USE OF NON-INVASIVE RGB IMAGING TO ASSESS THE CANOPY STATUS IN ORGANIC VITICULTURE

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Abstract

In organic viticulture, canopy features such as leaf area, canopy porosity and fruit exposure are critical due their impact on fungal disease incidence and grape composition. An adequate and accurate assessment of the canopy status is the first step towards appropriate and effective grapevine canopy management, therefore an easy, non-invasive, robust method to evaluate the main features of a grapevine canopy is needed. In this work a protocol for canopy status assessment based on non-invasive RGB imaging is presented and used to ascertain differences in the canopy status of grapevines grown under different degraded and non-degraded soil conditions. RGB images were processed using a classification algorithm based on the Mahalanobis distance, and then the pixels were classified in four classes: clusters, leaves, gaps and shoots. Overall, higher leaf exposure was observed in vines grown in non-degraded soil while the highest percent of gaps or canopy porosity corresponded to vines of the two cover crop treatments.

Keywords: *image analysis, leaf exposure, cluster exposure, canopy gaps, porosity, soil management*

Introduction

In viticulture, canopy features such as leaf area, canopy porosity and fruit exposure are key factors that configure the so called canopy status, which can be regulated by canopy management practices. These practices are aimed at achieving an adequate balance between the grapevine vegetative and reproductive growth, but also at balancing the need for sunlight capture for photosynthesis as well as gaps to allow airflow through the canopy to reduce humidity and favour the production of healthy fruit (Smart and Robinson, 1991). If canopy management is important in conventional viticulture, it is indeed critical in organic viticulture as lowered fungal and disease incidence is favoured by a proper canopy management (Austin et al. 2011). An adequate and accurate assessment of the canopy status is the first step towards appropriate and effective canopy management, therefore an easy, non-invasive, robust method to evaluate the main features of a grapevine canopy is needed. One of the most common ways of quantifiably assessing canopy porosity, leaf density and fruit exposure is Point Quadrat Analysis (PQA) (Smart 1987). PQA is based on the insertion of a probe through the canopy of grapevines and counting

the number and sections of the vine the probe comes into contact with: leaves, clusters, canes, or gaps. In addition to being subjective, PQA is labour and time consuming, and can potentially damage the fruit. RGB (red, green and blue) computer vision is a non-invasive technology which involves the acquisition, analysis and interpretation of useful information from a single RGB image or a sequence of images. The use of computer RGB vision outdoors has been used to characterize traits of the grapevine canopy (Tardaguila et al. 2010; Hill et al. 2011; Diago et al. 2012, 2016). However, special care in the methodology to acquire the images, which is a critical step, has to be paid as uncontrolled lighting conditions and the presence of confounding elements from adjacent vineyard rows are two issues which complicate RGB imaging in the vineyard. Therefore, the main goal of this work was to define a straightforward, easy-to-use protocol to assist the grapegrowers and viticulturists in the process of RGB photographing of grapevines to identify their canopy status, hence to provide useful information to take canopy management decisions. The main results of the assessment of the canopy status in an organic vineyard subjected to different soil management, obtained using the defined RGB imaging protocol, are presented.

Materials and methods

Definition of the protocol for RGB imaging of grapevine canopies

The following steps provide instructions of the proper way to manually acquire RGB images of grapevine canopies in the vineyard.
1. The vines should be photographed under similar natural light conditions (within one hour time frame approximately), and with diffuse light preferably. A standard digital reflex camera of good resolution 10 -14 megapixels with a flash light, in order to minimize shadows in the canopy, should be used. The camera should be mounted on a tripod set vertical to the canopy 2 meters away from row axis and at 1.00 m above the ground (Figure 1).
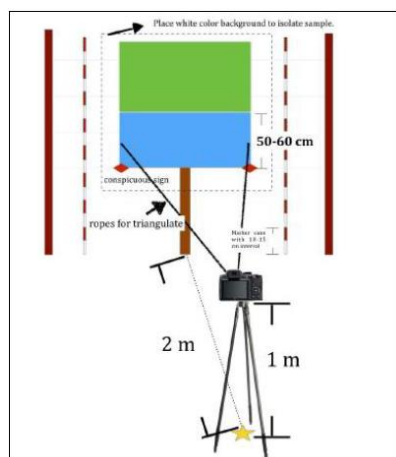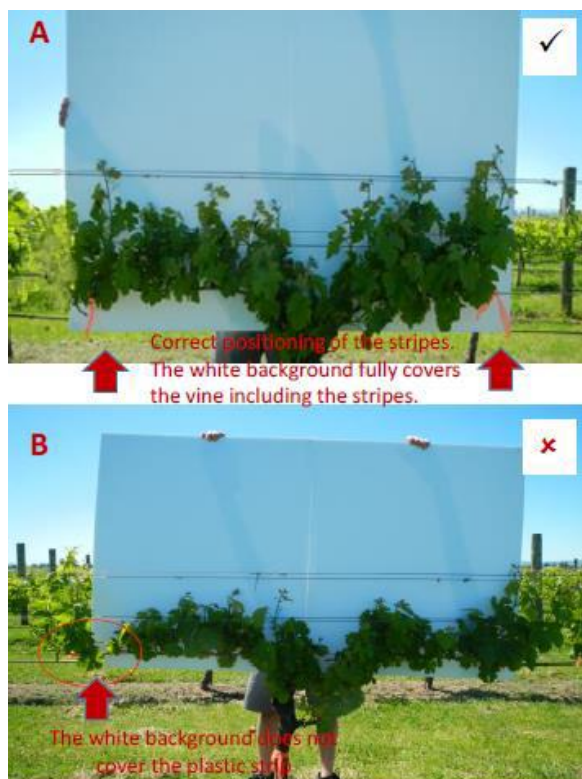

Figure 1
Correct positioning of the camera and additional features for proper image acquisition.

Different shadowing may occur from the influence of changing natural lighting conditions and the time of image acquisition. However, the algorithm processing the images can handle this variability. The only recommendation is to acquire all images to be compared on a given set at the same timing and light ambient conditions.

2. Put conspicuous signs (orange or red strips) in the two ends (both cordons) of the canopy. Alternatively, two woody or plastic canes can also be used instead of the plastic strips (Fig. 1). All images should be taken from the same point at the same distance. For this, it is advisable to define a "triangle" with two ropes or strips so that the position of the camera (with a tripod) does not change from the first date until the end of photo shooting period if temporal series of images are aimed (Fig.1).

3. In order to avoid the canopies of adjacent vines being photographed, thus interfering with the image of the vine of interest, a white cloth, paper, screen, background should be placed behind the canopy of the vine to be photographed (Fig. 2). All images should have the same number of pixels and field of view, to facilitate their comparison in temporal series. Figure 2 shows examples of correct and incorrect placement of the background.

Figure 2
(a) Correct positioning of the white background, as it fully covers the whole grapevine, including the two plastic stripes. (b) Wrong positioning of the background as it does not fully cover the vine, either the plastic stripe at the end.

4. Finally, the camera's automatic mode should be used to obtain the optimal images to be analysed in any weather condition.

5. Picture editing with any photo or image editing software is not recommended, only renaming the pictures indicating the grape variety, grapevine number, treatment and date of acquisition.

Testing of the protocol in a commercial organic vineyard

Image acquisition of grapevine canopies was conducted following the developed protocol one week after veraison in season 2017 at El Molino organic commercial vineyard at Bodegas Puelles (lat. 42º34'44.1''N; long. 2º42'24.0''W; Ábalos, La Rioja, Spain). The vineyard (called Plot A) was planted in 2006 with Tempranillo (clone ISV-F-V6 planted on rootstock SO4) vines following N-S orientation. Three replicates or experimental plots were delineated. These were located in soil degraded areas (by erosion mainly) of the vineyard. All of them were dry-farmed, spur-pruned on a bilateral cordon to retain eight spurs and two buds per spur and trained onto a vertical shoot positioned (VSP) trellis system with 2.5 m row spacing and 0.8 m vine spacing. For each experimental plot, four soil management treatments were applied (each treatment involved three rows): 1. Traditional tillage; 2. Compost (addition of mature manure at a dose of 25 T · ha^{-1}); 3. Green manure (cover crop with barley (150 Kg·ha^{-1}) and faba bean (200 Kg·ha^{-1}); the cover crop was mowed and incorporated to the soil); 4. Dry mulching (cover crop with oat (150 Kg·ha^{-1}) and Alfalfa (40 Kg·ha^{-1})) (Figure 3). Additionally, a non-degraded (Tillage non-degraded) soil zone was also considered close to each subplot, where tillage was performed. For each treatment and replicate, five different grapevines were photographed.

Figure 3
Experimental layout of the different soil management treatments applied.
(ND) Tilling, non-degraded;
(1) Traditional tillage;
(2) Compost (addition of mature manure at a dose of 25 T · ha^{-1});
*(3) Green manure (cover crop with barley (150 Kg·ha^{-1}) and faba bean (200 Kg·ha^{-1});*
(4) Dry mulching (cover crop with oat (150 Kg·ha^{-1}) and Alfalfa (40 Kg·ha^{-1})).

RGB images were processed with Matlab, using a classification algorithm based on the Mahalanobis distance (Mahalanobis, 1936). This algorithm uses a known

sample of values to classify an unknown group of pixels into classes based on a specific vector (the RGB colour values of each pixel). The process involved two steps: the first step was the delineation of a region of interest (ROI), covering the 50 cm height, from the vine cordons, and delimited by the two conspicuous signs; the second step consisted on a supervised manual selection of a representative number of points to be used as reference (also denoted as seed) for each class. The amount of pixels corresponding to exposed leaves, clusters, gaps and shoots was calculated for each treatment in the defined ROI area of each image. Then, the ratio between the number of pixels of the leaf, cluster and gap classes and total number of pixels in the ROI, constituted the percentage of each feature respectively.

Results and discussion

An example of a grapevine canopy RGB image and its detected classes of exposed leaves, clusters and gaps using the described methodology is shown in Figure 4.
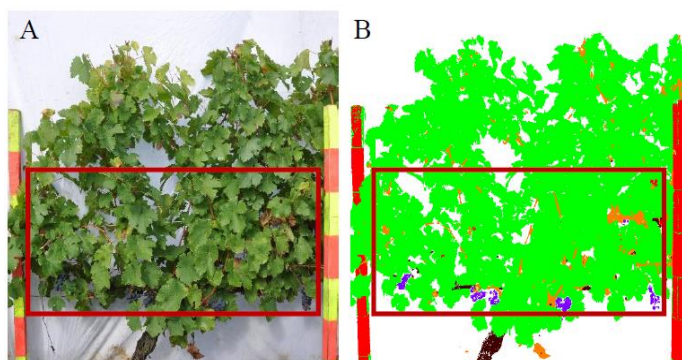
Figure 4
Grapevine canopy (a) RGB image, and (b) manually processed image using the pixel classification (purple: clusters, green: leaves, white: gaps o porosity and brown: shoots). The region of interest (ROI) is shown as the red rectangle.

The results obtained from the analysis of the RGB images of the grapevine canopies corresponding to the different soil treatments in the three replication plots are shown in the plots of Figure 5.

As observed, significant differences in the percentage of exposed leaves, clusters and gaps per vine were found using the RGB imaging method among the different soil treatments. The highest percentage of exposed leaves was observed for the vines growing in non-degraded soils (Figure 5a). The plants corresponding to the two cover crop treatments (green manure and dry mulching) exhibited much lower exposed leaf area (up to 50% less) than those of non-degraded soil and around a 30% less than the vines growing in degraded soils managed with tillage or compost addition (Figure 5a). In terms of cluster exposure (Figure 5b) and the percent of gaps (also denoted as canopy porosity), the lowest values were observed for the grapevines of non-degraded soils (Figure 5c). Specifically, for the canopy porosity, which favors air ventilation and light penetration, that are two phenomena highly aimed in organic viticulture, the highest percent of gaps (20%) was found in grapevines corresponding to the two cover crop treatments (Figure 5c).
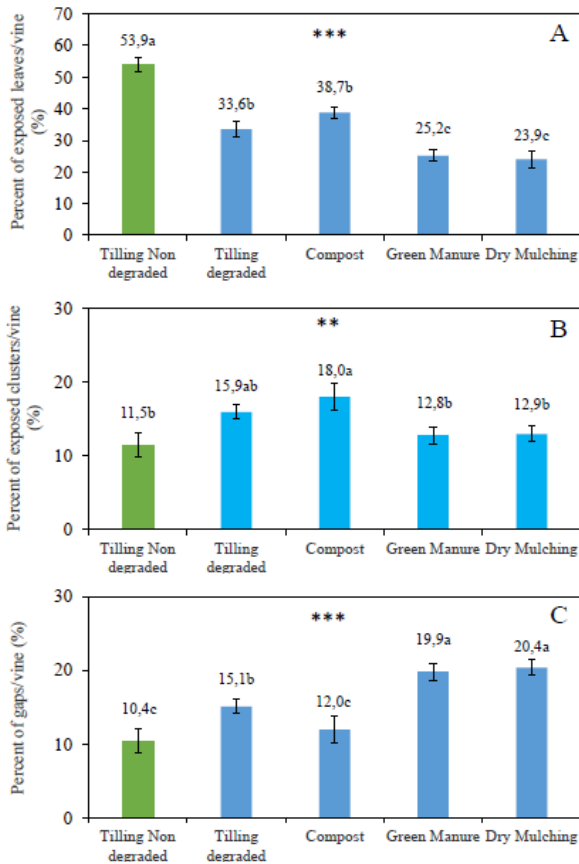
Figure 5

Amount of pixels, expressed in percentage (%) in each grapevine RGB image corresponding to (a) exposed leaves, (b) exposed clusters, and (c) gaps (n=15).

These values are in the range of optimum percentage of canopy gaps defined in previous works by Palliotti and Silvestroni (2004) and (Smart 1987), who reported ideal % of gaps between 10-20% and 20-40%, respectively. For a given soil treatment, such as tillage, the RGB image analysis revealed significant differences in the canopy status for the percentage of exposed leaves (Figure 5a) and canopy porosity (Figure 5c) between degraded and non-degraded areas.

Finally, a comparison of the canopy status between plants growing in non-degraded and degraded soils (comprising the four different soil treatments) is presented in Table 1.

Table 1. *Summary of the canopy status of grapevines grown in degraded (n=20) and non-degraded (n=5) soils, as determined by non-invasive, RGB image analysis.*

Parameters	Degraded soil	Non-degraded soil	p-value
Percent of exposed leaves/vine(%)	30.34b	53.94a	<0.001
Percent of exposed clusters/vine (%)	14.90a	11.46b	0.033
Percent of gaps/vine (%)	16.83a	10.44b	0.001

Overall, significantly lower percentage of exposed leaves was observed in plants corresponding to degraded soils, while the opposite was found for cluster exposure and canopy porosity.

Conclusions

The developed RGB image-based methodology has enabled the assessment of the canopy status of grapevines growing under various soil conditions in an easy and non-invasively way. The methodology is inexpensive and can be used to objectively assess the canopy status without damaging the plants, to help in management decision making and to identify differences among treatments.

Acknowledgments

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