Journal of Food Science and Engineering 2 (2012) 719-726

Effect of Leaf Removal on Grapes of Cabernet Sauvignon and Sangiovese Cultivated in Different Italian Environments

Leonardo Valenti[1], Isabella Ghiglieno[1] and Fulvio Mattivi[2]

1. Department of Agricultural and Environmental Sciences, Faculty of Agriculture, University of Milan, Milano 20133, Italy

2. Edmund Mach Foundation, Centre for Research and Innovation, San Michele all'Adige, Trento 38010, Italy

Received: September 6, 2012 / Published: December 20, 2012.

Abstract: Leaf removal is a farming practice that can affect must and grape quality; it is closely related to the meteorological conditions of the year and the climate of the area. The present study aims to analyse the effects of different types of defoliation, all conducted at veraison and removing 5-6 basal leaves. The trial provided four tests: leaf removal only on the east side, only on the west side, total defoliation (both sides), and a non-defoliated treatment (control test). Two different cultivars, the Sangiovese and the Cabernet Sauvignon, were studied in five different Italian environments: Puegnago (BS), Scansano (GR), Bolgheri (LI), Brisighella (RA), and Montefalco (PG). The trial was repeated four times, once per year for the successive years 2007, 2008, 2009, and 2010. The years differed mainly with regard to the total rainfall; because of the variability of the years, different results, both for the same cultivar and between the cultivars, were observed. The differences existing between these two varieties and among the different environments led to different reactions to defoliation, especially concerning the analytical parameters of musts and grapes.

Key words: Leaf removal, radiation, bunch weight, sugar concentration, anthocyanic content.

1. Introduction

The farming practice of defoliation can have multiple effects on plant physiology, in fact, it can lead to important changes in the microclimate around the bunches [1], with implications for grape health and quality [2, 3]. The partial removal of the canopy can also cause variations in photosynthetic efficiency, even if, working along the bunch zone, older leaves that are less photosynthetically active are removed [4]. It is well known that the effects resulting from this practice may determine the period of technological maturity of the grapes [5] and the polyphenolic content of skins and seeds [6], even if there is not a unique evaluation, especially with regard to the effects on polyphenolic content. Before choosing this kind of practice, a preliminary environmental survey is necessary, in particular because of its close relationship to climatic conditions such as radiation, temperature, and relative humidity [7, 8].

The present study aims to evaluate the effect of different leaf removal techniques (East, West, total leaf removal) in five different Italian wine areas (Brisighella, Montefalco, Puegnago, Scansano Bolgheri). To these end two different red grape cultivars, the Cabernet Sauvignon and the Sangiovese, were observed during four years (2007-2010) in each environment.

2. Materials and Methods

2.1 Materials and Locations

The study considered two red grape cultivars that differed in yield and grape quality: the Sangiovese and the Cabernet Sauvignon. Five environments, varying in geography, climate, and altitude, were also compared (Fig. 1).

Corresponding author: Leonardo Valenti, researcher, research field: viticulture. E-mail: leonardo.valenti@unimi.it.

Fig. 1 Location of the five places considered in the present study: letters a, b, c, d, e identify the location of the different sites.

The summary sketch of the climatic features of the 5 selected sites is based on the Pinna classification criteria [9] that follow the Koeppen approach [10, 11].

a) Puegnago sul Garda (BS) shows a temperate, subcontinental climate with a yearly mean temperature of 12.4 °C and a yearly mean precipitation of 880 mm/y. The precipitation regime is characterised by two maxima (May and October) and two minima (the main in winter and the secondary in summer). The proximity to the main pre-alpine lake (Garda Lake) gives rise to an effective mitigation of the continentality typical of the Po River Plain. The vineyards considered for data collection (Sangiovese and Cabernet Sauvignon) belong to "Azienda Agricola San Giovanni" (240 m asl.). In both vineyards, the applied training system is a cordon system, planted 0.9 m on the row with a grass-covered distance of 2.5 m between rows.

b) In Scansano (GR), the Mediterranean effect is attenuated by the distance from the sea and the relief. The climate of this location is classified as temperate sublitoranean, with a yearly mean temperature of 14.2 °C and a mean total precipitation of 793 mm. The precipitation regime presents two maxima in spring and autumn, respectively, and a main minimum in summer. The vineyard (Sangiovese) is located in "Azienda Poderi di Ghiaccioforte" (172 m asl.). In this vineyard, the applied training system is a cordon system, planted 0.8 m on the row with a grass-covered distance of 2,4 between rows.

c) Bolgheri (LI) has a warm temperate climate with a yearly mean temperature of 14.8 °C and a yearly mean precipitation of 740 mm. The precipitation regime presents two maxima in spring and autumn, respectively, and a rather pronounced summer minimum with significant drought conditions that are a clear symptom of mediterraneity. The vineyard (Cabernet Sauvignon) is located in "Azienda Tenuta Caccia al Piano" (40 m asl). In this vineyard, the applied training system is a bilateral cordon system, planted 0.75 m on the row with 1.3 m of tilled soil between rows.

d) Brisighella (RA) shows a temperate sublitoranean climate, with a yearly mean temperature of 14.0 °C and a yearly mean precipitation of 822 mm. The precipitaton regime shows two maxima in spring and autumn, respectively, and a main minimum that drops in summer. The vineyards studied (Sangiovese and Cabernet Sauvignon) belong to "Azienda F.lli Ronchi" (115 m asl.). In both vineyards, the applied training system is a cordon system, planted 1 m on the row with a grass-covered distance of 3.5 m between rows.

e) The climate of Montefalco (PG) is classified as temperate sublitoranean with a yearly mean temperature of 14.3 °C and a yearly mean precipitation of 822 mm. The precipitation regime presents two maxima in spring and autumn, respectively, and the main minimum in summer. The vineyards (Sangiovese and Cabernet Sauvingon) are located in "Azienda Agricola Arnaldo Caprai" (220 m asl.). In this vineyard, the applied training system is a cordon system, planted 0.75 m on the row with a grass-covered distance of 2.2 m between rows.

Meteorological data was derived from stations located in different places: Puegnago (Puegnago weather station, data provided from "Centro Vitivinicolo di Brescia", altitude 142 m asl., 50°48′35″N, 16°19′45″E); Scansano (Magliano weather station, data provided from "Arsia Toscana", Colle del Lupo, altitude 190 m asl., 42°61′52″N, 11°32′58″E); Bolgheri (Donoratico weather station, data provided from "Arsia Toscana",

altitude 15 m asl., 43°22′36″N, 47°59′58″E); Brisighella (Monte Lodolone weather station, data provided from "ARPA Cesena", altitude 250 m asl., 44°11′43″N, 11°52′26″E); and Montefalco (Azienda Agricola Arnaldo Caprai weather station, altitude 231 m asl., 42°55′91″N, 12°38′72″E).

2.2 Methods

The trial was carried out during four consecutive years (2007 through 2010) in all environments with the exception of Puegnago, where the trial was not conducted for the year 2010. In that year, according to the plan, the tests were conducted at veraison, but at harvest it was impossible to collect data because of phytosanitary problems. Four tests were set for both cultivars: leaf removal only on the east side (L.R. East), only on the west side (L.R. West), total defoliation (both sides: L.R. Tot), and non-defoliated treatment (NO L.R.: control test). This experimental plan was chosen because of the North-South orientation of the rows in all the vineyards. Moreover, in this way, it was quite easy for the wineries to implement the plan. The defoliation was performed at veraison (about 10% of coloured berries at the beginning of veraison) on plots of 30 plants per test, of which afterwards 10 were chosen for the data collection, which involved measuring and calculating the number of shoots per vine, the number of bunches per vine, the yield per vine (kg), the average bunch weight (g), the potential fertility, and analytical parameters such as sugar content (°Brix), titratable acidity (g/L), and pH. The content in extractable polyphenols and anthocyanins was also analysed for each test [12] in conjunction with the measure of the average berry weight (g).

2.3 Data Analysis

Data obtained from agronomical surveys such as yield per vine (kg), average bunch weight (g), potential fertility and berry weight (g), as well as those from analytical analysis (sugar content, titratable acidity, and pH), were processed using the SPSS software. In particular, the statistical analysis provided for the use of ANOVA and Duncan tests to identify the real differences between tests.

Polyphenolic and anthocyanic data were not statistically processed, because the method used [12] does not provide sufficient repetitions. In this case, differences between the averages of treatments and vintages were discussed.

3. Results and Discussion

3.1 Year and Environmental Weather Characterization

In general, the four years under consideration (2007-2010) were characterized by different weather conditions, especially with regard to rainfall. The years 2008 and 2010 were rainier than 2007 and 2009, although the growing season in 2008 in Brisighella and Magliano showed comparable behaviour for this parameter to the years 2007 and 2009. Puegnago recorded higher values of annual and growing season rainfall than the other places in all years (2007-2009). With regard to annual average temperatures, there were no significant differences among the places, whereas, the weather stations at both Magliano and Donoratico showed higher temperatures than the others for the growing seasons of 2009 and 2010. The Magliano weather station recorded higher annual minimum temperatures, even if this difference tended to vanish, considering only the growing season.

3.2 General Results Obtained for Sangiovese

First taking into account the average results obtained in the five places during the four years of observation, vegetation and production did not show significant differences either in fertility potential or yield per plant (data not shown); therefore, leaf removal does not seem to have influenced these parameters, whereas there are significant differences for the average bunch weight. The control test presented an average bunch weight significantly higher than the east-side leaf removal test. This difference is not associated with a different average berry weight, a parameter for which the differences were not significant among the tests (Fig. 2).

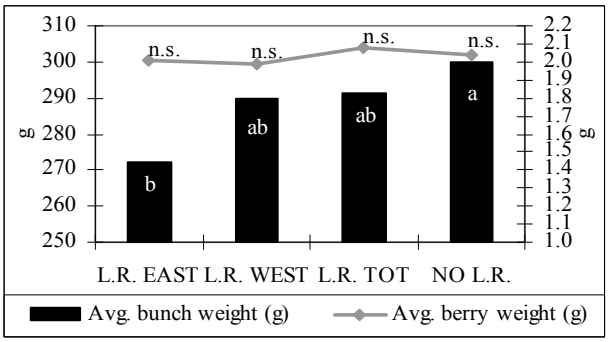

Fig. 2 Results obtained in terms of bunch and berry weight on average of the places and of the years (2007-2008-2009-2010) for the cultivar Sangiovese (Duncan test for significance at $P \leq 0.05$).

Defoliation, especially if carried out on the east side, seems to have led to a lower average bunch weight because of fewer berries per cluster. This particular behaviour reinforces previous studies that have shown that grapevines, subjected to stress caused by previous leaf removal, could present some repercussions the following year on vegetative growth, which may lead to the formation of a limited inflorescence number per shoot and a lower flower number per inflorescence [13]. With regard to the analytical parameters, differences were recorded in sugar content at harvest; however, pH and acidity did not show valid statistical differences. The east-side leaf removal showed a higher sugar content (24.1 °Brix). This particular behaviour could not be explained by a lower average berry weight. In fact, this parameter, as shown before, did not present differences between tests, while the good sugar concentration observed for the east-side defoliation treatment can be related to the combination of the lower average bunch weight and the low level of alteration of the photosynthetic activity of the plant. Other studies [14] have shown how defoliation can not affect the photosynthetic activity if the leaf removal level allows the plant to maintain the necessary level of photosynthetically active leaves. In this sense, the defoliation on the east side creates the best microclimate at the canopy level, maintaining a quota of basal leaves, but ameliorating the exposure of the grapes.

Considering extractable polyphenols and anthocyanins in general, the defoliation showed, for this cultivar, higher anthocyanin contents than the control test, in accordance with previous studies that showed how defoliation tended to increase anthocyanic concentration [15-17].

3.3 Annual Behaviour of Sangiovese

There were no significant differences in terms of potential fertility, whereas the average yield per plant showed interesting results with respect to the average bunch weight. In 2008 and 2009, the control test was more productive and recorded a higher average bunch weight (Fig. 3). This fact, as explained before, is probably due to a higher number of flowers per inflorescence, because there were no differences in average berry weight.

In 2007 and 2010, this behaviour was not observed. In the first case (the first year of the trial), the vines were not affected by the treatment applied in the previous year, whereas in 2010, the particularly rainy conditions could have affected the result. With regard to the must quality, the sugar content did not differ significantly in the years 2009 and 2010, whereas in 2007 and 2008, defoliation showed higher values. This discontinuous behaviour between years emphasizes the relationship between defoliation and climatic conditions of the year [7, 8] which obliges a rational choice of the type of intervention variable from year to year.

In general, the pH and titratable acidity did not record valid differences (data not shown).

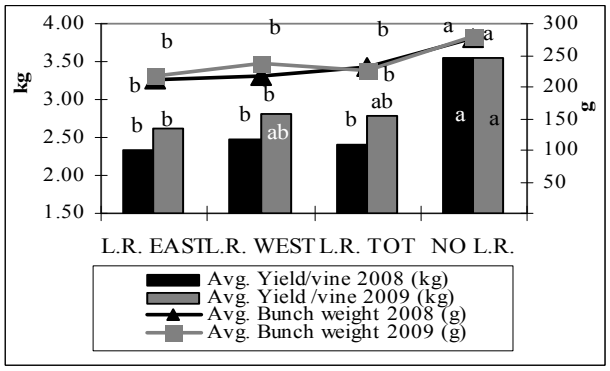

Fig. 3 Yield per plant and average bunch weight observed for the years 2008 and 2009 for the cultivar Sangiovese (Duncan test for significance at $P \leq 0.05$).

Also the polyphenolic content did not differ significantly among the tests, whereas, higher anthocyanin content was observed in the defoliated tests compared to the control test, as shown in the evaluation of data from the average of the years.

3.4 Sangiovese Behaviour in Different Environments

Considering the results obtained in different places within the four years of observation (three in Puegnago), no significant differences were observed in the average berry weight, although the control showed a berry weight higher than or equal to the other tests (data not shown). In Puegnago and Scansano, this test also presented the highest average bunch weight. In the Scansano vineyard, this test recorded significantly higher production and a higher average bunch weight compared to defoliated tests (2.8 kg and 278 g, compared to 2.5 kg and 250 g, on average). In the vineyards of Montefalco and Brisighella, there were no significant differences in either the average weight of the bunch or the yield per plant.

The grape sugar content did not register significant differences in the vineyards of Montefalco and Scansano, whereas in Brisighella and Puegnago, the east-side leaf removal showed significantly higher values ($P \leq 0.05$). The significant difference observed in the average of the years is then mainly caused by the results obtained from these two sites which emphasize the better performance of east-side leaf defoliation in sugar accumulation.

Defoliation did not show significant results with regard to the acidity level, except for Brisighella, where the highest acidity was recorded for the control test, in agreement with what other authors observed. There was a lower activity of enzymes responsible for the degradation in acidity in vines that were not defoliated [2, 18]. Concerning the pH, there were no interesting differences, whereas, the extractable anthocyanin content showed higher values for the total defoliated test (Puegnago, Montefalco, and Scansano). In the Brisighella vineyard, the highest content for this parameter was observed for the east-side leaf removal (data not shown). The positive influence of defoliation on the anthocyanic content seems, therefore, to be confirmed by the results obtained at all of the four sites under observation.

3.5 General Results Obtained for Cabernet Sauvignon

For this cultivar, there were no significant differences regarding the vegetative-productive parameters, in terms of potential fertility or for average bunch and berry weight. This behaviour could be associated with the characteristics of this cultivar, which presents a thick and consistent skin [19] that leads to less sensitivity to the effects of solar radiation. From this point of view, this cultivar may be more flexible to these kinds of farming practices, showing qualitative effects without changes in the yield level.

The sugar content and pH in the musts at harvest showed higher values for the total defoliated test (24.4 °Brix and pH 3.6); this further strengthens the relationship between defoliation and increases in sugar concentration observed for the previous cultivar, while the increases of pH level could be related to the decrease in the acidity level already observed in the defoliation experimental trial [20]. The east-side leaf removal and the control test recorded lower pH and higher acidity (Fig. 4). The different behaviour showed by the east-side defoliation compared to other defoliation, in terms of pH and acidity of musts, can be related to the different levels of irradiation as described in previous studies [21].

With regard to the anthocyanin and polyphenol contents, the non-defoliated treatment seems to result in better performances (Fig. 5). This result seems in contrast to data obtained from the cultivar Sangiovese, emphasizing again the differences between these two cultivars, particularly in terms of skin thickness.

3.6 Annual Behaviour of Cabernet Sauvignon

There were no significant differences in yield per plant or for average bunch weight, in accordance with the previous observation made for the annual average. Regarding the analytical parameters on musts at vintage,

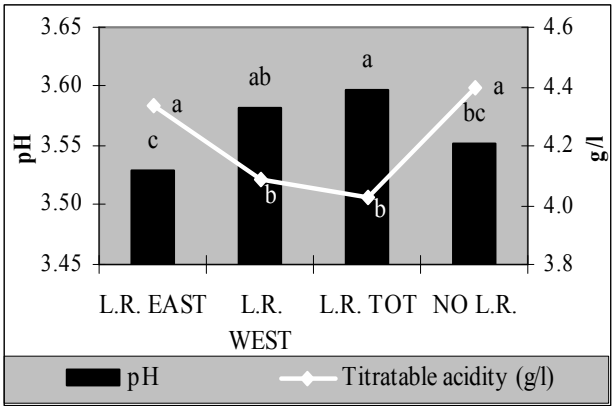

Fig. 4 Analytical parameters (pH and acidity) for the cultivar Cabernet Sauvignon, averaged over four years (2007-2010) and for the locations under observation (Duncan test for significance at $P \leq 0.05$).

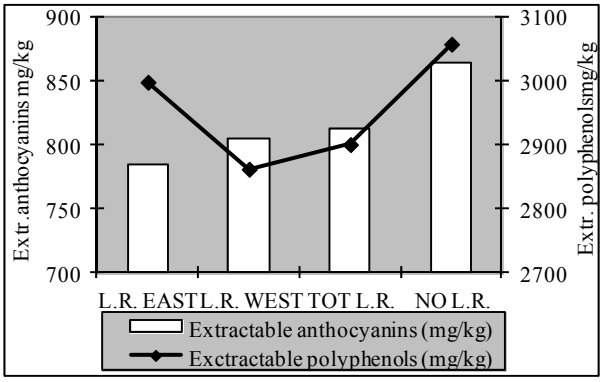

Fig. 5 Polyphenol and anthocyanin contents for Cabernet Sauvignon, averaged over four years (2007-2010) and for the environments under consideration.

the behaviour of sugar content observed for the average of the years was mainly determined by the significance recorded in 2007, in which the total defoliated test showed the highest level (data not shown); this year led to greater differences, probably in relation to its particularly low rainfall level. The control test and the east-side defoliation showed similar behaviour observed for the annual average. In fact, they exhibited higher acidity levels (this difference is only significant for 2007 and 2010) and lower pH levels than the other ones (data not shown); a lower temperature inside the canopy leads to a greater preservation of the acidity level, as shown in previous studies [22].

Regarding the content of anthocyanins, the behaviour changed from year to year, whereas the value of total extractable polyphenol was in general higher for the test without leaf removal (data not shown).

3.7 Cabernet Sauvignon Behaviour in Different Environments

With regard to the potential fertility, there were no significant differences, whereas the control test recorded higher yield per vine compared to the total defoliated test, although significant values were observed only for Brisighella and Montefalco. These sites showed also the highest average bunch weight for the non-defoliated test, even though the berry weight is similar to the others. For this parameter the Cabernet Sauvignon grown in Brisighella and Montefalco seems therefore more similar to the Sangiovese cultivated in Puegnago and Scansano.

The behaviour of the sugar content and the concentration of extractable polyphenols and anthocyanins were similar for Bolgheri and Brisighella; in both places in fact the control test showed the highest contents for all the three parameters, with statistical significance observed for the concentration of sugar (data not shown). Conversely, Montefalco and Puegnago showed lower sugar content in the control test that recorded, together with the east-side leaf removal, the highest acidic level at all places apart from Bolgheri, where east and west-side defoliation had higher values (Fig. 6).

4. Conclusions

In conclusion, important differences were observed between Cabernet Sauvignon and Sangiovese; in fact, the second cultivar seems to have been positively affected by the east-side defoliation regarding its sugar content, whereas the leaf removal showed in general better performances on anthocyanin and polyphenol content. For Cabernet Sauvignon, the control test had in general recorded better results with regard to the good maintenance of anthocyanin concentration. The close relationship among this agronomic practice, the weather, and the environment has been also revealed; in fact, the case of Sangiovese showed how a very rainy vintage such as in 2010 minimised differences among

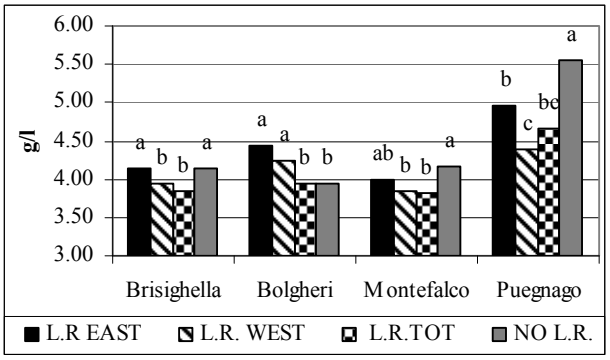

Fig. 6 Acidic values recorded in each place on average for four years (2007-2010) for the cultivar Cabernet Sauvignon (Duncan test for significance at $P \leq 0.05$).

the tests, in particular with regard to the analytical parameters such as sugar content, polyphenols, and anthocyanins, whereas different locations such as Brisighella and Scansano showed different results for all analytical parameters. A hot and dry vintage such as in 2007 allowed the Cabernet Sauvignon to better appreciate the leaf removal effects and the benefits determined by the total defoliation regarding the must sugar content. For this cultivar, places such as Brisighella and Bolgheri showed better results for the non-defoliated test, whereas in Montefalco and Puegnago the entire leaf removal test registered the highest sugar level.

Acknowledgments

The authors thank Luigi Mariani, Andrea Gozzini e Graziano Manenti (DIPROVE-Univeristà degli studi di Milano); furthermore, The authors thank all wineries that have participated to the preparation of this project and the "Centro Vitivinicolo provinciale di Brescia", Arsia Toscana and ARPA Cesena, Hotel Cortevecchia for the meteorological data provided.

References

[1] L. Haselgrove, D. Botting, Canopy microclimate and berry composition: The effect of bunch exposure on the phenolic composition of *Vitis vinifera* L. cultivar Shiraz, Australian Journal Grape and Wine Research 6 (2) (2000) 141-149.

[2] D.C. Percival, K.H. Fisher, J.A. Sullivan, Use of fruit zone leaf removal with *Vitis* vinifera L.cv Riesling grapevines, II, Effects on fruit composition, yield, and occurrence of bunch rot (*Botrytis cinerea* Pers.), American Journal of Enology and Viticulture 45 (2) (1994) 133-139.

[3] S. Poni, L. Casalini, F. Bernizzoni, S. Civardi, C. Intrieri, Effect of ealy defoliation on shoot photosynhesis, yield components and grape composition, American Journal of Enology and Viticulture 57 (4) (2006) 397-407.

[4] F. Campostrini, F. Serina, Gestione della chioma con cimatura e sfogliatura, Informatore Agrario 59 (21) (2003) 59-63.

[5] W.M. Kliewer, L.A. Lider, Influence of cluster exposure to the sun on the composition of Thompson seedless fruit, American Journal of Enology and Viticulture 19 (3) (1968) 175-184.

[6] M.O. Downey, N.K. Dokoozlian, M.P. Kratic, Cultural practice and environmental impacts on the flavonoid composition of grapes and wine: A review of recent research, American Journal of Enology and Viticulture 57 (3) (2006) 257-268.

[7] D.D. Beer, E. Joubert, D. Van Schalkwyk, M. Manley, Climatic region and vine structure: Effect on Pinotage wine phenolic composition, total antioxidant capacity and colour, Suoth African Journal of Enology and Viticulture 27 (2) (2006) 151-166.

[8] C. Bridi, Con il clima cambia il vino, Vignevini, 31 (6) (2004) 52-53.

[9] M. Pinna, L'atmosfera e il clima. Utet, collana Il nostro universo, 1978, p. 478.

[10] W. Koppen, R. Geiger, Handbuch der Klimatologie, Berlin, Verlag von Gebruder Borntraeger, 1936, p. 556.

[11] C. Mennella, I climi d'Italia, F.lli Conte, Napoli, 1977.

[12] F. Mattivi, A. Prast, G. Nicolini, L. Valenti, Validazione di un nuovo metodo per la misura del potenziale polifenolico delle uve rosse e discussione del suo campo di applicazione. Riv. Vitic. Enol. 56 (2-3) (2002) 55-74.

[13] J. Bennet, P. Jarvis, G. Creasy, Influence of defoliation on overwintering carbohydrate vreserves, return bloom and yield of mature Chardonnay grapevines, American Journal of Enology and Viticulture 56 (4) (2005) 386-393.

[14] M.C. Candolfi-Vasconcelos, W. Koblet, G.S. Howell, W. Zweifel, Influence of defoliation, rootstock, training system, and leaf position on gas exchange of Pinot noir grapevines, Am. J. Enol. Vitic. 45 (2) (1994) 173-180.

[15] W.M. Kliewer, Effect of day temperature and light intensity on coloration of vitis vinifera L. grapes, J. Amer. Soc. Hort. Sci. 95 (6) (1970) 693-697.

[16] W.M. Kliewer, Influence of temperature, solar radiotion and nitrogen on coloration and composition of sultana grapes, Am. J. enol. Vitic. 21 (1977) 26-36.

[17] R.E. Samrt, J.B. Robinson, G.R. Due, C.J. Brien, Canopy microclimate modification for the cultivar shiraz, effects on must and wine composition, Vitis 24 (1985) 119-128.

[18] A.N. Lasko, W.M. Kliewer, The influence of temperature on malic acid metabolism in grape berries, Plant. Physiol. 56 (1975) 370-372.

[19] A. Calò, A. Scienza, A. Costacurta, Vitigni d'italia. ed. Agricole, 2006.

[20] D.D. Crippen, J.C. Morrison, The effect of sun exposure on the phenolic content of cabernet Sauvignon berries during development, Am. J. Enol. Vitic. 37 (4) (1986) 243-247.

[21] S.B. Weiss, D.C. Luth, B. Guerra, Potential solar radiation in a VSP trellis at 38°N latitude, Practical Winery and Vineyard 25 (2003) 16-27.

[22] J.C. Morrison, A.C. Noble, The effects of leaf removal and cluster shading on the composition of Cabernet Sauvignon grapes and on fruit and wine sensory properties, Am. J. Enol. Vitic. 41 (3) (1990) 193-200.