Introducing on the go selective harvest in wine grape vineyard: criticality and chance

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Abstract

Mechanical grape harvesting is worldwide spreading rapidly. At present, looking around the main wine makers sites, the mechanization ranging between 3% of Argentina, to 75% of Australia. In Europe approximately 40% of the overall productions is mechanically picked up. The main reason is the need to reduce production costs, instead quality parameter often is assumed such us secondary condition into decision making system. Nevertheless, in an increasingly wide and competitive international market, the management of quality grapes appears an effective way for differentiating and enhance profits. In wine industry this perspective has been implemented through precision viticulture techniques, oriented towards selective harvesting. Recently a new grape harvester developed by New holland Agriculture has allowed to overcome this barrier using a patented selection system (EnoControlTM system) able to sorting two type of harvest quality on the go. To that chance, this study sought to analyze criticality and potential of selective harvesting in Italy. The study was carried out in 2015 season in four vineyards as many varieties, for a whole of 24 Ha located in central Italy. Specifically, a combination of proximal sensing based on NDVI vegetation index compared to main productive-composition parameters and berry sensory analysis were employed. Results, as a whole, highlighted the usefulness of Enocontrol selective system to achieve higher grape quality and from its relative wines.

Keywords: variable rate treatment, NDVI, mapping, precision vintage, grape harvester

1. Introduction

Precision Viticulture techniques are beginning to have a broader diffusion on wine growing. A lot of experiences both in the research field, like in productive sector, were conducted in Europe in order to seek to bring together the actuation of principles of BAT (best agricultural practies), promoted by EU the enhancement of quality. In this respect many researcher have been highlighted with their studies the relationship between variability, grape quality and yield (Bramley 2005, Bramley and Hamilton 2007; Tisseyre et al. 2008, Bramley et al. 2011, Martìnez-Casasnovas et al. 2012) as well as have been stated the achievable profitability by different management of grapes variability. However, many questions arises on differential management and the methods of their introducing. Concerning the first one, the main constraints is the subsistence of a spatial variation its extension and temporal stability that would justify such approach (Arnó et al., 2009). Indeed, whereas the vineyards are very uniform the generalized approach, at best, is to manage per areas or plots. Nevertheless, where there are actual variations with a therein spatial structure, the differential management may actually allows an optimization of the production process. This is where, issues concerning the definition of the most representative parameter for quality expression and thus to define a criteria to attribute a ranking for specific plots or a thereof part come into play. By the way of this, few indexes have been developed and used to represent and manage variability basically measuring yield per hectares and vegetative vigour. The first one, based on the assumption that increasing in yields leads to a perceived decrease in quality (Bravdo et al., 1985) may be usefully employed in wine industries and whereas there are no constrain in product specification. In these scenarios, the management seeks to achieve the cost reduction, through the differential management of cultivation stages (fertilization, irrigation) at the same way of open field cultivation. The yield variability is synonymous of vigour variation hence the strategies are organized on data acquired in the previous campaign which could be exempt of error biased e.g. the seasonality, instrumental etc. whether an annual calibration it is not done. This is feasible in extensive viticulture, but in wine production sites, such as those Italians characterized mainly by small (<1 ha) and medium (>50<100 ha) wine farms with orographical variability that may be very strong even inside the same plot, the only way is to count on quality. In this respect, premium wine makers have to take into account the set of variables directly or indirectly related to quality. Generally, the early approaches is the use of vegetative vigour index NDVI or PCD which have been shown to correlate with yield (Arno´ et al., 2011, Bramley and Hamilton, 2004) but not totally with grape composition (Santesteban et al. 2010, Smart et.al., 2013). Arnó and Santesteban (Arnó et al. 2012; Santesteban et al. 2013) have been highlighted the usefulness of different information sources combination such as elevation, fruit load and soil characteristics for within-vineyard zoning that were on the whole more satisfactory but moderate in the relationship between phenolics compounds.

Another key point is the technological availability of commercial systems which allow the variable rate management within vineyard variability. Currently, talking about vineyard management stages, have been developed systems for variable-rate of fertilizer spreading (Casella, 2016), leaf strippers (Spezia, 2016) spraying (Avidor, 2016).

Recently, this scenarios was broadened thanks to a new solution for managing grape quality at the within-field level through selective harvest. The innovation is a precision grape harvester that allows the sorting of two types of grape quality in accordance with zoning. That solution goes further than the actual selective harvesting generally carried out in a batch mode on large scale, per plots or within an alone vineyard thus it is a chance for the wine grower to enhance grape quality level. In this respect, the aims of this work were to analyze the issues and potential advantages with introducing this technology in a wine farm where mechanical harvesting is already established.

2. Materials and Methods

2.1. Study area

The research was carried out in four commercial vineyard located in Tuscany (Florence, Italy) as many varieties (Sangiovese SGV, Cabernet Sauvignon CS, Merlot MT, Montepulciano MO) for a whole of 24 Hectares during the 2015 season. The study area falls within the Chianti Colli Fiorentini Designation of Origin therefore with certain product specification in terms of cultivars and maximum yield per hectares which must be observed. The climate is temperate sub-Mediterranean, with average temperatures of the coldest (January) and hottest (July) months were 5°C and 22.6°C, respectively. The rainfall was distributed over around 90 days on average, with a relative minimum in summer and a peak in autumn for an overall values comprised between 600 and 700 mm per year. The vineyards were on average 15-years old, trained to a horizontal spur-cordon (4-6 per spur), at 0.8 m height from the ground with a planting distances of 2.20 x 0.9 m and North-South oriented. Only the Sangiovese vineyard was planted differently with 3x1m layout. Soil in these fields are an interaction of between Belforte (BEL1) typic Haplustepts, fine-loamy/loamy-skeletal, mixed, mesict and Abbadia (ABB1) typic Ustorthents loamy-skeletal, mixed, mesict standard Soil Taxonomy classification (Tuscany Region, 2016). Soil management foresaw shallow plowing alternated to cover crops in SGV, CS, MT, MO and permanent natural grassing cover on SGV.

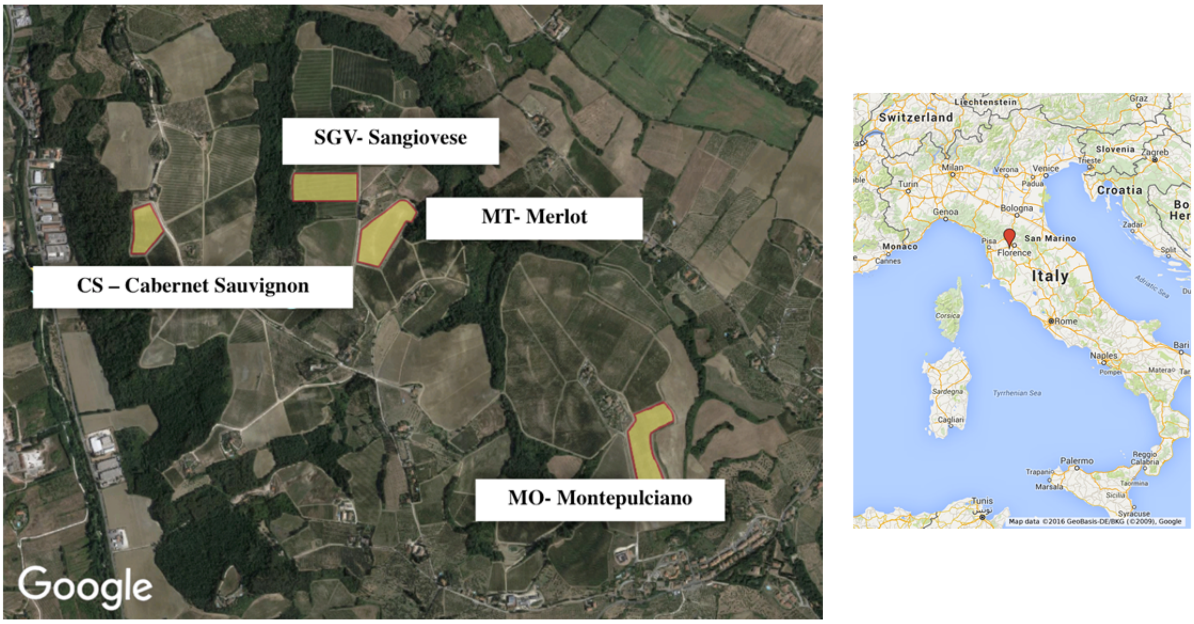

Figure 1. Location map of the study area. Four experimental vineyards are presented with their boundaries.

2.2. Selective grape harvester

The grape harvester was a New Holland Braud 9090L equipped with EnoControl™ system. The grape harvester elements were a harvesting assembly adapted to deliver a stream of harvested produced and a system for feeding a respective receptacle with said stream. The feeding system is made of two upper conveyors for feeding, a hopper along a respective feed path with the stream coming from the harvesting assembly and a lower upward path which moved toward the corresponding hopper. Specifically, each bucket conveyor tips a harvested stream onto the belt of an upper conveyor. Further, the machine enclose a DGPS for determining the location and an integrated display that allows two main functions i.e. the upload of prescription maps thus the feeding system control. At the basic principles is the division of the parcel of land into two areas as a function of at least one harvesting criterian.

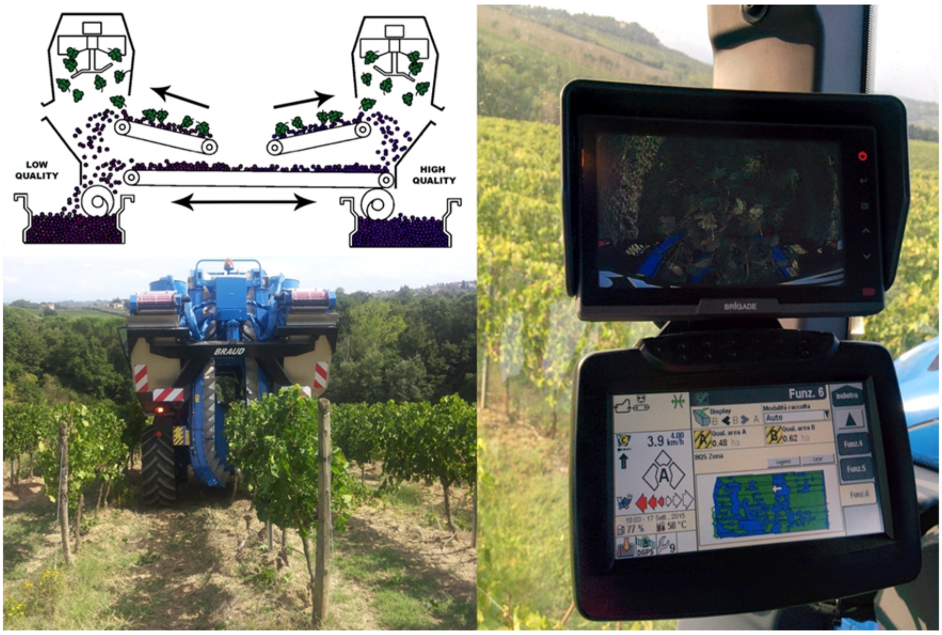

Figure 2. NewHolland EnoControl™ system main elements: functioning scheme of selective feeding system and display overview with graphical representation of prescription map.

2.3. Data acquisition

In order to define the two grape quality areas A premium and B standard, the methodologies foresaw the comparison between the results achieved by PV approach and the target imposed by agronomical technical manager. Specifically, the PV zoning was designed on the confining of three main areas from which A top quality grapes, M intermediate and B lower quality where, respectively were produced. That is as a consequence of the high difference observed for the seasonal evolution of the main oenological parameter that is a very common behaviour in hillside country and whereas there are marked soil typology variation such as in tat study area. On this basis, the constrains was whether the prescriptions resulting from PV analysis did not fulfill the therein threshold quality this must be adapted. Consequently, the M areas were assigned to A or B zone after grape attribute assessment made by chemistry analisys and berry sensory analysis.

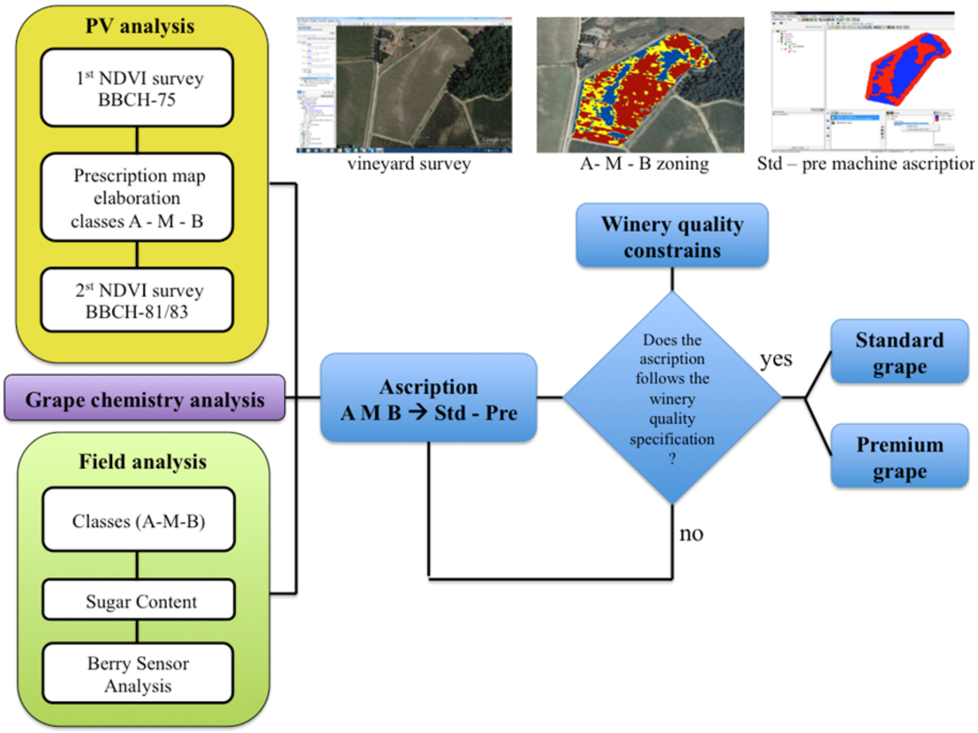

Figure 3. Data acquisition scheme

2.3.1. NDVI monitoring

NDVI information was obtained trough proximal measurements taken before first green pruning stage (BBCH-75) and at veraison (BBCH - 81/83). The sampling was performed with a ATV mobile unit equipped with a GPS receiver mod StarFire 3000 John Deere Company (precision accuracy SF2) with a sampling frequency of 0.1 m to geo-referencing and on-board PC equipped with a specific software (UNIFI SW) to couple the sensors and the continuous data acquisition. The plant vegetative vigour monitoring consisted of the Crop CircleTM ACS210 sensor by Holland Scientific Lincoln, USA that provides NDVI, PCD, WDRVI, NIR indexes. The sampling was done by taking a speed of 5 km/h in alternate rows. Then a geostatistical analysis was performed through ArcGIS 10.3.1 (ESRI) for each field using directional variograms, and spherical models were used to adjust the spatial correlation of NDVI values. Finally, NDVI values were classified by multivariate k-means cluster analysis. This procedure allows within vineyard differentiation in three NDVI classes.

2.3.2. Grape ripeness monitoring

In respect of quality assessment of each zone (A, M, B), two samples at twenty and seven days before the harvest were carried out. A total of fifteen bunches per area were randomly selected within the three areas taking account the higher and lower altitude of the vineyard in such a way that they were representative of the entire zone. For each sample, berry weight (BW) and the main composition parameters were determined using standard procedures: after crushing, total soluble solids (TSS) pH and titratable acidity (TA), malic (MalA) and tartaric acid (TarA), assimilable nitrogen (YAN), phenolic maturity total (TAnt) and extractable (EAnt), anthocyanins and of total phenolics (TP) were measured. Besides, simultaneous with sampling a simplified berry sensory analysis in order to assess the overall ripeness of fruit and to schedule the harvesting was done. The procedure foresaw the evaluation of ten grapes per area on the following parameter: visual and tactile examination (grape skin color, texture, resistance to penetration, separation aptitude from cap stem, transparency) pulp maturity (sweetness, acidity, aroma, must adhesion in the mouth and fingers; crunchiness), peel analysis (color on the fingers after pressing, hardness, acidity, tannins, astringency, dryness on the tongue, flavors), analysis of seeds (color, hardness, tannins, astringency, flavor). This information complement the inquiries made to elaborate the final allocation.

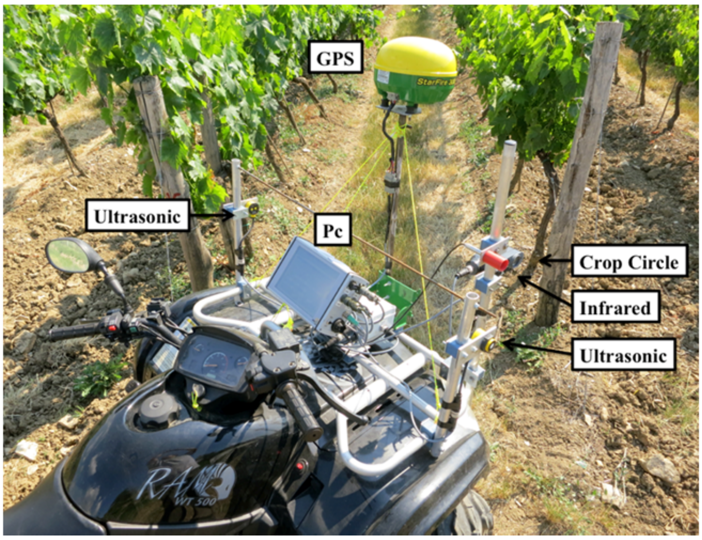

Figure 4. The ground sensing employed for NDVI monitoring

3. Results and Discussion

The PV zoning technique was concordant with the results obtained by chemical analysis and even with berries sensory analysis. From that analysis only the results of MT and MO cultivars showed a partial discordance by PV zoning. In particular in the M zones it was observed a structure soil change which evolved from fine-loamy/loamy to skeletal in B-M transition. That condition causes a changing in water availability therefore an orientation towards the vegetative luxuriance in the area B, that was richer in water and easiness of procurement, which was followed to a smaller area with limited availability where the vineyard is located in controlled water stress conditions so that the vigour was lower. The measurements of crown development, carried out by tree row volume technique TRV, confirmed this behaviour: have been measured values in the cv MT of 3350 ± 464 m^3 in the area B, and 2437 ± 352 in M m^3 in M, while in cv MO 2498 ± 278 m^3 in the area B and 2157 ± 252 m^3 in M area respectively. Whereas the soil composition skewed towards a high percentage of skeleton texture a water stress has been observed because of the long dry summer season, which resulted in a grapes qualitative decay. About the cultivar CS, indications gained from PV survey were in line with the chemical and sensory analysis. The SGV cultivar has been showed a much lower internal variability (NDVI Δ 0,12) also denoted at the berries chemistry analisys as can be seen in Table 1. Such behavior, the subject of future investigations, could be traced to the presence of a permanent grass cover and to the planting layout of 2,5x1m that might restrict the onset stress conditions. Overall, the chemistry analysis of B clusters highlighted best grape characteristics. The variety MO, differently as stated in experimental design, was not selectively collected on account to the chemical analysis of the grapes which during the season have shown a marked reduction in variability. As can be seen in table 2, values become less extreme. The causes of this trend are probably the longer growing season than the other cultivars (harvest October 2, 2015) and the optimal climate seasonal pattern that has not induced certain stress conditions. With regard to the specific aspects of the grape harvester, effective field capacity was similar to conventional machines i.e. 0.56 ± 0.14 ha h^{-1}. However, as Briot stated, a greater number of discharges consequently to irregular allocation of harvested between the buckets were needed (Briot et al.,2015). The Enocontrol selection system response timing were on average good, allowing a clear separation between the grapes harvested. This is also supported by wine characteristics at the end of first fermentation, that keep the properties trend of standard and premium grapes. In particular the latter wines showed in spread term, higher alcohol content +2.36 ± 0.27 %, total anthocyanins minimum +13.43%, maximum + 61.07% and a level of total phenolics ranging from a minimum of +10.97% and a maximum of +31,51% table 4. However, the introduction of that technology in an unstructured cellar to simultaneously handling the vinification of several lots, has shown some organizational adaptation issues in the harvested receiving stages despite the availability of two separate vinification plants. Indeed, it has been necessary from time to time to adjust the harvested amount in relation to the vinario vessel being set to a minimum quantity of 500 kg grapes. Therefore, in view of a successful introduction grape productivity assessment are required to optimize the management in the cellar.

4. Conclusions

This preliminary study showed the gross potential of selective harvester for the enhancement of wine production. The two wine types, standard and premium, were substantially different for all varieties investigated with better organoleptic properties for the second ones. The achievements highlighted the importance of simultaneous satisfaction of properly machine setup and executions: incorrect implementation might undermine the upstream phases thus, the final results. Hence, to the goal, the requirements of multi integrated approach which involves machine logistics, winery, and vineyard steps, to make selective harvesting it seems essential. Selective harvesting leads a great opportunity to winemaker in the perspective to differentiate winemaking procedures and management stages to valorize those vineyard where "grape levelling" cannot be realized.

Table 1. Descriptive statistics for the tree cultivar and their sub-zone of grape quality parameters.

	Date	TSS	Brix	Tot.A	pH	MA	YAN	Ant Ph1*	Ant Ph 3,2*	EAnt %*	TPI
MT - A		240,70	23,90	5,94	3,34	1,27	89	1027	429	58	44
MT - M	04/09/15	247,40	24,20	5,99	3,28	0,82	91	1417	611	57	21
MT - B		262,70	25,60	5,37	3,31	0,54	49	1638	728	56	72
SGV - A		207,5	20,6	5,94	3,15	0,79	78	1073	501	53	52
SGV - M	14/09/15	212,5	21,1	5,93	3,14	0,95	63	1126	515	53	55
SGV - B		214,6	21,3	5,61	3,22	1,2	74	1149	536	53	21
CS - A		239,70	23,30	5,79	3,34	1,25	109	1378	679	51	53
CS - M	25/09/15	241,30	23,70	4,76	3,46	1,09	58	1391	689	50	55
CS - B		278,40	27,40	3,55	3,81	0,81	25	1729	949	45	67
MO - A		215,0	21,3	6,41	3,14	0,86	45	1041	520	50	50
MO - M	14/09/15	239,3	23,5	5,60	3,21	0,92	57	1195	546	54	59,8
MO - B		242,9	24,0	6,00	3,17	1,11	77	1321	524	53	65,4

*Data referred to harvest time. *TSS* - Total Soluble Solids (g l^{-1}), Brix, *Tot.A* - Total Acidity (g l^{-1} as Tartaric Acid), pH, *MA* – Malic Acid (g l^{-1}), *YAN* – Yeast Assimilable Nitrogen (mg l^{-1}), *Ant Ph1* - Total anthocyanins at ph1(mg l^{-1}), *Ant Ph3.2* - Total anthocyanins at ph3.2 (mg l^{-1}), *TPI* - Total Phenol Index (TPI – OD 280 nm).

Table 2. Descriptive statistics for the MO cultivar at veraison and vintage stages.

	Date	TSS	Brix	Tot.A	pH	MA	YAN	Ant Ph1*	Ant Ph 3,2*	EAnt %*	TPI
MO - A		215,0	21,3	6,41	3,14	0,86	45	1041	520	50	50
MO - M	15/09/14	239,3	23,5	5,60	3,21	0,92	57	1195	546	54	59,8
MO - B		242,9	24,0	6,00	3,17	1,11	77	1321	524	53	65,4
MO - A		252,7	24,7	5,60	3,23	1,07	-	-	-	-	-
MO - M	15/10/02	251,1	24,6	5,16	3,27	0,93	-	-	-	-	-
MO - B		259,0	25,2	5,00	3,33	1,03	-	-	-	-	-

*Data referred to harvest time. *TSS* - Total Soluble Solids (g l^{-1}), Brix, *Tot.A* - Total Acidity (g l^{-1} as Tartaric Acid), pH, *MA* – Malic Acid (g l^{-1}), *YAN* – Yeast Assimilable Nitrogen (mg l^{-1}), *Ant Ph1* - Total anthocyanins at ph1(mg l^{-1}), *Ant Ph3.2* - Total anthocyanins at ph3.2 (mg l^{-1}), *TPI* - Total Phenol Index (TPI – OD 280 nm).

Table 3. Comparison between the analysis results to assign category to the grapes

PV zoning	Chemistry analysis	Berry analysis	Final
MT - A	std	std	standard
MT - M	std	pre	premium
MT - B	pre	pre	
SGV - A	std	std	standard
SGV - M	std	std	
SGV - B	std	pre	premium
CS - A	std	std	standard
CS - M	std	std	premium
CS - B	pre	pre	
MO - A	std	std	standard
MO - M	std	pre	
MO - B	pre	pre	premium

Table 4. Descriptive statistics of wine composition for the two qualities and cultivars investigated at the ending of malolactic fermentation.

	AA	Sugars	Tot. A	pH	MA	TA	TP	T	Harvested
MT standard	14,48	2,25	6,63	3,28	1,44	440	2164	2,64	15.000
MT Premium	14,77	2,00	7,49	3,26	1,73	525	2448	3,68	5.000
spread %	*2,00*	*-11,11*	*12,97*	*-0,61*	*20,14*	*19,32*	*13,12*	*39,39*	-
SGV standard	11,53	2,54	6,55	3,19	0,95	134	1714	2,71	9.000
SGV premium	11,81	2,60	6,86	3,18	0,94	152	1902	3,00	14.000
spread %	*2,43*	*2,36*	*4,73*	*-0,31*	*-1,05*	*13,43*	*10,97*	*10,70*	-
CS standard	13,59	1,90	5,91	3,37	1,25	149	2498	3,80	38.000
CS premium	13,95	1,79	5,84	3,44	1,29	240	3285	4,74	6.000
spread %	*2,65*	*-5,79*	*-1,18*	*2,08*	*3,20*	*61,07*	*31,51*	*24,74*	-

A.A - Acquired Alcool (%), *Sugars* (g l^{-1}), *Tot.A* - Total Acidity (g l^{-1} as tartaric acid), *pH*, *MA – Malic Acid* (g l^{-1}), *TA* - Total anthocyanins (mg l^{-1}), *TP* - Total phenolics (mg l^{-1}), T- Tannins (g l^{-1}), Harvested (Kg)

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