A new closing Y-shaped training system for grapevines

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Abstract

Background and Aims: Total leaf area and its distribution inside the canopy are known to influence the photosynthesis capacity as well as grape quality and health. The aim of this work was to evaluate the effectiveness of a simple and innovative training system characterised by an open canopy called 'SAYM' (a closing Y-shaped training system derived from the spur-pruned single cordon and trained to an inclined shoot-positioned trellis type) as well as the possibility of using traditional machines during harvesting and pruning after closing the structure just before grape harvesting.
Methods and Results: The SAYM was applied on eight rows of 80 vines from an experimental Sangiovese vineyard and compared to vertically shoot-positioned (VSP) trellis type during the 2004–2008 seasons. In comparison to VSP vines, the SAYM was able to reduce the incidence of botrytis rot and improve grape and wine quality (alcohol, anthocyanins, phenolics, tannins and colour intensity), while maintaining an adequate yield (about 13 t/ha) without significantly increasing the management operations of the vineyard.
Conclusions: The SAYM was able to bring together economically and easily the advantages guaranteed by training systems characterised by horizontally divided canopy with the limitation of production costs by the use of traditional mechanical harvesters and pruners.
Significance of the Study: SAYM can be proposed as a functional training system able to improve grape and wine quality, which is easy and inexpensive to manage.

Keywords: *grape composition, mechanical harvesting, mechanical pruning, training system, vine yield*

Introduction

In grapevine cultivation, the achievement of producing high quality premium wine grapes presupposes a long-lasting equilibrium between vine growth and yield, the possibility of overcoming stresses, either climatic or parasitic and an optimal microclimate around and inside the canopy (Jackson and Lombard 1993, Kliewer and Dokoozlian 2005). The training system in general greatly influences all these aspects (Carbonneau 2009, Reynolds and Vanden Heuvel 2009), as well as the priority requirement of maximising the net return. This last objective can be realised by increasing mechanisation of the management practices or choosing a completely mechanised training system. This assumes particular importance especially when the wines produced must be sold in unbottled form or within large organised distribution (LOD) chains, like supermarkets, hypermarkets and discount markets. Currently, at least in Italy, the LOD commercialise more than 70% of the entire Italian wine production (which corresponds to about 48–50 million hl per year) (Istituto di Servizi per il Mercato Agricolo Alimentare 2007).

It is well known that total leaf area and its distribution inside the canopy define the functional leaf area (well exposed and healthy leaves) (Smart 1985, Smart and Robinson 1991). The microclimate that characterises grape growth and ripening, as well as the radiation intercepted, determines the potential photoassimilate source of a given canopy (Smart 1985, Cartechini and Palliotti 1995, Poni et al. 2003, Kliewer and Dokoozlian 2005). Obviously, these canopy properties markedly influence grape composition and health and hence wine quality. Recently, it has been stated that total canopy light interception and the whole-canopy net CO_2 exchange rate (Poni et al. 2003) and dry matter production (Pelaez et al. 2000, Montes and Korbulewsky 2002) are highly correlated, regardless of shoot density or training system.

In the past, numerous attempts have been made to horizontally divide the vine canopy in order to increase the exposed leaf area, to optimise the canopy microclimate and to improve grape quality. Some successful examples of these attempts are: Lyra, GDC, Duplex, Combi, etc. (Shaulis et al. 1966, Carbonneau 1982, 2009, Intrieri and Filippetti 2000). Other training systems to aimed at improving grape quality, consisting of a movable framework to increase light interception and penetration inside the canopy, have been developed in the last two decades, like the Lys trellis, foldable Lyre and the Modulated Vertical Shoot Positioning trellis (Castro et al. 1995, Carbonneau 2009).

However, despite the optimal results obtained with some of these horizontally divided canopy training systems, especially with respect to grape composition and wine quality, only a few of them have found wide application. The reasons may reside in the fact that some of these training systems are particularly complex and difficult to manage, while others are for high yielding vineyards or exclude the possibility of mechanising pruning and harvesting with conventional machines.

Nowadays, the quality/cost ratio is assuming a dominant role in the wine trade that is increasingly competitive and globalised. For this reason it is necessary to use a careful crop-control strategy as well as to mechanise the management practices to reduce labour. Intrieri and Poni (1995) reported that the use of a mechanical harvester and pruner reduced the yearly labour requirement in a Geneva Double Curtain vineyard to about 70 h per hectare.

This paper concerns a five-year study aimed at evaluating the effectiveness of a simple and innovative grapevine training system called 'SAYM' (Figure 1). This closing Y-shaped training system is derived from a spur-pruned single cordon and trained to

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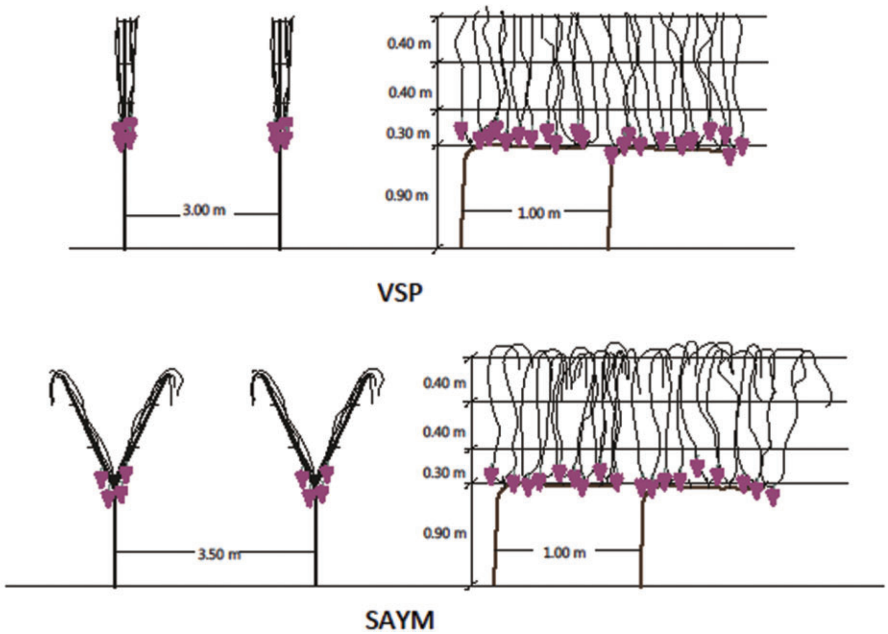

Figure 1. Schematic view of the vertically shoot-positioned (VSP) trellis type and the closing Y-shaped training system (SAYM).

Figure 2. The device used to open and close the Y-shaped structure mounted onto each stake of the Sangiovese vineyard. A 1.1 m, V-shaped galvanised iron frame with an overall aperture angle of 50° were used to divide the canopy in two sloping walls. This structure remained open from just before bud-burst (begin of March) to harvesting and then was closed just before grape harvest (approximately half of September).

an inclined shoot-positioned trellis type. The study was designed to evaluate the SAYM and the vertically shoot-positioned (VSP) trellis types in order to: (i) establish the effects of the training systems on vine growth, canopy characteristics, yield components, grape composition and wine quality; and (ii) assess if with the SAYM, it is possible to combine the presence of an open and divided canopy during the vegetative season with the use of conventional machines during the harvesting and pruning operations after closing the structure just before grape harvesting.

Materials and methods

Experimental vineyard

The study was carried out near Perugia, central Italy (Umbria region, 42°58′N, 12°24′E, elevation 405 m a.s.l., loamy soil type) during the 2004–2008 seasons on 5-year-old Sangiovese (*Vitis vinifera* L.) grapevines (clone VCR30) grafted onto 420A rootstock. Sixteen 80 m long rows were used; eight of these rows were spaced at 3.5 × 1.0 m (equivalent to a density of 2857 vines/hectare), and the others were spaced at 3.0 × 1.0 m (equivalent to a density of 3333 vines/hectare). The rows were 15° NW-SE oriented. All vines were trained to a VSP spur pruned cordon trellis with a bud-load of about 12 nodes per vine (Figure 1). The trellis consisted of a unilateral permanent cordon at 0.90 m above the ground with three pairs of surmounting catch wires for a canopy wall extending about 1.1–1.2 m above the cordon. In both training systems, an average of 12 shoots per vine was retained.

In 2003, the eight hedgerows spaced at 3.5 × 1.0 m were modified into the SAYM by mounting onto each stake of all hedgerows, a 1.1 m, V-shaped galvanised iron frame with an overall aperture angle of 50° (Figures 1,2). This structure remained open from bud-burst (begin of March) to harvesting and then was closed just before harvest (approximately half of September), by using an appropriate device (Figure 2). This system allowed traditional mechanical harvesters and subsequently pre-pruning machines to be used.

Local standard practices were followed for pest management. In all years, vines were not irrigated, no leaf removal was conducted, and shoots were mechanically trimmed when most of them started to outgrow the top wire. Depending on the year, trimming took place during the first 10 days of July. The weather

Table 1. Rainfall and growing degree days (GDD, base 10°C) from 1st April to 30th September at the experimental site during 2004–2008 growing seasons and mean values over 52 years (1951–2003).

Year	Rainfall (mm)	GDD
1951–2003	380	1706
2004	352	1806
2005	344	1839
2006	324	1815
2007	204	1848
2008	369	1734

conditions during the study were monitored by an automated meteorological station located near the vineyard (Table 1).

Vine growth, leaf area development and canopy characteristics and light interception by the canopy

Every year, at the end of May, on 30 representative vines per training system bud fruitfulness was estimated as the number of clusters per shoot.

Each year when shoot growth had stopped (usually by mid-August), six representative fruiting shoots per treatment were taken from non-monitored vines and the total leaf area per shoot, with the primary and lateral leaves being kept separate, was measured with an area meter (Hayashi Denko C., AAM-7, Tokyo, Japan). Earlier studies about canopy growth in both training systems showed that six shoots per vine was an adequate sample in order to have an accurate estimate of canopy leaf area. This occurs also because the vineyard is very homogeneous as regards vine development, disease and soil properties including a good water retention capacity. Total leaf area per vine was then estimated on the basis of mean shoot area assessment and shoot counts per vine. In both training systems, the canopy surface area was also estimated according to Smart (1985), taking into account the geometrical shape of the respective canopies; thus VSP and SAYM systems were compared to a single parallelepiped and a double rhombohedron, respectively.

Each year, at the end of February, canes from 30 representative vines per training system were pruned and weighed to estimate the annual vine growth. These data were then used to calculate the Ravaz index (yield-to-pruning weight ratio, kg/kg) (Ravaz 1903). Vine balance was also assessed by calculating the total leaf area-to-yield ratio and the canopy surface area-to-yield ratio (vine basis) in both training systems.

In the 2006 and 2007 seasons, approximately 1 month before and 1 month after veraison, the total light canopy interception was calculated on 2.0 m row sections of each trellis type, including the permanent cordon. The amount of radiation transmitted to the vineyard floor was measured under clear-sky conditions using a 1-m linear quantum sensor (mod. RG99, Silimet, Modena, Italy) equipped with 10 photosynthetic active radiation (PAR) sensors. Using a 2.0×2.0 m grid, the linear sensor was moved to 10 locations per grid under the canopy so as to yield a total of 20 individual light readings per trellis type, all taken in about 2 min. On both days of measurements, light readings were taken at 11:00, 13:00 and 15:00 h solar time by moving the grid over the ground to cover the entire ground area shaded by the canopy. Canopy light interception was calculated from the means of these three measurements. Similarly, 1 month before and 1 month after veraison, the PAR availability in the cluster region was also estimated between 12:00 and 13:00 h using a LiCor Li-190S point quantum sensor (Lincoln, Nebraska, USA) placed vertically upward near clusters on both sides of the canopy. One hundred clusters per trellis type were labelled, half of them on the east side of the canopy and the other half on the west side, and used for measurements.

Yield and grape composition

Grapes were manually harvested on 14, 9, 11, 12 and 16 September in 2004, 2005, 2006, 2007 and 2008, respectively when the soluble solids in the berries stopped increasing. Clusters were individually picked and crop weight and the number of clusters per vine were recorded as well as the incidence of bunch rot (fraction of affected clusters). Compactness was visually estimated on 100 clusters per treatment using code OIV 204 (OIV 1983), which ranks from 1 'berries in grouped formation with many visible pedicels' to 9 'misshapen berries'.

Each year, at harvest, berry weight, total soluble solids (°Brix), titratable acidity (TA) and pH were determined on a 500-berry sample (five 100-berry replicate samples per training system). Total soluble solids were determined using a temperature-compensating refractometer (RX-5000 Atago-Co Ltd, Tokyo, Japan). TA was measured with a Titrex Universal Potentiometric Titrator (Steroglass S.r.l., Perugia, Italy) with 0.1 N NaOH to an end point of pH 8.2, and results expressed as g/L of tartaric acid equivalent. Total anthocyanin and phenolic contents were determined according to Iland (1988) on 250 berries per trellis type (five replicate samples of 50 berries each). Total anthocyanins and phenols are expressed as mg per kg of fresh berry mass.

Microvinification and wine analysis

For vinification, for the 2004, 2006 and 2007 vintages, grapes from the two training systems were harvested by manually removing the fruit from 45–50 vines until 200 kg had been collected. The fruit was transported to the experimental winery in 20 kg plastic boxes. Each year duplicate micro-vinifications per training system were performed. In the winery, grapes were mechanically crushed, de-stemmed and transferred to 50-L stainless steel fermentation containers. SO_2 (35 mg/L) was added to the fruit and it was inoculated with 35 mg/L of a commercial yeast strain (Lalvin EC-1118, Lallemand Inc., Ontario, Canada). Wines were fermented on the skins for 14–18 days and punched down twice daily. Fermentation temperature ranged from 20 to 28°C. After alcoholic fermentation, wines were pressed and inoculated with 0.3 g/L of *Oenococcus oeni* (Lalvin Elios 1® MBR, Lallemand Inc., Ontario, Canada). After completion of malolactic fermentation, samples were racked and transferred to 100 L stainless steel containers and adjusted to 25 mg/L of SO_2. After 2 months, the wines were racked again, put into 750 mL bottles and closed with cork stoppers. After 1 year, duplicate samples of the wines were analysed for alcohol, titratable acidity and pH (Iland et al. 1993). Wine colour intensity ($OD_{420}+OD_{520}$), colour hue (OD_{420}/OD_{520}) and total phenols and anthocyanin concentrations were determined by spectrometry, with the total phenols quantified according to Ribéreau-Gayon (1970) by measuring the absorbance at 280 nm of wine diluted 1:100 with distilled water. Anthocyanins were analysed as reported by Ribéreau-Gayon and Stonestreet (1965), whereas total tannins were quantified by precipitation with methyl-cellulose according to Montedoro and Fantozzi (1974).

Mechanical harvesting and pruning

For the 2004, 2005 and 2006 harvests, a self-propelled grape harvester (Braud mod. SB64, New Holland, Italy), fitted with seven pairs of bow rods operating at 450 beats/min and driven at 3 km/h was used in both training systems. The operating time, yield, free-running juice index and percentage of impurity per training system were recorded.

During the winter pruning, the operating time of two different pre-pruning machines was compared with hand pruning. One mechanical pre-pruner consisted of four tractor-mounted cutter bars adjustable in height and cutting angle so as to enable pruning above, below and on the both sides of the canopy. This pruning system included two workers that did the final pruning touches with pneumatic shears working on tractor-drawn platform. The operators simultaneously carried out follow-up pruning to retain 12–13 nodes per vine by eliminating the excessive bearers and shortening all the excessively long bearers. The second mechanical pre-pruner (Volentieri Pellenc Visio mod. TL00HD, Firenze, Italy) consisted of a basic head characterised by two power shafts for the vertical type trellis system equipped with several rotary discs rolled through the trellis which pre-pruned all canes above the level of the bottom disc cutter. For the harvest and pruning measurements, the experimental design was a randomised complete block with four blocks per treatment, each having 40 vines per rows.

Statistical analysis

Two-way analysis of variance (ANOVA) was used to examine training system and year effects on vegetative parameters, yield component, vine yield and grape composition using the SigmaStat 3.5 software package (Systat Software Inc., San Jose, CA, USA). Mean separation was performed by Student-Newman-Keuls test at a level of 0.05. Visual rating of bunch compactness and all parameters expressed in percentage were subjected to square root transformation prior to analysis. Unless a significant year × training system interaction occurred, values are presented as means over the years.

Results

In all seasons, the April–September rainfall and heat accumulation, calculated as cumulative growing degree days (GDD), gave similar values (Table 1). However, the growing seasons of 2004–2008 were warmest in comparison to mean values calculated for the time 1951–2003 (+102 GDD on average), whereas total average annual rainfall was about 61 mm less than long-term average. Despite the absence of irrigation, no visual symptoms of water stress or leaf yellowing were evident throughout the five seasons.

At the end of canopy growth, the SAYM vines had 20 and 28% higher total leaf area and lateral leaf area, respectively, compared to VSP, when calculated on a per vine basis (Table 2). When the total leaf area was expressed on a per hectare basis, there was no difference between training systems because of 476 fewer vines per hectare in the SAYM vineyard. At the same time, SAYM vines had a significant increase in canopy surface area (about 52%) compared to VSP vines, whereas the leaf area/canopy surface area ratio was significantly lower (–22%). Vine size and vigour increased significantly in the SAYM vines as compared to VSP vines (Table 2). The 5-year averages of 1-year-old pruning weight was 17% higher and attributable above all to a 15% increase in cane diameter (measured along the entire stem) and to a lesser extend to longer canes remaining after shoot trimming.

One month before and 1 month after veraison, there was a 9.8 and 11.6% increase, respectively in light intercepted by the canopy of SAYM vines compared to VSP vines, but PAR availability near the clusters was significantly lower (–38 and –43% respectively) (Table 3).

While the following season's bud fruitfulness, estimated as clusters/shoot, was not affected by training system, the vines trained to the SAYM system yielded about 13% more fruit due to the 15% higher cluster weight and 13% berry mass compared to VSP vines over the 5-year period (Table 4). However, yield per hectare was not higher because of the lower number of vines per hectare. No significant differences were found in the number of berries per cluster or in cluster compactness. On a 5-year average, the SAYM system reduced the percentage of botrytis rot to about one third of the rot found in VSP.

At harvest, grapes from SAYM vines had higher total soluble solids concentration (+ 1.6 °Brix averaged over 5 years), whereas there were no significant changes in titratable acidity and pH (Table 4). Total anthocyanin and phenolic concentrations (mg/kg) were significantly improved in grapes from SAYM vines as compared to VSP vines, with increases of about +38 and +25%, respectively.

The yield-to-pruning weight ratio was unaffected by training system (Table 4), and the values fell within the ideal range of 4 to 7 reported by Smart and Robinson (1991). Also, the total leaf area-to-yield ratio was unchanged between the SAYM and VSP system, whereas the canopy surface area/yield ratio in the SAYM vines increased by about 36% (on 5-year average).

The improvement in grape composition, especially the phenolic compounds assessed all 5 years at harvest time, was also found in wine composition (Table 5). Wines from SAYM vines showed a significant increase in alcohol, anthocyanin, total phenolic and tannin concentrations compared to VSP wines, as well as more intense colour, whereas no differences were found in total acidity, pH or hue.

At harvest, in the SAYM vines the closure of the supporting V structure by means of an appropriate device (Figure 2) was easy and rapid, requiring about 3–4 h of work per hectare. No significant differences were found in the operating time of the over-row mechanical harvester which ranged from 128 min/ha in VSP vines to 135 min/ha in SAYM vines (Table 6). Nor were differences found between the treatments for yield, free-running juice index or the percentage of impurity in the juices.

Table 2. Canopy characteristics of Sangiovese grapevines trained to vertically shoot positioned (VSP) or Y-shaped (SAYM) trellis systems. Values are the means of 2004–2008.

Parameter	VSP	SAYM	Trellis	Trellis × year
Total leaf area (m^2/vine)	5.71	6.88	*	ns
Lateral leaf area (m^2/vine)	1.81	2.32	*	ns
Canopy surface area (m^2/vine)	2.78	4.24	*	ns
Leaf area/canopy surface area (m^2/m^2)	2.07	1.61	*	ns
Pruning weight (g/vine)	738	861	*	ns

*Indicates significance at $P \leq 0.05$. ns, not significant.

Table 3. Total canopy light interception (per cent of maximum incident radiation) and photosynthetic active radiation (PAR) available on the cluster region in Sangiovese grapevines trained to vertically shoot positioned (VSP) or Y-shaped (SAYM) trellis systems measured at the pre- and post-veraison stage. Values are the means of the 2006 and 2007 data.

	VSP	SAYM	Trellis†	Trellis × year†
One month before veraison				
Total canopy light interception (%)‡	36.1	45.9	*	ns
PAR in the cluster region (μmol/m²/s)§	198	122	*	ns
One month after veraison				
Total canopy light interception (%)‡	55.2	66.8	*	ns
PAR in the cluster region (μmol/m²/s)§	126	72	*	ns

†*Indicates significance at $P \leq 0.05$. ‡Calculated as 100 – ((It/Ii) × 100), where It is transmitted irradiance and Ii is incident irradiance above the canopy (data are the means of measurements taken at 11:00, 13:00 and 15:00 h solar time). §Calculated between 12:00 and 13:00 h. ns, not significant.

Table 4. Parameters for yield, grape and vegetative growth of Sangiovese grapevines trained to vertically shoot positioned (VSP) or Y-shaped (SAYM) trellis systems. Values are the means of data from 2004–2008.

Parameter	VSP	SAYM	Trellis†	Trellis × year†
Nodes (N°/vine)	12.1	12.3	ns	ns
Bud fertility (clusters/shoot)	1.10	1.19	ns	ns
Yield (kg/vine)	4.13	4.65	*	ns
Yield (t/ha)	13.6	13.3	nd	nd
Clusters (N°/vine)	15.5	15.2	ns	ns
Cluster weight (g)	265	303	*	ns
Berry weight (g)	2.08	2.36	*	ns
Berries/cluster (N°)	127	129	ns	ns
Cluster compactness (rating)‡	6.2	6.5	ns	ns
Botrytis rot (%)	9.6	2.7	*	ns
Total soluble solids (°Brix)	21.2	22.8	*	ns
Titratable acidity (g/L)	6.4	6.1	ns	ns
Must pH	3.25	3.30	ns	ns
Total anthocyanins (mg/kg)	772	1068	*	ns
Total phenolics (mg/kg)	1652	2062	*	ns
Yield/pruning weigh (kg/kg)	5.60	5.41	ns	ns
Leaf area/yield (m²/kg)	1.38	1.48	ns	ns
Canopy surface area/yield (m²/kg)	0.67	0.91	*	ns

†*Indicates significance at $P \leq 0.05$. ‡Rated according to OIV 204 standard. nd, not determined; ns, not significant.

Table 5. Wine analysis of Sangiovese grapevines trained to vertically shoot positioned (VSP) or Y-shaped (SAYM) trellis systems. Values are the means of data from 2004, 2006 and 2007.

Parameter	VSP	SAYM	Trellis†	Trellis × year†
Alcohol (% v/v)	12.7	13.9	*	ns
Total acidity (g/L)	5.69	5.56	ns	ns
pH	3.43	3.47	ns	ns
Anthocyanins (mg/L)	147.3	231.5	*	ns
Total phenolics (mg/L)	1287	1598	*	ns
Total tannins (mg/L)	746	1165	*	ns
Colour intensity (au)‡	6.5	9.1	*	ns
Colour hue (OD_{420nm}/OD_{520nm})	0.68	0.65	ns	ns

†*Indicates significance at $P \leq 0.05$. ‡au = arbitrary units ($OD_{420nm} + OD_{520nm}$). ns, not significant.

Table 6. Operating times, yield, free-running juice index and percentage of impurity with a self-propelled mechanical harvester and operating times and labour requirement for hand- and mechanical winter pruning in Sangiovese grapevines trained to vertically shoot positioned (VSP) or Y-shaped (SAYM) trellis systems. Values are the means of data from 2004–2006.

	VSP	SAYM	Trellis	Trellis × year
Mechanical harvesting				
Operating time (min per ha)	128	135	ns	ns
Harvested yield (%)†	95.0	94.5	ns	ns
Free-running juice index (%)	7.1	6.8	ns	ns
Impurity (%)‡	6.1	6.5	ns	ns
Winter pruning				
Hand pruning (h/ha)	80	90	*	ns
Cutter bar pre-pruner				
Total labour requirement (h/ha)§	34	35	ns	ns
Rotary disc pre-pruner				
Pre-pruner operating time (h/ha)	2	2	ns	ns
Total labour requirement (h/ha)	32	32	ns	ns

†*Grape loss includes both vine and ground losses. ‡Includes bark, canes, leaves and petioles. §Includes pre-pruning operation and manual follow-up pruning to retain about 12 nodes per vine. ns, not significant.

In SAYM, manual winter pruning required about 10 h per ha more in comparison to VSP (Table 6). The mechanical cutter bar pre-pruner required 34–35 h/ha (including the time required for turning at the hedgerows), but there was no differences between the training systems. Regardless of training system, the mechanical rotary disc pre-pruner required about 2 h/ha, whereas the manual follow-up pruning to retain 12–13 nodes per vine required about 32 h/ha.

Discussion

The results from this 5-year study confirmed that in Sangiovese, the SAYM system, characterised by open vegetation during the entire season, resulted in improvement in grape composition and wine quality as well as a good yield per hectare when compared to the undivided vertical training canopy system. It is suggested that the results are due to the following significant changes: (i) higher total leaf area per vine; (ii) improved light interception during the day; (iii) reduction in the PAR level in the cluster region during the hottest hours of the summer days; (iv) improved leaf area/canopy surface area ratio; and (v) increased canopy surface area/yield ratio. These changes are probably also responsible for higher photosynthetic efficiency as it was reported previously (Cartechini and Palliotti 1995, Palliotti et al. 2000) that photosynthetic efficiency increased for external leaves well exposed to the sun.

It is likely that the reduced contact between adjacent clusters produced by the same bearer due to lateral shift of the shoots as well as the improvement in air circulation in the cluster zones were causing the reduced the incidence of botrytis rot (Marois et al. 1986). This is very important for grapevine cultivars, such as Sangiovese, genetically characterised by large cluster size and high compactness, high berry weight and low skin thickness, which make this cultivar particularly susceptible to several fungal diseases.

Of great interest is the significant increase in total anthocyanins in the Sangiovese grapes trained to SAYM trellis as well as more intense wine colour. In comparison to other red grape varieties, this cultivar typically has moderate aptitude to developing and accumulating colour (Mattivi et al. 2002). The lower value of leaf area/canopy surface ratio found in SAYM vines (precisely – 0.46 m^2/m^2) is a positive change because excessive within-canopy shading may occur when values exceed 1.5 (Smart 1985) and exert a negative effects on anthocyanins synthesis and accumulation into the grapes (Jackson and Lombard 1993, Cartechini and Palliotti 1995).

It is well known that high temperatures might increase the degradation of anthocyanins in grapes as well as reduce their synthesis through inhibition of mRNA transcription of the anthocyanin biosynthetic genes (Shaked-Sachray et al. 2002, Mori et al. 2007). We can assume that the significant increase in anthocyanin concentration found in grapes from SAYM vines may be correlated also to lower temperatures of the berry during the ripening stage, especially during the hottest hours of the summer days, where the inclination (about 25° from the vertical) of the two vegetative walls created some natural shading of the cluster zones. From this point of view, it can also be speculated that the geometrical characteristics offered by the SAYM training system can also be useful for limiting the negative effect of sunburn damage due to heat-induced and thermal death of exocarp and mesocarp cells of the berries (Spayd et al. 2002, Tarara and Spayd 2005, Greer et al. 2006). This physiological injury that significantly affect fruit quality are becoming a great concern in several areas of grapevine cultivation where high radiation regime is frequently associated with air temperatures higher than 40°C as reported by Nuzzo et al. (2009).

Contrary to Ravaz index and leaf area/yield ratio, which have proved ineffective despite significant differences especially in terms of composition of the clusters, the canopy surface area/yield ratio was found to be a suitable crop load index to predict and/or account for the differences in grape composition expressed by VSP and SAYM training systems as reported by Smart (1985) also because included the more functional amount of leaf area in the canopy at least from the photosynthetic point of view (Cartechini and Palliotti 1995, Palliotti et al. 2000, Poni et al. 2003). Thus, the canopy configuration of SAYM trellis may also improve the light microclimate of the remaining leaf area, increasing the interception of diffuse radiation, as reported by Smart (1988) and Mabrouk et al. (1997) for divided canopy. The lack of significance found on Ravaz index as well as on leaf area/yield ratio could be linked to the fact that these index are calculated at the end of growing season and usually do not take into account the seasonal evolution of canopy efficiency.

In the SAYM vines, the closure of the supporting structure was rapid, and use of the traditional mechanical harvester and pruner was easy, giving a considerable saving of labour in comparison to hand operations. Yield losses were acceptable as well as the amounts of free-running juice and impurities in the must, with no differences between the two training systems.

Conclusions

In Italy, the Sangiovese grapevine is the most cultivated red variety (about 10% of the total Italian vineyard acreage, i.e. more than 70 000 ha). It is used to produce both famous ultra-premium wines (like Chianti, Brunello di Montalcino, Nobile di Montepulciano, etc.), as well as table wines. Especially in the latter case, it is very important to reduce production costs, obtain an adequate yield per hectare and improve grape composition and wine quality. The SAYM open training system can help reach these objectives. The new SAYM created by mounting a simple catching frame to poles of a vineyard trained to VSP trellis is able to improve grape composition and wine quality and maintain a good yield per hectare without increasing significantly the management operations in the vineyard.

The increase in phenolic compounds in both grape and wine and the improvement in wine colour intensity is of great importance for producing high-premium wines, especially to improve the wines capacity to aging.

Finally, The SAYM system, which can be easily adapted to old vineyards trained to the VSP trellis with a row spacing of at least 3.0 m, is able to bring together, in an economical and simple manner, the advantages from a training system characterised by a horizontally divided canopy with the limitation of production costs through the use of traditional mechanical harvesters and pruners commonly used in viticulture all over the world.

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