santa Ynez Valley and Walker Bay) possess a cool coastal Mediterranean type climate they experienced significant warming with temperatures rising to >10^{o} C as early as February/August, peaking in July and then cools gradually with monthly means remaining above 10^{o} C beyond harvest. In the case of Walker Bay, monthly temperatures throughout the year exceed 14^{o} C. Mean monthly temperature during the September/March ripening period ranged from 20.3^{o} C for Russian River to 17.7^{o} C for Santa Maria Valley, while the mean total of GDDs ranged from 299 GDDs for the Carneros to 233 GDDs for Santa Maria Valley. Given the very early start of the growing season, with average bud break occurring in late February, Pinot noir is most likely to reach its full ripening potential in late August or early September in all but the Santa Maria Valley whose west to east orientation allows cool prevailing winds from the Pacific to moderate daytime highs. Consequently, this region has a long cool growing season with an equitable distribution of the heat units that peaks slightly in August and then declines gradually during the August to September ripening period.

Ripening Period Mean Temperature (Véraison to Harvest Temperature)

A comparison of ripening temperatures averaged for the two months ranged from a low of 15.5 ^{o} C for Schaffhausen to a high of 21^{o} C for Carneros. The average for all regions is 17.8^{o} C, while the average for Burgundy is 17.6^{o} C. The ripening and harvest temperatures for September/March showed higher values for the coastal California, South Africa and South Eastern Australia maritime climates as compared to the cooler temperatures for the middle latitude continental type climates of the French, German, Canadian and Central Otago wine regions. Given acceptable management practices and yield control, the ripening month mean temperatures for all the regions are most likely to yield wines that are well-balanced. However, the wines coming from the warmer California, South Africa, Australian and New Zealand regions, except Central Otago, are likely to exhibit fullness of body and flavour, while the cooler regions have the potential to yield light and more delicate fruit-flavoured wines.

Ripening Period Mean Maximum Temperatures

Assuming there are no limitations to moisture uptake by the vine, exposure to moderate daytime maximum temperatures below 25^{o} C enables optimum photosynthetic and enzyme activity. On one hand, higher growth temperatures are likely to lead to moisture stress, may hasten the ripening process and lead to a degradation of the color and flavor intensity, especially during the last month and more so during the last two weeks before harvest. In temperature control experiments. The accumulation of anthocyanins is severely inhibited by high daytime temperatures >30^{o} C during the ripening period, but values are substantially higher at 20^{o} C (Kliewer 1973; Yamane et al. 2006). On the other, high daytime maximum temperatures in the pre-harvest period may be desirable for the accumulation of sugar and fruit attributes in cooler regions, provided they are followed by cooler night temperatures. A comparison of Pinot noir regions show that large differences exist among the regions with respect to the growing season maximum temperature sum and the ripening period mean value. The Russian River, Willamette and Carneros regions exhibited the highest daytime values, while a cluster of regions consisting of Schaffhausen, Baden, Derwent Valley, Rheingau and Prince Edward County on the opposite end of the spectrum showed the lowest values (Figure 3). The maximum temperature sum ranged from 195 to 131, while the ripening mean value ranged from 24 to 29**.**

Ripening Period Mean Minimum Temperatures

It has been long recognized that overnight minimum temperatures are especially influential on the grape quality and the acidity and structure of the wine in the period immediately preceding the harvest. In analyzing the importance of night time temperatures, a cool night index using the mean minimum night temperature during the ripening month (September/March) appears to provide a good assessment of the qualitative potentials of wine-growing regions, especially in relations to secondary metabolites (polyphenols and aromas) in grapes (Tonietto, 1999; Tonietto and Carbonneau, 2004). In general, ripening mean minimum temperatures seem to correlate with certain quality indices of Pinot noir, such as the colour intensity and acidity levels. While warm days equate with ripeness and color, cool nights have even a stronger influence on color (Kliewer and Torres 1972; Fregoni and Pezzutto, 2000), in addition to promoting good acidity levels and fruit flavors. Vintners' experiences seem to suggest that overly warm nights with temperatures above 16^{o} C will cause a significant degradation in acidity that result in wines that are dull and flabby, while excessively cold nights could retard physiological ripening. The ripening period mean minimum temperature ranged from 16.1^{o} C for Walker Bay to 9.6 ^{o} C for Central Otago and Derwent Valley. Notwithstanding, the exceptionally high values noted for Walker Bay and low values for a small group (Willamette B, Taymar Valley and Central Otago), Pinot noir regions generally display more similarity with respect to their night-time minimum temperature values. Several regions share values that are not significantly different from those of Burgundy with a ripening mean of 12.3^{o} C and a growing season sum of 72^{o} C (Figure 3). Moreover, a greater degree of similarity amongst the regions exists with respect to temperatures for the September/ March ripening period. With the exception of Walker Bay, values range from 8.8^{o} C to 12.9^{o} C placing these regions in the very cool and cool night categories (Tonietto and Carbonneau 2004).

Ripening Period Mean Diurnal Range

Minimal temperature variability is essential to avoiding killing frosts at the cold limit of viticulture. The best wine producing regions of Europe are all characterized by narrow ranges in diurnal temperature and day-to-day variation during the growing and ripening periods. According to Gladstones (1992), relatively constant, intermediate temperature variability during ripening specifically favours the biochemical processes of color/flavor/aroma development in the berries. The narrower the range of variation about a given mean or average ripening temperature, the greater will be the grape flavour, aroma and pigmentation. Excessive daytime temperatures may inhibit the enzyme systems, while cold nights can retard physiological ripening and quality development. Kliewer and Torres (1972) suggest a daily range that exceeds 10^{o} C will greatly inhibit colour. The diurnal range appears to be the most important distinguishing factor in the regional climates of the Pinot Noir Regions. The sum of the growing season values range from a high of 120 for the Russian River region to a low of 53^{o} C for Walker Bay, while the average value for ripening period ranges from a high of 17.3 for Russian River to a low of 8.2^{o} C for the Derwent Valley. Values for Burgundy are closer to the overall average. The high day-time maximum temperature that are characteristic of the Willamette Valley and Northern California regions necessitate a significant drop in night- time temperatures that are essential for the preservation of the phenolic compounds and acidity.

Conclusions

This study has examined the climatic differences and similarities amongst these regions based on a number of climatic criteria that are considered influential on the quality of Pinot noir wines as exemplified by the Burgundian style. The results of the analysis show that the selection of regions fall into broad groups based on various combinations of climatic criteria, but principally those that pertain to the day time maximum temperature, precipitation totals, the diurnal temperature range and the mean temperature during the ripening period. These are also the main factors that distinguish one region from another, and consequently are likely to influence the uniqueness of the wines in each region. As a whole, the regions have more in common with respect to the growing degree-days and the minimum temperature, especially in the case of the September/March ripening period minimum temperatures, as depicted graphically by the close cluster around Burgundy.

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