POLYNOMIAL RELATION BETWEEN MEAN SHOOT AREA AND MEAN SHOOT WEIGHT FOR VIGOUR CALCULATION ON CV. TOURIGA NACIONAL

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Abstract

Aim : To develop a new methodology for determining vine vigour based on a polynomial relation between mean shoot area and mean shoot weight.

Methods and results : Thirty grapevines (cv. Touriga Nacional) characterized by low, medium and high vigour were selected for a three-year study. Vine vigour was determined each year by using the traditional "mean shoot weight" methodology. At the same time, the mean shoot area of each vine was determined by using digital image processing, where RGB images (Red Green Blue) were converted to HSV images (Hue Saturation Value) and then to binary images based on the saturation values with a threshold set to 0.15. Finally, we established a polynomial relation between mean shoot area and mean shoot weight, given by the equation $f(x) = 0.0047x^2 + 0.2254x + 0.0474$, where $f(x)$ corresponds to the mean shoot weight (vine vigour estimation) and x corresponds to the mean shoot area.

Conclusions : The proposed method for calculating vine vigour based on a digital image of a vine and a polynomial relation between mean shoot area and mean shoot weight provides a highly reliable estimate of the actual vigour. Correlation for the 30 grapevines with three-year average of 99.8 %.

Significance and impact of the study : With this new methodology, it is unnecessary to determine the pruning weight and the number of shoots per plant in the vineyard. Its implementation is simple, based on a digital photography of the vine under study, and independent of the plot pruning date.

Key words : vine, vigour, digital image processing

Résumé

Objectif : Développer une nouvelle méthodologie pour déterminer la vigueur d'un cep de vigne à partir d'une relation polynomiale entre la surface moyenne et le poids moyen des sarments.

Méthodes et résultats : Des ceps de vigueur faible, moyenne et forte ont été sélectionnés selon la méthode traditionnelle de pesée des bois effectuée pendant trois ans. Pour chaque cep, la surface moyenne des sarments a été déterminée à partir d'images numériques. Les images des sarments en format RGB (Red Green Blue) ont été converties dans un format HSV (Hue Saturation Value) et soumises à une binarisation sur les données de la saturation avec le seuil de 0.15. Enfin, il a été établi une relation polynomiale entre la surface moyenne et le poids moyen d'un sarment, définie par l'équation $f(x) = 0.0047x^2 + 0.2254x + 0.0474$, où $f(x)$ représente le poids moyen des sarments (estimation de la vigueur) et x représente la surface moyenne des sarments.

Conclusions : Cette nouvelle méthodologie pour le calcul de vigueur, à partir d'une image numérique d'un cep et d'une relation polynomiale entre la surface moyenne et le poids moyen d'un sarment, fournit des résultats de vigueur avec une corrélation de 99.8 %.

Signification et impact de l'étude : Cette nouvelle méthodologie dispense du travail de taille, du comptage et du pesage des sarments. Sa mise en œuvre est simple, il suffit d'une simple photographie numérique d'un cep, et ne dépend pas de la programmation de la taille de la parcelle.

Mots clés : cep, vigueur, traitement numérique d'images

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INTRODUCTION

Vine vigour is related to the dynamics of vine growth, being characterized by shoots of large diameter and length, with long internodes, a high number of lateral shoots, secondary shoots and water-sprouts, as well as a higher leaf surface and chlorophyll concentration (dark-green shade) (Champagnol, 1984; Fregoni, 1999; Magalhães, 2008; De Toda, 2008).

Vigour is one of several viticultural parameters, acting as an indicator of the vegetative / productive balance of a grapevine and, consequently, affecting the final grape quality (De Toda, 2008).

Pruning level in terms of bud count (number of buds left per shoot after pruning) directly influences vigour. Finding the right pruning level ensures not only the best balance between fruit yield and vegetative growth for good grape maturity and quality but also more stable production from year to year and greater grapevine longevity (Magalhães, 2008). A pruning level aiming at a moderate vigour must therefore seek to determine the maximum bud count for the minimum loss in vine's growth capacity. De Toda (2008) has reported that the number of buds retained per vine directly influences leaf area, yield, quality, and therefore canopy microclimate.

Whenever the vigour is very high, due to high soil fertility conditions or a very severe pruning, the resulting excessively dense canopy (Zufferey and Murisier, 2005) creates unfavourable microclimatic conditions for fruit bud differentiation (low temperature and luminosity) (Reynolds *et al.*, 2007). A larger amount of the carbohydrates synthesized in that year is distributed to a greater number of clusters, reflecting negatively on the vine carbohydrate reserves and consequently on the capacity of the vine to produce in the following year. According to Magalhães (2008), a low productivity associated with an insufficient number of buds per shoot does not necessarily lead to better grape quality, as a result of the low leaf area development and the high shoot vigour.

On the other hand, whenever the vigour is very low, due to low soil fertility, excessively long pruning or the occurrence of various diseases or accidents, bud differentiation is also affected, in this case by the lack of carbohydrates produced (Colova *et al.*, 2007) from a smaller leaf area and the reserves accumulated elsewhere in perennial parts of the vine (Kliewer & Dokoozlian, 2005).

We can then say that the optimum bud number per shoot must be established in order to achieve the maximum productive capacity of the vine without negatively affecting its qualitative potential (van Leeuwen *et al.*, 2009). All this is achieved with the choice of a medium vigour.

Vigour estimate, expressed in vineyard practice by the mean weight of a pruning shoot, is, in view of the above considerations, an indicator of the state of the entire training system (Oliveira, 2003).

This work presents the polynomial relation obtained between mean shoot area and mean shoot weight and its use in a new method for calculating vigour based on the digital image processing of a vine.

This methodology has a National Patent Register No. 105163 (Oliveira *et al.*, 2010) and an International Patent Application No. PCT/IB2010/055592 made to the International Bureau of the World Intellectual Property Organization.

MATERIALS AND METHODS

The methodology of vigour calculation is illustrated in Figure 1. To obtain the polynomial relation between mean shoot area and mean shoot weight, a three-year study (2009, 2010 and 2011) was conducted on cv. Touriga Nacional (30 vines/year) in the Douro Region (Portugal). The selection criterion was a low, medium or high estimated vigour, i. e., to cover the whole range of values.

The polynomial relation was obtained from the three-year mean of mean shoot area and mean shoot weight according to the following methodology:

- Determination of the mean shoot weight: this corresponds to an estimate of grapevine vigour by the traditional method;

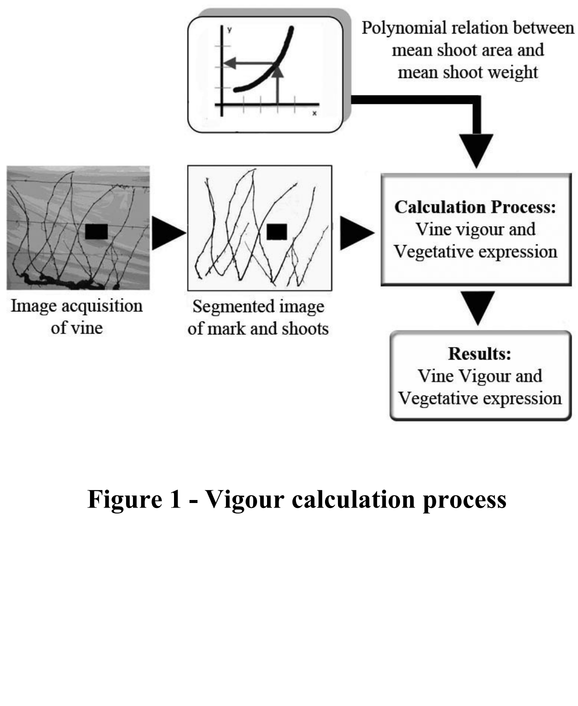

Figure 1 - Vigour calculation process

- Determination of the mean shoot area: using digital image processing; and then,

- Determination of the polynomial relation between mean shoot area and mean shoot weight.

1. Determination of the mean shoot weight

The mean shoot weight corresponds to the estimate of vine vigour by the traditional method. For each selected vine, we cut and weighted all the shoots (total pruning weight) and divided the result by the number of shoots.

As an example, Table 1 shows the three-year means of total shoot weight and mean shoot weight, expressed in grams, of some vines covering the low, medium and high range of values.

2. Determination of the mean shoot area

All the pruning shoots from each selected vine were cut into 20- to 25-cm sections and digitized in an A4 scanner. Those images were analyzed to obtain the total shoot area. The area of each digitized shoot section was determined as follows:

The area of a pixel in the image is determined from the total scanner area and the size of the digitized image matrix;

The digitized image (RGB – Red Green Blue) is converted to an HSV (Hue Saturation Value) image and then to a binary image based on the saturation values with the threshold level of 0.15, thus achieving a black and white image; and then,

The area of the shoot section is the number of black pixels multiplied by the area of one pixel.

The mean shoot area of a vine is determined from the sum of the areas of all the shoot sections of the vine divided by the total number of shoots.

$$\text{Mean Shoot Area} = \frac{\sum \text{Section Areas}}{\text{No. Shoots}}$$

Table 2 presents the three-year means of total shoot area and mean shoot area, expressed in cm^2, for the vines referred to in Table 1.

Table 1 – Touriga Nacional vigour estimation using the traditional "pruning weight" method

Vine ID	No. Shoots	Total Weight (g)	Total Weight/No. Shoots (g)
1	12	266.81	22.23
7	10	639.76	63.98
10	13	959.68	73.82
15	9	811.26	90.14
18	9	1042.01	115.78
22	8	1103.89	137.99
30	8	1401.16	175.15

Table 2 – Total and mean shoot area of Touriga Nacional grapevine using digital image processing

Vine ID	No. Shoots	Total Area (cm^2)	Total Area/No. Shoots (cm^2)
1	12	632.28	52.69
7	10	952.68	95.27
10	13	1379.17	106.09
15	9	1068.30	118.70
18	9	1226.07	136.23
22	8	1197.44	149.68
30	8	1381.84	172.73

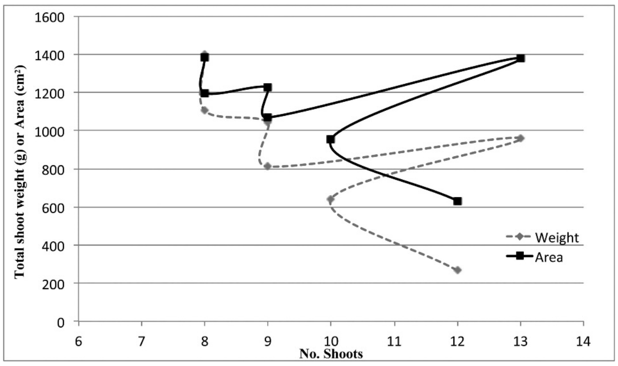

Figure 2 – Behaviour of total shoot weight and total shoot area according to shoot number. Data points correspond to the 7 vines referred to in Table 1 (total shoot weight-to-shoot number data; dashed line) and in Table 2 (total shoot area-to-shoot number data; solid line)

3. Determination of the relation between the mean shoot area and the mean shoot weight

The data presented in the previous subsections revealed a polynomial relation between mean shoot area and mean shoot weight. Those results were submitted to statistical analysis in order to determine the correlation between the vigour values obtained using the polynomial relation and the vigour values obtained using the traditional method.

RESULTS AND DISCUSSION

The year did not significantly influence the estimated vigour values recorded for the vines in the study. This is not surprising, given that vine vigour is more dependent on the pruning type performed (i. e., the number of buds left at pruning) than on the annual climatic conditions, which strongly affect, among other factors, the vine productivity and the fruit quality.

The results from these experiments showed that the weight behaviour according to shoot number was identical to the area behaviour, in all the three years (Figure 2, results are given as three-year means).

From these results, we concluded that there should be a relation between mean shoot area and mean shoot weight (vigour). Hence, we found a mathematical function (Fernandes, 1998), corresponding to a second-degree polynomial expression, which is able to describe the behaviour of the mean shoot weight as a function of the mean shoot area (Figure 3).

The polynomial equation is:

$$f(x) = 0.0047x^2 + 0.2254x + 0.0474$$

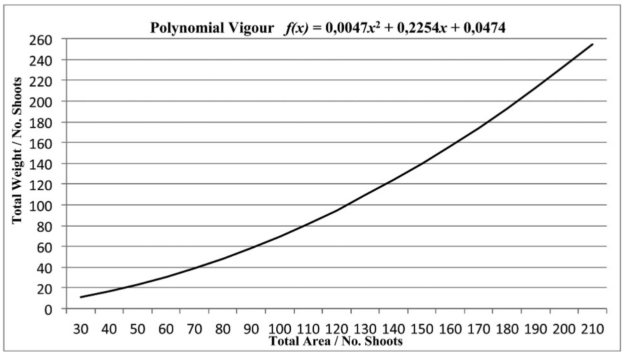

Figure 3 - Vine vigour as represented by the polynomial expression. *f(x)* corresponds to mean shoot weight and *x* to mean shoot area

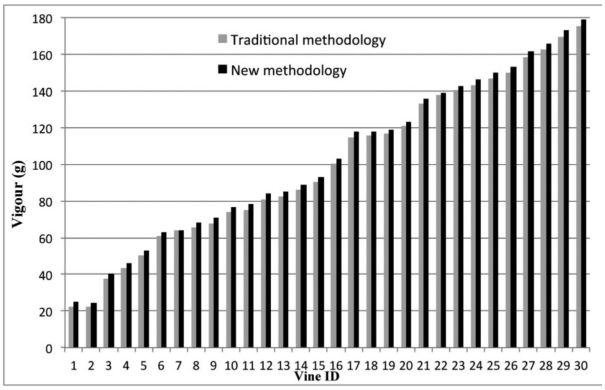

Figure 4 - Representation of the vigour obtained using the traditional method *versus* the new methodology

Where:
x corresponds to the mean shoot area
and
$f(x)$ corresponds to the mean shoot weight

For the 7 vines referred to above, Table 3 shows the three-year mean values of the mean shoot weight calculated by the traditional method and those obtained through our polynomial expression $f(x)$.

Table 4 and Figure 4 show, for all the 30 vines selected in this study, the values of vine vigour as calculated using the traditional method (total pruning weight divided by shoot number) and the new methodology (the entire plant image). The values are for the average of three years.

As can be easily seen, the results obtained using the polynomial expression are very close to those obtained by the traditional method. The correlation between the results of the two methods is 0.998.

CONCLUSIONS

The proposed method, based on a digital image of a vine and a polynomial relation between the mean shoot

Table 3 – Mean shoot weight as calculated by the polynomial relation *f(x)* and by the traditional method

Vine ID	*x*=Total Area/No. Shoots (cm^2)	*f(x)* = Total Weight/No. Shoots (g)[a]	Total Weight/No. Shoots (g)[b]
1	52.69	24.97	22.23
7	95.27	64.18	63.98
10	106.09	76.86	73.82
15	118.70	93.03	90.14
18	136.23	117.98	115.78
22	149.68	139.08	137.99
30	172.73	179.21	175.15

[a]Data obtained using the polynomial equation $f(x)$=0.0047x2 + 0.2254x + 0.0474
[b]Data obtained using the traditional method, as reported in Table 1

area and mean shoot weight, gives a very good estimate of grapevine vigour.

This new methodology simplifies the vigour determination in the vineyard. Its application is simple (based on a vine image) and does not depend on the pruning date of the plot under study. The error obtained using this methodology is minimal compared with the traditional method (correlation of 99.8 %).

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