CORVINA BERRY MORPHOLOGY AND GRAPE COMPOSITION AS AFFECTED BY TWO TRAINING SYSTEM (PERGOLA AND GUYOT) IN A CONTEXT OF CLIMATE CHANGE SCENARIO

Fabrizio BATTISTA[1], Despoina PETOUMENOU[1], Federica GAIOTTI[1], Lorenzo LOVAT[1], Duilio PORRO[2], Diego TOMASI[1]

[1]Centro di Ricerca per la Viticoltura, Consiglio per la Ricerca e la Sperimentazione in Agricoltura, Viale 28 Aprile 26, Conegliano (TV), Italy

[2]Fondazione Edmund Mach, Centro di Trasferimento Tecnologico, via Mach 1, S.Michele a/A (TN), Italy

Corresp. author: Battista F., 0039 0438 456719, e-mail : fabrizio.battista@entecra.it

Abstract

The Valpolicella area (Veneto Region, Italy) is famous for its high quality wines: Amarone and Recioto, both obtained from partial post-harvest dehydrated red grapes. The main cultivars used for these wines are Corvina and Corvinone. In this Region hundreds of years ago a particular training system (Pergola, cordon/cane with horizontal shoot-positioning) was developed. In the last 20 years the Guyot have been introduced in the area; now Pergola and Guyot are equally widespread in the Valpolicella area. In two different environmental conditions (hill and floodplain) two vineyards, one for each type of training system, were studied along two years (2011-2012).

Different canopy architectures determined differences in canopy density and bunch microclimate. Point quadrat analysis (PQA), photosynthetically active radiation (PAR) in the fruiting zone and berry temperature measurements were performed to evaluate the differences between the two training systems. The different leaf layer number (LLN) between the two trellis determined a different PAR reaching the bunch that resulted in a different berry temperature. Pergola showed a higher LLN and a consequent lower berry temperature compared with Guyot trellis.

The ThS of Pergola always showed a thinner skin compared with the Guyot. Tartaric acid content was significantly affected by the training system and resulted higher in the Pergola trellis. The ANT was higher where maximum berry temperature was lower, i. e. in intracanopy bunch of Pergola. Ew and TSS content were not affected by both the position in the canopy and the training system; just a year effect was founded. This study highlight the effect of the training system on some important grape parameters in a context of climate change, also for the post-harvest dehydration process of Corvina.

Keywords: training system, Pergola, post-harvest dehydration, epicuticular wax, skin thickness, Corvina

1 INTRODUCTION

The Valpolicella area (Veneto Region, Italy) is famous for its high quality wines: Amarone and Recioto, both obtained from partial post-harvest dehydrated red grapes. The main cultivars used for these wines are Corvina and Corvinone.

In this Region hundreds of years ago a particular training system (Pergola) was developed. In the last 20 years the Guyot have been introduced in the area; now Pergola and Guyot are equally widespread in the Valpolicella area. Pergola can be classified as cordon/cane with horizontal shoot-positioning (HSP) at 1.5-2.0m from the ground. While Guyot shows an head/cane with vertical shoot-positioning (VSP). The difference of the shoot position between the two training system affects the bunch microclimate.

Solar radiation and temperature of the fruit zone influence the berry composition at harvest (Chorti et al. 2010, Haselgrove et al. 2000, Smart et al. 1985). Excessive sunlight exposure causes sunburn damage (Greer et al. 2006) and did not increase total soluble solids and anthocyanin accumulation. High berry temperature is not desirable because cause alteration of the grape composition: minor aroma complexity, low total acidity, high pH and low anthocyanin synthesis (Bergqvist et al. 2001). For this reason in this context of climate change (Jones et al. 2005) training systems that avoid a direct bunch sun exposure are preferable.

The property of the grapes to be dehydrated after harvest are influenced by their morphological characteristics which can be affected as well by vineyard microclimate (Muganu et al. 2011). Light intensity, berry and air temperature can modify grape morphological and anatomical characteristics that influence the postharvest dehydration of the berry (Tonutti and Mencarelli 2005, Porro et al. 2008), in particular the skin thickness, the quantity of epicuticular wax, the bunch density and the berry size (Battista et al. 2012).

In two different environmental conditions (hill and floodplain) two vineyards, one for each type of training system, were studied along two years (2011-2012). Berry skin thickness (ThS), epicuticular wax (Ew), total soluble solids (TSS), total acidity (TA), malic acid, tartaric acid and anthocyanin content (ANT) were quantified in berries from bunches developed intracanopy (Pergola) and extracanopy (Guyot).

2 MATERIALS AND METHODS

2.1 Investigated vineyards site

The study was carried out in the AOC "Valpolicella-Valpantena" vineyards located just to the north of Verona (Italy) (45°29'22.21"N, 11°0'49.24"E). In two different environmental conditions (hill and foodplain) two Corvina vineyards, one trained with a simple Guyot and one with Pergola were selected and observed.

The vines in both the environmental condition were planted in East-West oriented rows, spaced 0.9 m (between vines) x 2.5 m (between rows) for the Guyot and 4.2 m for the Pergola.

In a previous study of this area a soil map (Benciolini and Gaiotti 2014), based on the landscape genesis was performed. In the hilly area the soil has a depth of 50cm and derives from limestone, in the foodplain the soil has a depth of 150cm and has a clay loam texture.

Air temperature and rainfall were recorded in the two different environmental conditions with an automatic weather station.

2.2 Canopy characterization and berry temperature

Point quadrat analysis (PQA), photosynthetically active radiation (PAR) in the fruiting zone and berry temperature measurements were performed to evaluate the differences between the two training systems.

On June 2012 in order to assess canopy density, the PQA was performed as described by (Smart and Robinson 1991). A thin 1m-long metal probe was randomly horizontally (in the Guyot) and vertically (in the Pergola) inserted into the fruiting zone of 4 representative vines per vineyard, counting contacts made with leaves, clusters or gaps. In this way each canopy was assessed, at least 80 to 100 times in order to obtain a representative data. From these data were calculated the following canopy parameters (Smart and Robinson 1991):

- % gaps = total gap to total insertions ratio
- LLN = total leaf contacts to total insertions ratio
- % interior leaves = interior leaves to total recorded leaf ratio
- % interior clusters = interior clusters to total recorded cluster ratio

Berry temperature was recorded by a WatchDog 1000 datalogger (Spectrum Inc), provided with 4 sensors placed inside the berries.

2.2 Grape composition and morphology

Furthermore at harvest the yield and the qualitative grape characteristics were determined: total soluble solids (TSS), total acidity (TA), malic and tartaric acid and total anthocyanins (ANT) content.

In addition to the normal qualitative parameters, additional parameters which could be more correlated to grape dehydration rate, were evaluated: quantity of epicuticular wax (Ew) and skin thickness (ThS). The Ew was extracted by dripping 30 berries in chloroform and the quantity was expressed per unit of berry surface area (Rogiers et al. 2004). The berry surface was calculated, with the formula of a prolate spheroid, measuring the height and equatorial diameter of the berry. The ThS was measured with a Texture Analyzer as reported in literature (Letaief et al. 2008).

3 RESULTS AND DISCUSSION

3.1 Environmental conditions

Heat accumulation values calculated as growing degree days (GDD) from 1st April to 30th September showed a small difference between the two season studied. The 2012 season was characterized by the highest maximum temperature during June, July and August; while in September were recorded low mean and maximum temperature compared with 2011 (Table 1). The rainfall amount over the same period was similar in the two seasons and between sites. The rainfall distribution was different between the two season studied: June, July and August 2012 were dry months with less than 35mm per month; while in 2011 the rainfall was well distributed during the ripening period. Considering the site, the floodplain environment showed the highest mean and maximum temperature.

3.2 Canopy characteristics

Differences in canopy density were evident, with Guyot training system having the highest percentage of gaps (more than four times higher compared to Pegola trellis), but no influence was registered by environmental condition for this parameter (Table 2**).** This low presence of gaps for the Pergola training system (only 3%) is attributed to the higher number of leaf layers that result also in a higher percentage of interior leaves (almost double compared to Guyot vines). In addition, this less opened canopy structure of the Pergola trellis doubled the percentage of shaded clusters compared to Guyot. All the Pergola bunches were in the shadow on both the environmental condition. In the Guyot this parameter was influenced by the growing site; in the hillside just the 22.4% of the bunch were inside to the canopy, while in plain side the 77.8% of bunch were interior (Table 2). This difference is due to the vine vigour, in the floodplain the higher soil volume lead to a greater available water for the plant that promote an higher vine vegetative grow.

These data underline the importance of Pergola trellis on grape's microclimate; berries exposed to the direct sunlight can experience an higher temperatures than ambient (Spayd et al. 2002), as confirmed by our data

(Table 3) which could delay or even stall fruit ripening and block colour accumulation (Kliewer and Torres 1972, Sadras and Moran 2012).

In the Guyot the 50% of the total bunches were directly exposed to the sun; in this situation during the day the berry temperature was always higher than the air temperature (Table 3), and in some days the difference between berry and air temperature reached more than 10°C (Figure 1).

Concerning the intracanopy bunches the photosynthetic active radiation that reached the berry surface resulted different between the two training system and this determined a different berry temperature during the season. The cause of this difference was the LLN that in the Guyot was of 2.4 while in the Pergola was of 3.5 (Table 2)

3.3 Yield and Fruit composition

The TTS did not show difference between training system (Table 4), comparing the two years of the study the 2012 showed a higher accumulation due to the hot temperature and the dry season (Bergqvist et al. 2001). TA was generally higher in the Pergola training system but this difference was not always statistically significant. This behaviour was confirmed by the tartaric acid and malic (just in 2011) content, the Pergola showed an higher content of its. The low temperature of the shadow berry preserved the tartaric and malic acid (Bergqvist et al. 2001). Anthocyanins decreased when the sunlight exposure increased as the PAR on the exposed berry surface was always over 100 μmol /m^2 sec, threshold of light that cause an excessive berry temperature increase (Bergqvist et al. 2001) as reported by our data (Table 4). Excessive temperature caused a decrease of anthocyanin accumulation (Chorti et al. 2010).

The yield per plant of the two training system was different, the Guyot produced an average of 2.7 kg while the Pergola produced 5.0 kg; considering the different distance between row of the two pruning system the yield per surface area was similar.

3.4 Berry morphology

The ThS was thicker in the Guyot compared to the Pergola, except for the floodplain in 2011. This result is linked with the berry temperature and sun exposure, berry developed into the shadow showed thinner skin (Muganu et al. 2011).

Also the atmospheric condition could affect the ThS (Porro et al. 2008, Letaief et al. 2008, Rolle et al. 2012). In 2012, the wormer season between the two studied (see maximum temperature), the thickness was thinner, this could appear in contrast with Letaief et al. (2008) that reported thin skin in cold years. But the heat wave and the three consecutive dry month in 2012 could have affected the cell division after the berry set leading to a thin berry skin (Wang et al. 2003, Thomas et al. 2006, Chaves et al. 2010).

The Ew content varied between the growing sites, in the hillside where the maximum and mean temperature were low a higher wax synthesis was recorded (Shepherd and Wynne Griffiths 2006). This behaviour was confirmed in both seasons, the cold one showed more Ew. Concerning the two training systems just in 2012 there was a difference between Pergola and Guyot in the hillside. Guyot in this environmental condition showed more Ew then Pergola. This difference is probably linked with the greater quantity of sun insolation that in 2012 was higher and in the Guyot was not attenuate by the leaf layer. The amount of berry surface Ew normally decrease from 60 to 110 DAF, whatever the position of the bunch in the canopy, and the reduction in Ew was greater in the intracanopy berries (Muganu et al. 2011)

4 CONCLUSION

Different canopy architectures determined differences in canopy density and bunch microclimate.

The different leaf layer number (LLN) between the two trellis determined a different PAR reaching the bunch that resulted in a different berry temperature. Pergola showed a higher LLN and a consequent lower berry temperature compared with Guyot trellis.

The ThS of Pergola always showed a thinner skin compared with the Guyot. Tartaric acid content was significantly affected by the training system and resulted higher in the Pergola trellis. The ANT was higher where maximum berry temperature was lower, i. e. in intracanopy bunch of Pergola. Ew and TSS content were not affected by both, the position in the canopy and the training system; just a year effect was observed. This study highlight the effect of the training system in a context of climate change scenario on some important grape parameters, also for the post-harvest dehydration process, of Corvina.

5 LITERATURE CITED

Battista, F., L. Lovat, D. Porro, E. Tosi, L. Bavaresco and D. Tomasi. 2012. Corvina and Corvinone grape berries grown in different areas and their aptitude to postharvest dehydration. In Proceedings IX International Terroir Congress. B. Bois, J. Gervais and D. Moncomble (eds.), pp. 6-7-6-10. Univeristé de Bourgogne, France.

Benciolini, G. and F. Gaiotti. 2014. Geologia, morfologia e suolo. In I segreti del territorio, dei vigneti e del vino Amarone della Cantina Valpantena. F. Battista and D. Tomasi (eds.), pp. 69-93. CRA-VIT, Italy.

Bergqvist, J., N. Dokoozlian and N. Ebisuda. 2001. Sunlight exposure and temperature effects on berry growth and composition of Cabernet Sauvignon and Grenache in the Central San Joaquin Valley of California. Am.J.Enol.Vitic. 52:1-7.

Chaves, M., O. Zarrouk, R. Francisco, J. Costa, T. Santos, A. Regalado, M. Rodrigues and C. Lopes. 2010. Grapevine under deficit irrigation: hints from physiological and molecular data. Annals of botany. 105:661-676.

Chorti, E., S. Guidoni, A. Ferrandino and V. Novello. 2010. Effect of different cluster sunlight exposure levels on ripening and anthocyanin accumulation in Nebbiolo grapes. Am.J.Enol.Vitic. 61:23-30.

Greer, D.H, S.Y. Rogiers and C.C. Steel. 2006. Susceptibility of Chardonnay grapes to sunburn. Vitis 45:147-148.

Haselgrove, L., D. Botting, R.v. Heeswijck, P.B. Høj, P.R. Dry, C. Ford and P. Land. 2000. Canopy microclimate and berry composition: The effect of bunch exposure on the phenolic composition of Vitis vinifera L cv. Shiraz grape berries. Australian Journal of Grape and Wine Research. 6:141-149.

Jones, G.V., M.A. White, O.R. Cooper and K. Storchmann. 2005. Climate change and global wine quality. Clim.Change. 73:319-343.

Kliewer, W.M. and R.E. Torres. 1972. Effect of controlled day and night temperatures on grape coloration. Am.J.Enol.Vitic. 23:71-77.

Letaief, H., L. Rolle and V. Gerbi. 2008. Mechanical behavior of winegrapes under compression tests. Am.J.Enol.Vitic. 59:323-329.

Muganu, M., A. Bellincontro, F.E. Barnaba, M. Paolocci, C. Bignami, G. Gambellini and F. Mencarelli. 2011. Influence of bunch position in the canopy on berry epicuticular wax during ripening and on weight loss during postharvest dehydration. Am.J.Enol.Vitic. 62:91-98.

Porro, D., M. Ramponi, T. Tomasi, L. Rolle and S. Poni. 2008. Nutritional implications of water stress in grapevine and modifications of mechanical properties of berries. In VI International Symposium on Mineral Nutrition of Fruit Crops. Acta Horticolturae, 868. Anonymous , pp. 73-80.

Rogiers, S.Y., J.M. Hatfield, V.G. Jaudzems, R.G. White and M. Keller. 2004. Grape berry cv. Shiraz epicuticular wax and transpiration during ripening and preharvest weight loss. Am.J.Enol.Vitic. 55:121-127.

Rolle, L., F. Torchio, S. Giacosa, S.R. Segade, E. Cagnasso and V. Gerbi. 2012. Assessment of Physicochemical Differences in Nebbiolo Grape Berries from Different Production Areas and Sorted by Flotation. Am.J.Enol.Vitic. 63:195-204.

Sadras, V.O. and M. Moran. 2012. Elevated temperature decouples anthocyanins and sugars in berries of Shiraz and Cabernet Franc. Australian Journal of Grape and Wine Research. 18:115-122.

Shepherd, T. and D. Wynne Griffiths. 2006. The effects of stress on plant cuticular waxes. New Phytol. 171:469-499.

Smart, R. and M. Robinson. 1991. Point Quadrat. In Sunlight into wine: a handbook for winegrape canopy management. Anonymous , pp. 21-23. Winetitles, Adelaide.

Smart, R., J. Robinson, G. Due and C. Brien. 1985. Canopy microclimate modification for the cultivar Shiraz. II. Effects on must and wine composition. Vitis. 24:119-128.

Spayd, S.E., J.M. Tarara, D.L. Mee and J. Ferguson. 2002. Separation of sunlight and temperature effects on the composition of Vitis vinifera cv. Merlot berries. Am.J.Enol.Vitic. 53:171-182.

Thomas, T.R., M.A. Matthews and K.A. Shackel. 2006. Direct in situ measurement of cell turgor in grape (Vitis vinifera L.) berries during development and in response to plant water deficits. Plant, Cell Environ. 29:993-1001.

Tonutti, P. and F. Mencarelli. 2005. Physiological aspects of withering and dehydration of wine grapes (Vitis vinifera L.). Informatore Agrario. 14:19-21.

Wang, Z.P., A. Deloire, A. Carbonneau, B. Federspiel and F. Lopez. 2003. An in vivo experimental system to study sugar phloem unloading in ripening grape berries during water deficiency stress. Annals of Botany. 92:523-528.

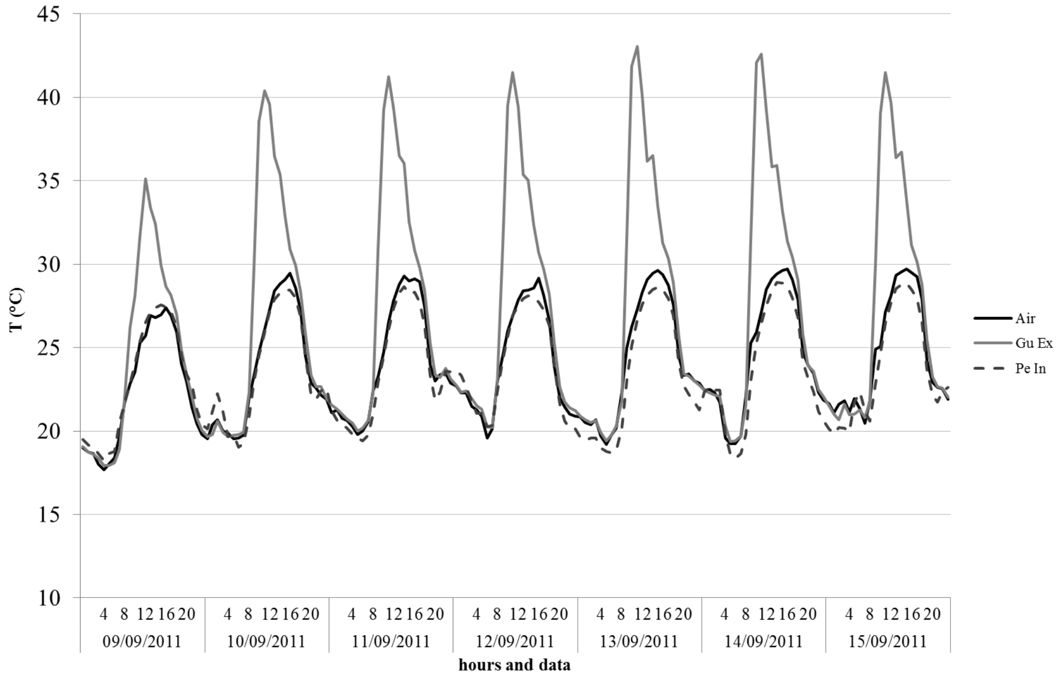

Figure 1 – Air temperature (°C) from 9th September 2011 to 15th September 2011. Gu Ex (Guyot extracanopy), Pe In (Pergola intracanopy) and Air temperature.

Table 1 – Growing degree days (GDD, base 10°C) and rainfall (mm) from 1st April to 30th September at the two experimental site in 2011 and 2012. Mean (T mean), maximum (T max) air temperature (°C) and rainfall (R) (mm) recorded in June, July, August and September 2011 and 2012.

		April-September		June			July			August			September		
Year	Site	GDD	rainfall	T mean	T max	R	T mean	T max	R	T mean	T max	R	T mean	T max	R
2011	*Floodplain*	2169	359	22.0	32.4	141	23.4	35.2	81	26.4	38.5	11	22.6	33.7	83
	Hill	2057	351	21.5	31.6	146	22.8	33.1	77	25.6	36.4	19	22.3	32.4	74
2012	*Floodplain*	2098	379	24.0	36.0	26	26.4	37.6	28	27.3	39.2	17	19.9	31.4	120
	Hill	2006	395	23.4	34.8	30	25.8	36.4	33	26.8	36.8	14	19.8	30.7	132

Table 2 – Effect of pruning method (Pergola and Guyot) and environmental condition on canopy architecture

	% gaps	LLN	% interior leaves	% interior clusters
Training system				
Guyot	12.4 a	2.4 b	38.8 b	50.1 b
Pergola	3.0 b	3.5 a	72.4 a	100.0 a
sign	***0.008103***	***0.000145***	***0.000002***	***0.000002***
Area				
Hillside	8.1	2.6 b	52.3 b	61.2 b
Floodplain	7.3	3.4 a	58.9 a	88.9 a
sign	*ns*	***0.001161***	***0.042979***	***0.000176***
Interaction				
Guyot hillside	11.1	2.0	34.4	22.4 c
Guyot floodplain	13.6	2.9	43.3	77.8 b
Pergola hillside	5.1	3.2	70.1	100.0 a
Pergola floodplain	0.9	3.9	74.6	100.0 a
sign	*ns*	*ns*	*ns*	***0.00018***

Table 3 - Average values for photosynthetic active radiation (PAR, $\mu mol/m^2$ sec), berry and air temperature detected at 0900, 1200, and 1600 hr in August and September in different zones of the canopy (± standard deviation) and different environmental condition

		0900 hr			1200 hr			1600 hr		
		Extracanopy	Intracanopy Pergola	Intracanopy Guyot	Extracanopy	Intracanopy Pergola	Intracanopy Guyot	Extracanopy	Intracanopy Pergola	Intracanopy Guyot
Floodplain										
August 2011	PAR	1294.8 ± 89.9	12.7 ± 6.8	27.9 ± 8.4	1348.2 ± 45.7	16.8 ± 13	47.2 ± 21.9	1169.9±100.1	11.2 ± 4.6	35.0 ± 10.5
	air T (°C)		30.4			33.0			34.2	
September 2011	PAR	974.9 ± 69.8	31 ± 20	186.2 ± 35	1066.3 ± 31.9	28.6 ± 15	175.5 ± 64	1622.4 ±160.0	21 ± 11	69.9 ± 41.3
	Berry T (°C)	35.9 ± 1.1	22.4 ± 0.4	25.1 ± 0.2	32.1 ± 0.3	28.4 ± 0.01	29.4 ± 0.2	32.8 ± 0.2	30.2 ± 0.1	31.17 ± 1.3
	air T (°C)		28.5			30.5			32.4	
Hillside										
August 2011	PAR	1239.6 ± 86.1	9.6 ± 4.8	73.1 ± 36	1352.7 ± 40.9	9.6 ± 6.2	61.4 ± 18.6	1157.7 ± 94.4	8.6 ± 4.5	54.3 ± 17.6
	air T (°C)		29.8			30.7			31.7	
September 2011	PAR	868.3 ± 199	6.4 ± 2.5	143.2 ± 86	1767.1 ± 52.8	12.8 ± 6	138.2 ± 92	898.8 ± 146.9	14 ± 17	45.7 ± 17.3
	Berry T (°C)	30.6 ± 1.8	22 ± 1.0	26.2 ± 0.4	40.8 ± 1.2	27.6 ± 0.8	31.9 ± 0.4	32.9 ± 0.8	28.6 ± 0.6	31.8 ± 1.2
	air T (°C)		24.9			28.1			29.5	
August 2012	PAR	1280 ± 45.7	14 ± 6.5	55.98 ± 44	1980.3 ±139.6	11.4 ± 3.2	43.4 ± 15	1578.2 ± 36.9	16 ± 3.2	50.3 ± 3.23
	Berry T (°C)	33.8 ± 0.7	24.9 ± 1.1	28.1 ± 1.1	39.3 ± 1.9	34.0 ± 0.6	35 ± 0.8	38.9 ± 1.4	35.5 ± 0.4	37.5 ± 0.1
	air T (°C)		31.4			34.1			35.3	

Table 4 – Grape composition and yield. Total soluble solids (TSS), total acidity (TA), tartaric and malic acid, total anthocyanins content and yield in the two seasons (2011 and 2012), in two environmental condition (floodplain and hillside) of *Cv.* Corvina trained with two system (Pergola and Guyot).

Parameters	2011				2012			
	Floodplain		Hillside		Floodplain		Hillside	
	Guyot	Pergola	Guyot	Pergola	Guyot	Pergola	Guyot	Pergola
TSS (°Brix)	20.9 ab	20.2 b	19.6 b	19.7 b	21.7 a	21.3 a	21.5 a	21.4 a
TA (g/l)	5.9 b	6.8 a	5.5 b	5.9 ab	6.2 b	6.2 b	6.8 a	7.1 a
Tartaric Acid (g/l)	6.4 b	6.7 a	5.5 c	5.8 b	6.4 b	6.5 b	6.3 b	6.8 a
Malic Acid (g/l)	1.4 b	1.9 a	1.5 b	2.0 a	0.1 c	0.2 c	0.1 c	0.2 c
Tot.anthocyanins (mg/berry)	0.70 c	0.75 c	0.76 c	0.86 b	0.46 d	0.65 c	0.62 c	1.14 a
Plant yield (kg)	2.9 b	5.3 a	2.7 b	5.1 a	2.3 b	4.8 a	2.6 b	4.9 a

Note: Mean followed by the same letter do not differ significantly. Two way ANOVA to evaluate the year, area and training system effect. Duncan test at p=0.05.

Table 5 – Berry morphology. Skin thickness (ThS, µm) and epicuticolar wax (Ew, µg/mm^2) in the two seasons (2011 and 2012), in two environmental condition (floodplain and hillside) of *Cv.* Corvina trained with two system (Pergola and Guyot).

Area	Training system	2011		2012	
		ThS	Ew	ThS	Ew
Floodplain	**Guyot**	193.6 ab	1.5326 b	163.0 b	0.8345 c
	Pergola	191.4 ab	1.5163 b	154.3 c	1.0743 c
Hillside	**Guyot**	197.8 a	1.6303 ab	169.2 a	1.5032 a
	Pergola	189.0 c	1.7841 a	159.0 cd	1.2619 b

Note: Mean followed by the same letter do not differ significantly, Duncan test at p=0.05.