A climatic characterisation of the sub-Appellations in the Niagara Peninsula wine region

Caractérisation climatique des appellations secondaires dans la région vinicole de la Péninsule de Niagara

Tony B. SHAW

Department of Geography, Brock University, St. Catharines, Ontario, L2S 3A1, Canada
E-mail: tshaw@brocku.ca

Abstract: This study used climatic and topographic data to characterize the sub-appellations that have been recently delineated in the Niagara Peninsula viticulture area in order to assess their potential for ripening early to late season *Vitis vinifera* varieties. No major differences were found in the ripening-period mean temperatures, but major differences in the diurnal temperature ranges were observed.

Key words: Niagara Peninsula, climate, sub-appellations

Introduction

Appellation of origin is increasingly been used to declare the geographical environment of grapes from which wines are produced. In Ontario, Canada, wines produced in accordance with Vintners Quality Alliance (VQA) regulations have three distinct but broad appellations (Niagara Peninsula, Lake Erie North Shore and Pelee Island). Wineries may also indicate a more specific origin by using a vineyard designation, if 100% of the grapes originate from a single vineyard. Over the years, consumers have become increasingly interested in the specific origin of Niagara Peninsula wines and to learn more about their growing environments or terroirs. Wineries have responded by labelling their wines with names that reflect the local geographic features, such as the Beamsville Bench, the St. David's Bench and Ontario Lakeshore. Although commonly used on wine labels for some time, only recently have these physical features been officially delineated and recognized legally as sub-appellations (Shaw, 2004). In identifying and delineating a more specific place of origin of Niagara's wines, the viticultural area was divided up into ten geographic zones or sub-appellations. All but the Vinemount Ridge Sub-Appellation are located below the Niagara Escarpment (figure 1). Although boundaries that encompassed the attributes of the soil and topography have been more easily identified, defining the climatic boundaries and characterising the macroclimates of the sub-appellations are yet to be fully examined.

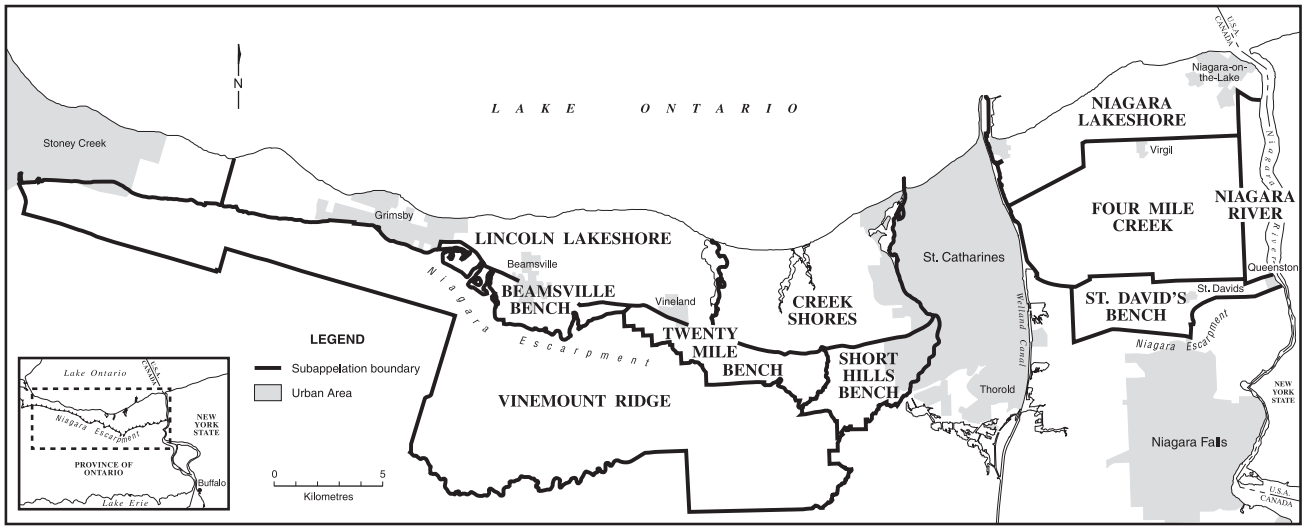

Figure 1. The Niagara Region Sub-appellations

The study used climatic and topographic data to characterize the sub-appellations that have been recently delineated in the Niagara Peninsula viticulture area and assessed their potential for ripening early to late season *Vitis vinifera* varieties. To determine whether each sub-appellation possesses a unique set of climatic characteristics that are likely to influence grape quality, the study analysed such factors as the length of the growing season with a threshold temperature >10 ^{o}C, the mean daily temperature distribution, the diurnal temperature range and fluctuation, distribution of heat units, and frequency of occurrences of maximum temperature <25 ^{o}C. Also analyzed are the mean ripening temperatures in the months of August and September. Data for the mean soluble solids expressed as ^{o}Brix along with the total titratable acid (TA) at the harvest for each sub-appellation were not yet made available at the time when this study was being prepared.

Role of Climate

Several studies have sought to establish at various scales the relationship between climate and wine quality and style (Winkler *et al*., 1974; Gladstones, 1992; Jackson and Lombard, 1993; van Leeuwen *et al*., 2004) and other complex environmental influences (soil, sub-soil, water table, geology, slope and aspect) collectively referred to as viticultural terroir on fruit and wine attributes within a vineyard site (Tesic *et al*., 2002; Vaudour, 2002). According to Becker (1985), the finest white wines are found in cooler vine-growing areas where the average temperatures during the warmest month lie between 18 to 20 ^{o}C. Another characteristic of cooler districts is that the daily temperature fluctuations are quite high during the late summer to autumn ripening period. This has been proposed as an important contributor to wine quality (Kliewer, 1973; Smart and Dry, 1989. Also correlated to wine quality are the night time temperature (Fregoni *et al*., 2002) and the mean daily temperature and growing degree days from veraison to harvest (Reynolds *et al*., 1995). In another study, photosynthetically active radiation was also found to correlate with factors such as vine budbreak, bloom date, veraison and technological and phenolic maturity (Failla *et al*., 2004).

Climate of the Niagara Viticulture Region

A distinctive feature of the Niagara viticulture region is the mild climate that favours the extensive cultivation of a wide range of grape varieties. Its location just north of the 43rd parallel would normally endow this region with a continental climate characterized by hot summers and cold winters. However, its position between the cooler waters of Lake Ontario to the north and eastern end of Lake Erie to the south exposes the Region to strong lake breezes that help to cool the summer temperatures. Continental Polar air masses that frequently invade the Niagara Region from the north in the winter are moderated by the relatively warm surface of Lake Ontario before arriving on its south shore. In the spring and summer, the prevailing southwesterly winds traverse the full length of Lake Erie and moderate temperatures in the southern half of the region.

The spring weather is highly variable and very turbulent, with high wind speeds, frequent cyclonic systems and alternating warm and cold fronts, marking the transition from winter to spring. Cold spells interspersed with warm spells are especially common in the months of March and April as migratory cyclones move through the Region in response to large-scale temperature differences between the tropical and polar regions. Occasionally, high pressure systems accompanied by clear, calm conditions and the possibility of radiation frosts are common in late April and early May. Consequently, these are often the most dangerous periods for the dormant buds of early season *Vitis vinifera* vines as they are likely to open in response to warm temperatures after having completed their endo-dormancy or rest period.

Summer weather is dominated by frequent high pressure systems and maritime tropical air masses from the Gulf of Mexico bringing warm sunny days but often humid conditions. Isolated convective systems caused by strong solar heating of the land mass produce most of the precipitation in the months of July and August. Occasionally, cold fronts move through the area causing heavy and widespread precipitation, but leave behind much needed moisture for the vineyards. The cool, refreshing dry air keeps humidity levels low and fungal diseases in check As the warmest month, July's mean daily temperatures range from 20.9 ^{o}C to 22.2 ^{o}C and the mean daily maximum vary between 25 ^{o}C and 27 ^{o}C over the region. The area has an average of 1,400 GDDs during the April to October growing season and frost-free period of 195 days. Total annual precipitation amounts to 887 mm with 536 mm falling during the growing season.

Materials and Methods

The data base comprised daily heat units, mean, maximum and minimum temperatures and the diurnal temperature range for each sub-appellation. The length of the record extends from 1995 to 2005. Each sub-appellation has at least one monitoring site that is considered representative of the mesoclimate of the sub-appellation in which it is located. The temperature sensors are located in the vine canopy and in a few cases about two metres from the nearest vine row. The data are archived on an hourly basis from which the statistics for various climatic parameters are compiled. The viticulture area has one monitoring site with daily values extending over thirty years.

Growing Season Temperatures

Ripening Mean Temperatures

The late veraison to harvest period for most cool climate French vinifera varieties normally occurs during the months of August and September. However, this period may occur much earlier in exceptionally warm years especially for early season varieties such as Chardonnay and Pinot noir. In a cool macroclimate, warmer mesoclimate temperatures during the ripening period invariably result in grapes with a higher soluble solids. Warm temperatures will also accelerate growth and ripening and could produce less flavour and aroma constituents. In a cooler mesoclimate total volatile terpenes increase more slowly, but may finally reach higher concentrations as compared to a warm mesoclimate. Warmer mesoclimates are also likely to produce wines with a high phenolic content. According to Gladstone (1992) grapes with ripening-month mean temperature below 15 ^{o}C reach ripeness, if they do so at all, with high acid levels. Ripening-period mean temperatures between 15 and 21 ^{o}C provide mostly well-balanced musts for dry table wines. Wines from the cooler end of the range tend towards lightness of body, freshness and delicacy; and those from the warmer end towards fullness of body and flavour. Table 1 shows the results of the analysis of the mean monthly temperatures for the months of August and September based on eleven years of data. Also included are results of an unusually warm year and a cool year. There are no significant differences in the mean values, except for those of the Vinemount Ridge Sub-Appellation located on top of the Niagara Escarpment. These sub-appellations can be characterized as having warm mesoclimates in so far as growing early to mid season varieties such as Chardonnay, Pinot noir, Pinot gris and Gewürztraminer. The varieties are most likely to reach their ripening potential in most years before ripening temperature drop below 15 ^{o}C by mid-October (figure 2). Grapes are likely to ripen with high acidity and low SS in a cool year such as 2003 when ripening-period mean temperatures fell below 20 ^{o}C.

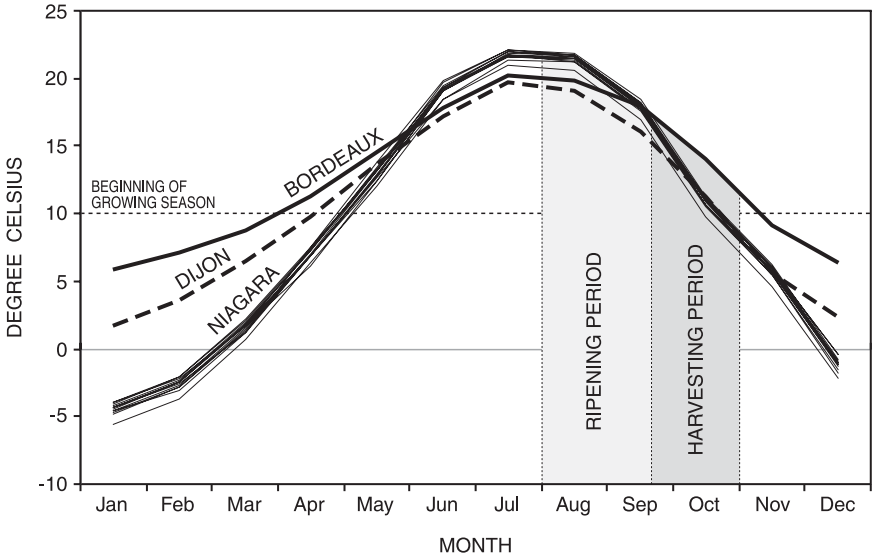

Figure 2. Distribution of Mean Daily Temperatures

In exceptionally warm years such as 1998, 2002 and 2005 the late season varieties such as Merlot, Cabernet-Sauvignon and Riesling would likely reach their full ripening potential. However, in most years these red varieties are likely to ripen at temperatures just below 15 ^{o}C. During the eleven years, the ripening-period mean temperatures exceeded 15 ^{o}C, but remained below 21 ^{o}C.

Table 1 - Ripening period mean temperatures and heat units

Months	St. David's Bench	Four Mile Creek	Niagara River	Niagara Lakeshore	Creek Shores	Short Hills Bench	Twenty Mile Bench	Beamsville Bench	Lincoln Lake shore	Vinemont Ridge
Aug.	21.8 (365)	21.4 (351)	21.6 (359)	21.3 (355)	21.4 (355)	21.7 (341)	21.0 (341)	21.3 (355)	21.2 (334)	20.4 (325)
Sept.	18.2 (248)	17.7 (230)	17.9 (239)	17.5 (229)	17.6 (232)	17.2 (220)	17.2 (218)	17.7 (233)	17.3 (223)	16.6 (200)
Oct.	11.1 (77)	11.0 (71)	11.3 (78)	11.2 (70)	11.0 (66)	10.7 (65)	10.7 (66)	10.7 (66)	10.7 (66)	9.9 (57)
*Mean T	20.0	19.6	19.8	19.4	19.5	19.1	19.1	19.4	19.2	18.5
1998										
Aug.	22.3 (385)	22.2 (380	22.4 (384)	21.9 (370)	22.0 (372)	21.8 (365)	21.7 (364)	22.1 (374)	21.6 (360)	21.0 (340)
Sept	18.7 (257)	18.4 (271)	19.1 (272)	18.9 (266)	18.7 (265)	18.3 (249)	18.4 (250)	19.1 (264)	19.4 (262)	18.7 (233)
Oct	11.1 (63)	10.7 (68)	10.9 (76)	12.0 (74)	11.1 (68)	11.2 (62)	11.4 (62)	11.5 (64)	11.9 (262)	11.2 (49)
*Mean T	20.5	20.3	20.8	20.4	20.4	20.1	20.4	20.6	20.5	19.4
2003										
	21.9 (368)	21.8 (366)	22.0 (371)	21.7 (363)	22.1 (342)	21.5 (356)	21.4 (352)	21.7 (364)	21.9 (368)	20.9 (366)
Sept.	17.3 (221)	17.3 (218)	17.6 (216)	17.1(212)	16.6 (163)	16.8 (206)	16.8 (201)	16.9 (208)	16.7 (202)	15.9 (179)
Oct	10.1 (52)	9.8 (45)	10.2 (43)	9.6 (39)	9.3 (43)	9.4 (49)	9.6 (42)	9.4 (42)	9.5 (41)	8.5 (33)
*Mean T	19.6	19.5	19.8	19.4	19.4	19.2	19.1	19.3	19.3	18.4

*Mean ripening period temperatures for August and September; Figures in bracket are monthly growing degree days

Diurnal Temperature Variability

Apart from the risks of frost damage during the late spring and early fall, an important criterion in determining the climatic suitability of sites and the potential wine quality relates to the temperature variability during the growing season, but especially during the ripening period. 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 temperatures variability during the ripening specifically favour the biochemical processes of colour/flavour/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. Figure 2 shows the diurnal temperature range for the Niagara sub-appellations and comparative values for Bordeaux and Dijon. The diurnal range appears to be the most important distinguishing factor in the mesoclimates of Niagara's sub-appellations. Mean growing season values range from 10.3 ^{o} C to 12.6^{o} C, while values for individual months range from 9.4 ^{o}C to 13.7 ^{o}C with the exception of the Niagara River (NR) and the Shorthill Bench (SHB) the ripening month values are generally considered moderate. The Creek Shores (CS), Beamsville Bench (BB), Lincoln Lake Shore (LLS) and Vinemount Ridge (VR) are the generally experience the lowest diurnal range due to their higher elevation and close proximity to Lake Ontario. Values are not significantly different from those of Bordeaux and Dijon.

Moreover, a characteristic feature of the regional climate is the day-to-day variation in temperature especially in September and October caused by large scale weather systems with their associated warm and cold fronts (figure 4). These variations are more pronounced in the sub-appellations that are located at greater distances from Lake Ontario, such as the St. David's Bench and the Niagara River and Vinemount Ridge Sub-Appellations. The implications for wine quality are yet to be fully explored.

Table 2 - Diurnal temperature range

	NR	FM	NL	DB	SHB	CS	BB	TMB	LLS	VR	Bordeaux	Dijon
A	9.4	11.3	10.3	10.1	11.1	11.2	10.1	10	10.6	11.5	10	9.7
M	12.4	13.1	12	12.1	12.6	11.6	10.9	10.8	11.6	12.2	10.2	10
J	13	13.3	12	12	12.5	13	10.8	10.5	11.9	12.1	10.8	10.4
J	13.4	13.5	12.3	12.2	13.6	12.1	10.3	10.6	11.3	12.8	11.6	11.2
A	**12.1**	**12.4**	**10.8**	**11.7**	**13.4**	**10.9**	**10.4**	**10.1**	**12.1**	**12.3**	**11.4**	**10.8**
S	**13.5**	**13.2**	**11.8**	**12.5**	**13.7**	**11.7**	**10.2**	**10.2**	**10.6**	**11.7**	**11.5**	**10.4**
O	**11.3**	**11.3**	**10.7**	**10.4**	**10.5**	**9.9**	**9.2**	**9.1**	**10.4**	**10.7**	**9.8**	**8.3**
Mean	**12.2**	**12.6**	**11.4**	**11.6**	**12.5**	**11.5**	**10.3**	**10.2**	**11.2**	**11.9**	**10.8**	**10.1**

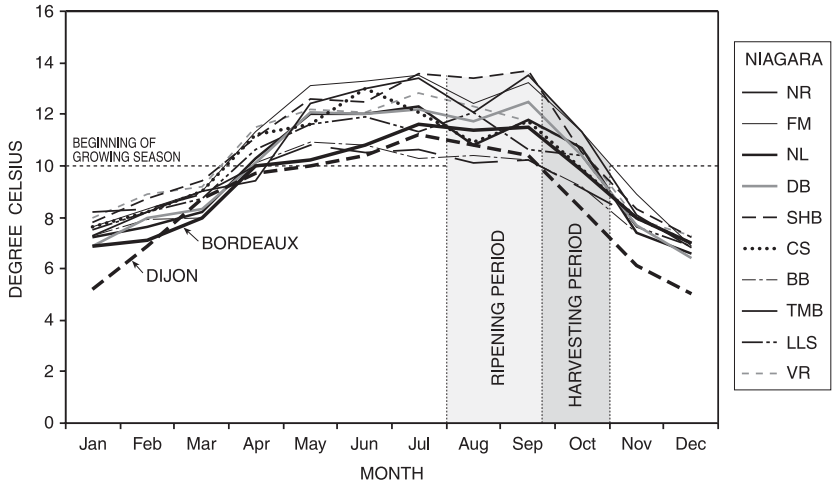

Figure 3. Mean Daily Temperature Range

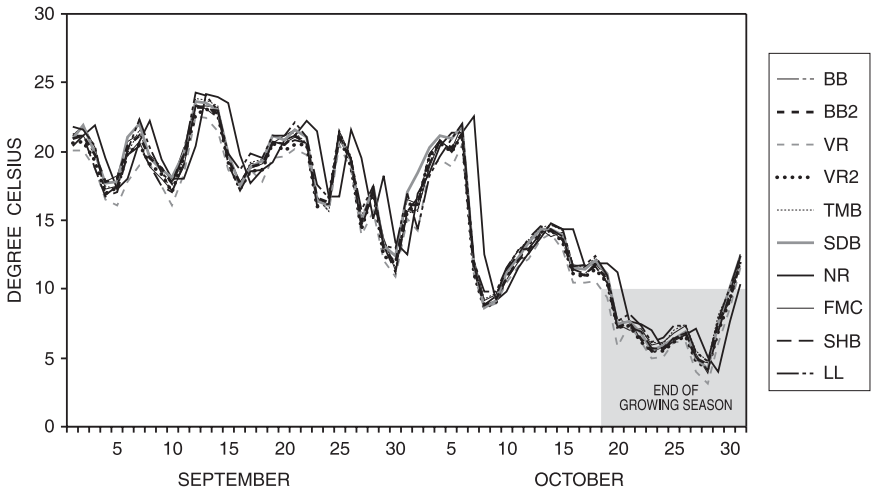

Figure 4. Decline in Growing Season

Distribution of Heat Units

Average heat summation for the sub-appellations ranges from 1367 to 1470 GDDs allowing early and mid season varieties to achieve their full ripening potential. These values are unadjusted for temperatures exceeding a daily average of 25^{o} C when photosynthesis is likely to decline. The long-term accumulated value for the main viticulture area below the Niagara Escarpment is 1392 GDDs. Pronounced differences in monthly values are most noticeable in the warmer months of July and August. The lake breeze is the strongest during the warmest part of the summer when the largest temperature differentials exist between the cooler lake surface and the warmer land area. Moreover, frequent high pressures systems characterised by clear, calm conditions are highly conducive to the development of lake breeze circulations. Sub-Appellations such as the Niagara River, St. Davis's Bench, Four Mile Creek and Short Hill Bench are likely to experience

warmer daytime temperatures due mainly to their greater distances from Lake Ontario. The sub-appellations (Niagara Lakeshore and Lincoln Lakeshore) that are located closer to Lake Ontario warm up gradually in the month of April; and experience a gradual rise in heat units as the growing season progresses. In general, heat units peak in July but following the ripening-period from August to September the values decline sharply. October accounts for less than 5% of the growing season total. With the exception of Merlot and Pinot Noir, the ripening of Bordeaux red varieties, especially Cabernet-Sauvignon is likely to be problematic in spite of the significantly high number of biologically effective day degrees received over the region as a whole and the individual sub-appellations.

Conclusions

This study has provided a cursory analysis of the climatic attributes with the objective of providing a climatic characterisation the Niagara Peninsula wine sub-appellations. It utilized daily values of temperature obtained at eleven representative locations within each sub-appellation over an 11-year period together with long-term data extending over a 30-year period. The study examined growing season temperature and biologically effective day degrees especially during the ripening and harvest periods. The analysis indicates only minor differences observed in the mean ripening-period temperatures and heat units between the sub-appellations. However, distance from Lake Ontario and elevation appears to have a significant influence on the diurnal temperature range observed for each sub-appellation.

References

Becker N., 1985. Site Selection for Viticulture in Cooler Climates Using Local Climatic Information, *In: Proceedings of the International Symposium on Cool Climate Viticulture and Enology*. D. A. Heatherbell, P.B. Lombard, F.W. Bodyfelt and S.F. Price, pp.20-30. Eugene, OR. Oregon State University Experiment Station Technical Report, No. 7628.

Fregoni M., Biondi S. F and Pezzuto S. The bioclimatic index by Fregoni applied to Brunello of Montalcino, *Progrès Agricole et Viticole,* Montpellier, 119, 257-259.

Gladstones J., 1992. *Viticulture and Environment*, Adelaide, Winetitles.

Jackson D.I and Lombard P.B., 1993. Environmental and Management Practices Affecting Grape Composition and Wine Quality : A Review. *American Journal of Enology and Viticulture*, **44**, 4, 409-429.

Kliewer W.M. 1973. Berry composition of *Vitis vinifera* cultivars as influenced by photo-and-nycto-temperatures during maturation, *Am. J. Soc. Hortic. Sci.*, **98**, 153-159.

Kliewer W.M and Torres R.E., 1972. Effect of controlled day and night temperatures on grape coloration. *American Journal of Enology and Viticulture*, **23**, 71-77.

Failla O., Mariani L., Brancadoro L., Minelli, R. Scienza, A., Murada G and Mancini S., 2004. Spatial Distribution of Solar Radiation and Its Effects on Vine Phenology and Grape Ripening in an Alpine Environment, *American Journal of Enology and Viticulture*, **55**, p.128.

Reynolds A. G., Wardle D.A., Hall J.W. and Dever M. J. 1995. Fruit maturation of four *Vitis vinifera* cultivars in response to vineyard location and basal leaf removal. *American Journal of Enology and Viticulture*, **46**, 542-558.

Smart R.E. and Dry P.R. 1980. A Climatic classification for Australian viticultural regions, *Australian Grapegrower and Winemaker*, **17**, 8-16.

Shaw A.B., 2004. Delimiting Sub-Appellations within the Niagara Peninsula and Lake Erie North Shore.
Viticultural Areas, *Report prepared on behalf of the Vintners Quality Alliance Ontario*, pp. 55.

Tesic D., Wolley D.J., Hewett E.W. and Martin D., 2002. Environmental effects on cv Cabernet-Sauvignon *(Vitis vinifera* L) grown inHawk's Bay, New Zealand: Phenology and Characterization of Viticultural Environments, *Australian Journal of Graape and Wine Research*, **8**, 15-26.

Van Leeuwen C, Friant P and Chone X, Trégoat O, Koundouras S and Dubourdieu D., 2004. Influence of Climate, Soil, and Cultivar on Terroir, *American Journal of Enology and Viticulture*, **55**, 3, 207-217.

Vaudour E., 2002. The quality of grapes and wine in relation to geography: notions of terroir at various scales. *Journal of Wine Research*, **13**, 117-141.

Winkler A.J., Cook J.A., Kliewer W.M. and Lider L.A., 1974. *General Viticulture*, University of California Press, Berkeley.