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Estimation of grape quality in vineyards using a new viticultural index

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Summary

Crop yield, total leaf area, canopy surface area and other vineyard parameters were determined on different 'Tempranillo' and 'Grenache' (*Vitis vinifera* L.) vineyards situated in Rioja appellation (Spain). All parameters were determined during three years. Grape vineyard assessment was performed by Vitur score-sheet, proposed by Tardaguila and Martinez de Toda (2005). The main chemical composition parameters of grape pulp and skin were also determined. The correlations between the viticultural variables and the chemical composition variables of the grapes were also analysed. The parameter that displayed the best correlation with grape phenolic composition was the CSA/Y/ShL parameter, referred to as the Toda Index. This index could be used to estimate the phenolic composition of grapes. It also presented the best correlations with grape quality, estimated using the Vitur score-sheet. These results suggest that, for winegrape vineyard assessment, Vitur score-sheet (necessarily subjective) may be replaced with the new Toda index (faster and objective). The main advantage of this new parameter is that it is easy to determine and is completely objective, unlike visual estimation which offers a high degree of subjectivity.

K e y w o r d s : Winegrape vineyard assessment, Vitur score-sheet, Toda Index, 'Tempranillo' and 'Grenache'.

Introduction

The wine sector would find it very useful to have a fast and reliable procedure or method for evaluating grape quality. Currently there is no single global method accepted by the wine sector as a whole for evaluating quality in the vineyard or when grapes are received at wineries. Many wineries only use one or several parameters to evaluate grape quality, but this is not the best approach because it is too simplistic and does not allow them to establish a close relationship with the final grape and wine quality.

As regards the estimation of grape quality in the vineyard, the application of a evaluation score-sheet was initially proposed by Smart and Robinson (1991). Later, in Australia, Gray *et al*. (1994 and 1997) tried to identify different vineyard characteristics associated with grape quality, and consequently wine quality, but they did not obtain good results. In this connection, Allan (2003) published an interesting report on the estimation of grape quality in Australian vineyards. In Europe, various researchers have studied the evaluation of grape quality in vineyards, notably in France (Carbonneau 1995) and Italy (Bertamini *et al*. 1994).

Research into the ecophysiological characterisation of vineyards has developed in recent years all around the world. As a result, five viticultural parameters have been proposed as the most important parameters for defining a balanced vineyard capable of producing high quality grapes and wines (Kliewer and Dokoozlian 2005). The five parameters and their ranges, proposed by the aforementioned authors, are the following: total leaf area/crop yield, yield/pruning weight, pruning weight/linear metre of canopy length, total leaf area/linear metre of canopy length and leaf density.

In the case of very high-quality wine productions, *i.e.* ones with high levels of demand, numerous authors have shown the usefulness of two more variables: canopy surface area and visual assessment using an evaluation card (Smart and Robinson 1991, Tardaguila and Martinez de Toda 2005).

Most of the abovementioned studies were performed in vigorous vineyards with fertile soils and no water restrictions. For these reasons, it would also be interesting to develop methods for assessing grape quality in the vineyard in warm and dry climates, characteristic of most mediterranean wine growing regions.

In recent years, within the scope of different experiments aimed at estimating grape quality in the vineyard, we have applied the following two methodologies: the canopy surface area/yield ratio and the Vitur score-sheet for the visual evaluation of the winegrape (Tardaguila and Martinez de Toda 2005). The Vitur score-sheet is basically a simple and fast method for evaluating overall grape quality at the vineyard itself, although it requires further study and more specific adaptations. The main drawback of a visual vineyard evaluation card such as the Vitur score-sheet is its subjectivity (Fig. 1). Therefore, it would be very interesting to find an objective parameter that is easy to measure in vineyards and which could be used to replace this subjective visual evaluation and provide the same type of information.

The aim of this study was to analyse the relationships between the main objective viticultural parameters, Vitur value and grape composition.

Material and Methods

In 2002, the experiment was performed on 11 'Grenache' and on 10 'Tempranillo' commercial vineyards of Bodegas

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Unit of Viticulture University of La Rioja	**VITUR score-sheet for vineyard assessment**

GENERAL DATA

Date:		Wine region:
Technician:		Vineyard Code:
Grower:		Vineyard surface:
Rootstock:		Variety and clone:
Type of soil:		Training system:
Row spacing:	Vine spacing:	Vine density (vines/ha):

CANOPY DATA

Sv: Shoots per vine:	**Bv:** Bunches per vine:
Bw: Bunch weight:	**Y:** Crop yield (kg/vine):
Hc: Exposed canopy height:	**Wc:** Exposed canopy width:
Wi: "windows" in the canopy (%):	**CSA:** Exposed canopy surface area (m^2/ha):

Criteria	Points			Weighting Factor	Points
	1	2	3		
CSA/Y (m^2/Kg)	□ < 0.8	□ 0.8 - 1.2	□ > 1.2	5	
Leaf layer number	□ > 4	□ < 3	□ 3 - 4	2	
Leaf condition (% unhealthy leaves)	□ > 10 %	□ 2 % - 10 %	□ < 2 %	2	
Water stress symptoms	□ High or very low	□ Moderate	□ Light stress	2	
Growing tips presence	□ High	□ Moderate	□ None	2	
Vigour	□ High	□ Low	□ Moderate	2	
Fruit health status (% bunches with diseases)	□ > 5 %	□ 1 % - 5 %	□ < 1 %	4	
Fruit exposure (%)	□ < 20 %	□ > 70 %	□ 20 - 70 %	3	
Bunch size	□ Big	□ Moderate	□ Low	2	
Fruit colour	□ Heterogeneous	□ Light Heterogeneous	□ Homogeneous	3	
Berry size	□ Big	□ Moderate	□ Low	3	
VITUR Value (Total points)					

Fig. 1: Vitur score-sheet used for winegrape assessment in the vineyard (Tardaguila and Martinez de Toda 2005).

Marques de Reinosa in Autol (DOCa Rioja, Spain). In 2003, 12 plots 'Tempranillo' vineyards of the above-mentioned winery were analysed. In 2004, the experiment was carried out on 11 'Tempranillo' vineyards of Bodegas Riojanas, in Cenicero (DOCa Rioja). Vineyards were maintained under dry and irrigation conditions. All vineyards were trained to vertical shoot positioning and spur pruned. Normal cultural practices in DOCa Rioja were applied.

Vineyard assessment: The characterisation of the vineyard was performed one week before the grape harvest. The following techniques were applied to determine vineyard status: I. Evaluation of growth and yield. The following parameters were determined in 10 vines representative of each plot: shoot number, total shoot length (main + laterals), cluster number and yield. Pruning weight was also determined in the winter. The indexes proposed by Kliewer and Dokoozlian (2005) were also determined. II. Total leaf area and canopy surface area. These were determined according to the method proposed by Smart and Robinson (1991) on 10 representative vines from each plot.

III. Grape vineyard assessment was performed by Vitur index score-sheet, proposed by Tardaguila and Martinez de Toda (2005). The Vitur score-sheet was used to visually estimate eleven viticultural variables (Fig. 1). IV. Vineyard data were used to calculate the parameter (canopy surface area/yield)/total shoot length ((CSA/Y)/ShL), referred to as the Toda Index.

Grape analysis: One week before the grape harvest (late September), a sample was taken of 20 clusters representative of each plot. Phenolic maturity was determined applying the method proposed by Saint-Cricq *et al*., (1998). The following parameters were determined: total polyphenol index, colour intensity, total anthocyanins, and extractable anthocyanins.

To determine the chemical composition of the grape pulp, 100 berries were taken and crushed manually. After filtering the resulting must, the following parameters were analysed: sugar content, total acidity, pH, tartaric acid and malic acid; a WineScan FT 120 analyzer (FOSS, Denmark) with Grapescan software was used.

Statistical analysis: Linear correlation analyses were performed using Pearson's correlation coefficient among the different viticultural parameters studied, evaluation using the Vitur index score-sheet and the analytical parameters of grape composition, in order to detect any significant correlations and high levels of correlation.

Results and Discussion

Dimensions of the parameters included in the Toda Index: To have an idea of the values of the parameters that compose the Toda Index in the different vineyards, the parameter CSA/Y changed between 0,63 and 1,46 and the parameter ShL changed between 1,33 and 1,94 m.

Correlation between the Toda Index and Vitur value: In the three years studied, the viticultural parameter or index that presented the best correlation with Vitur index was the Toda Index in all cases (data not shown). Therefore, the following figures only show the correlations of the aforementioned index. The graphs in Figs 2 and 3 show the correlation between the Toda Index (defined as CSA/Y/ShL) and the Vitur value in the 'Tempranillo' vineyards in 2003 and 2004. The results show the strong relationship between both parameters, particularly in 2004 ($R^2 = 0.856$**). The Toda Index proved to be a very good estimator of vineyard status, determined using the Vitur score-sheet. These results indicate that, when estimating vineyard quality, visual evaluation with the Vitur index score-sheet may be replaced with evaluation by the Toda Index. The main advantage of this new index is that it is objective, fast and easy to determine in the vineyard, whereas the Vitur score-sheet is both more complex and necessarily subjective.

Correlation between the Toda Index and grape composition: The Toda index displayed a strong correlation with the phenolic composition of the grapes (Tabs 1, 2 and 3). In the three years studied, the viticultural parameter or index that presented the best correlation with grape phenolic composition was the Toda Index in all cases (data not shown). Therefore, the following tables only show the correlations of the aforementioned index and the correlations of the parameters from which it originated (CSA/Y and ShL) with grape composition.

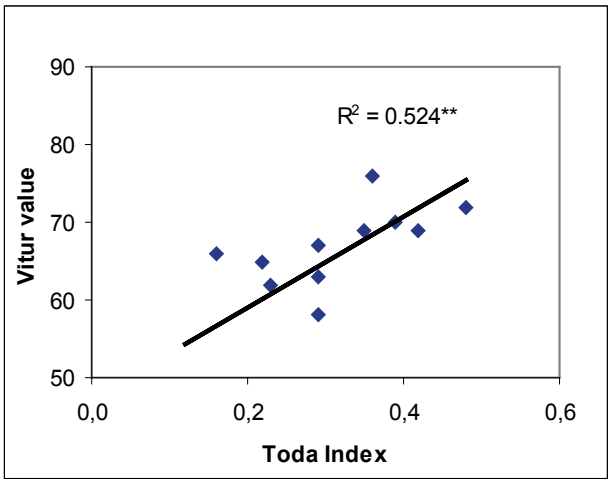

Fig. 2: Significant correlation between Vitur value and Toda Index in 'Tempranillo' vineyards in 2003 ($p < 0.01$). The correlation coefficient R^2 and the fitted straight line are shown.

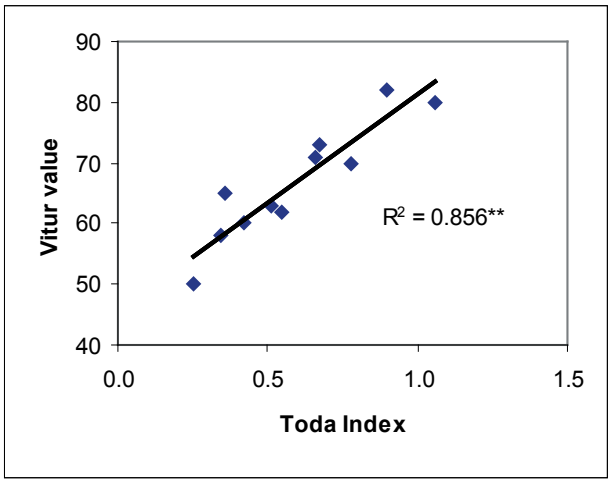

Fig. 3: Significant correlation between Vitur value and Toda Index in 'Tempranillo' vineyards in 2004 ($p < 0.01$). The correlation coefficient R^2 and the fitted straight line are shown.

Tab. 1 shows the results of the analysis of linear correlation between these vineyard parameters and the chemical composition of the berries for 'Tempranillo' in 2002. There was a significant correlation between the CSA/Y parameter and grape phenolic composition, but no correlation was observed with pulp composition. The coefficient of correlation with phenolic composition improved substantially when the CSA/Y/ShL parameter was considered. Fig. 4 shows the regression analysis between the Toda Index and extractable 'Tempranillo' anthocyanins in 2002; the results were similar for regression with total anthocyanins and colour intensity. As can be seen, this parameter was a good estimator of phenolic maturity of the grapes.

Tab. 2 shows the results for 'Grenache' in 2002. The results may be interpreted in the same way as those ob-

Table 1

Correlation (Pearson's correlation coefficient and significance) between grape quality parameters and some vineyard variables (canopy surface area/yield -CSA/yield-, total shoot length and Toda Index) in 'Tempranillo' vineyards in 2002

	Extractable anthocyanins	Total anthocyanins	Total polyphenols index	Colour intensity	Sugar content	Titratable acidity	pH	Tartaric acid	Malic acid
CSA/Yield	0.690 *	0.751 *	0.135 ns	0.796 **	0.489 ns	-0.080 ns	0.276 ns	0.481 ns	-0.284 ns
Total shoot length	-0.398 ns	-0.396 ns	-0.337 ns	-0.067 ns	-0.327 ns	0.789 **	-0.410 ns	0.197 ns	0.602 ns
Toda Index	0.840 **	0.819 **	0.278 ns	0.784 **	0.508 ns	-0.479 ns	0.594 ns	0.151 ns	-0.377 ns

ns, * and ** represent not significant and significant differences at the 0.05 and 0.01 levels, respectively.

Table 2

Correlation (Pearson's correlation coefficient and significance) between grape quality parameters and some vineyard variables (canopy surface area/yield -CSA/yield-, total shoot length and Toda Index) in 'Grenache' vineyards in 2002

	Extractable anthocyanins	Total anthocyanins	Total polyphenols index	Colour intensity	Sugar content	Titratable acidity	pH	Tartaric acid	Malic acid
CSA/Yield	0.600 ns	0.766 **	-0.385 ns	0.367 ns	0.220 ns	-0.577 ns	0.204 ns	0.695 *	-0.789 **
Total shoot length	-0.239 ns	0.004 ns	-0.273 ns	-0.039 ns	-0.141 ns	0.396 ns	-0.079 ns	0.148 ns	-0.094 ns
Toda Index	0.778 **	0.807 **	-0.121 ns	0.409 ns	0.404 ns	-0.801 **	0.245 ns	0.642 *	-0.785 **

ns, * and ** represent not significant and significant differences at the 0.05 and 0.01 levels, respectively.

Table 3

Correlation (Pearson's correlation coefficient and significance) between grape quality parameters and some vineyard variables (canopy surface area/yield -CSA/yield-, total shoot length, Toda Index and Vitur value) in 'Tempranillo' vineyards in 2003

	Extractable anthocyanins	Total anthocyanins	Total polyphenols index	Colour intensity	Sugar content	Titratable acidity	pH	Tartaric acid	Malic acid
CSA/Yield	0.336 ns	0.437 *	-0.174 ns	0.464 *	0.744 **	0.092 ns	0.568 ns	0.604 *	0.125 ns
Total shoot length	-0.374 ns	-0.370 ns	-0.591 *	-0.178 ns	0.268 ns	0.490 ns	0.219 ns	0.239 ns	0.171 ns
Toda Index	0.844 **	0.919 **	0.349 ns	0.798 **	0.522 ns	-0.414 ns	0.434 ns	0.299 ns	0.030 ns
Vitur value	0.782 **	0.830 **	0.315 ns	0.807 **	0.395 ns	-0.142 ns	0.265 ns	0.512 ns	-0.127 ns

ns, * and ** represent not significant and significant differences at the 0.05 and 0.01 levels, respectively.

tained in the case of 'Tempranillo'. With 'Grenache', good correlations were also observed between the CSA/Y/ShL parameter and the phenolic composition of the grapes (extractable and total anthocyanins); no significant correlation was observed with colour intensity but significant correlations were recorded with total acidity, tartaric acid and malic acid. Tab. 3 shows the results for 'Tempranillo' in 2003. The results were similar to those obtained in 2002. Once again, highly significant correlations were observed between the CSA/Y/ShL parameter and total anthocyanins, extractable anthocyanins and colour intensity. Fig. 5 shows the regression analysis between the Toda Index and total anthocyanins; the results were similar for regression with extractable anthocyanins and colour intensity. In this year also, the CSA/Y/ShL parameter was a good estimator of grape phenolic maturity.

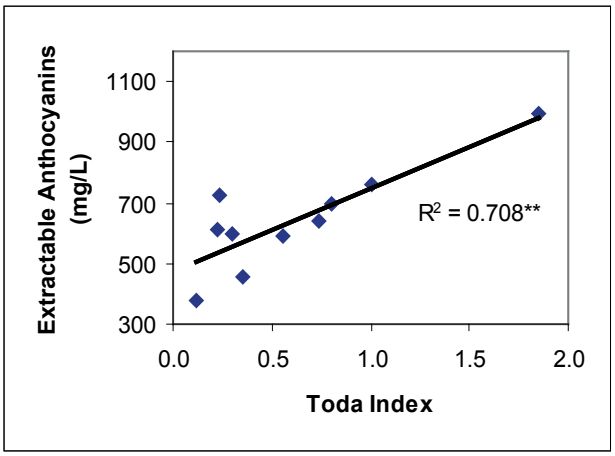

Fig. 4: Significant correlation between extractable anthocyanins and Toda Index in 'Tempranillo' vineyards in 2002 ($p < 0.01$). The correlation coefficient R^2 and the fitted straight line are shown.

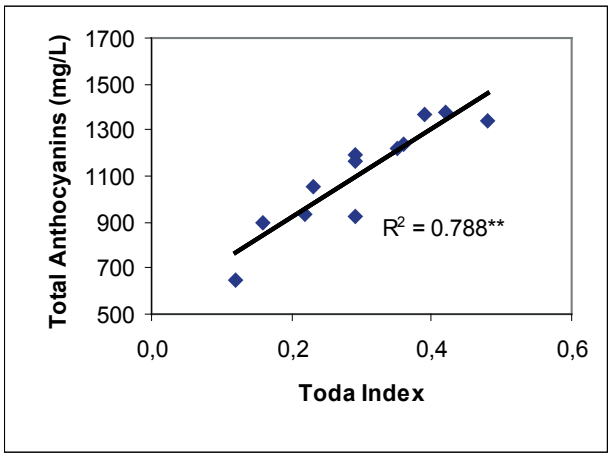

Fig. 5: Significant correlation between total anthocyanins and Toda Index in 'Tempranillo' vineyards in 2003 ($p < 0.01$). The correlation coefficient R^2 and the fitted straight line are shown.

Based on these results, we may conclude that in these experimental conditions the Toda Index was a good estimator of grape phenolic composition.

Tab. 3 shows, for the 'Tempranillo' variety in 2003, the results of the correlations between grape composition, Vitur value and the CSA/Y/ShL parameter. As can be observed in this table, the Vitur value presented a good correlation with grape phenolic composition, but the correlation coefficients were lower than those corresponding to the Toda Index, which indicates that this index is a better estimator of phenolic composition than the Vitur value.

Lastly, Tab. 4 shows the results obtained for the Tempranillo vineyards in 2004 in terms of the correlations of the CSA/Y/ShL parameter and the parameters from which it originated, CSA/Y and ShL, and the Vitur value with the chemical composition of grape pulp. As in the previous case, the coefficient of correlation with sugar content was probably the most significant in the Toda Index than for the Vitur value, which indicates that this index was a better estimator of sugar content than the Vitur value.

Table 4

Correlation (Pearson's correlation coefficient and significance) between grape quality parameters and some vineyard variables (canopy surface area/yield -CSA/yield-, total shoot length, Toda Index and Vitur value) in 'Tempranillo' vineyards in 2004

	Sugar content	Titratable acidity	pH	Malic acid
CSA/Yield	0.502 ns	-0.464 ns	-0.046 ns	-0.260 ns
Total shoot length	-0.413 ns	0.216 ns	-0.146 ns	0.626 *
Toda Index	0.658 *	-0.465 ns	0.024 ns	-0.480 ns
Vitur value	0.381 ns	-0.470 ns	0.168 ns	-0.353 ns

ns, * and ** represent not significant and significant differences at the 0.05 and 0.01 levels, respectively.

In this study performed in La Rioja, the Toda Index proved to be a more powerful indicator for grape quality assessment than other viticultural indexes (data not shown), including the indexes proposed by Kliewer and Dokoozlian (2005).

The Toda Index is a ratio between two parameters already known for their viticultural interest: the canopy surface area/yield ratio, and total shoot length. The power of the canopy surface area/yield ratio for estimating the equilibrium and oenological potential of the vineyard has been shown by numerous authors (Smart and Robinson 1991, Carbonneau 1995, Kliewer and Dokoozlian 2005, Tardaguila and Martinez de Toda 2005). Moreover, total vine shoot length is an indicator of the vine vigour. Therefore, the Toda Index estimates the relationship between vegetative growth-yield balance and vigour.

Conclusions

The new Toda Index, defined as CSA/Y/ShL, presented very good correlations with the vineyard quality status, determined by Vitur score-sheet. In winegrape assessment in the vineyard, Vitur score-sheet, which is necessarily subjective, could be replaced with new Toda index, which is faster and more objective.

In turn, the Toda Index displayed a very good correlation with the phenolic content of the grapes and could therefore be used to estimate this phenolic composition.

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