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USING IMAGE ANALYSIS FOR ASSESSING DOWNY MILDEW SEVERITY IN GRAPEVINE

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Abstract

Aim: Downy mildew is a crucial disease in viticulture. In-field evaluation of downy mildew has been classically based on visual inspection of leaves and fruit. Nevertheless, non-invasive sensing technologies could be used for disease detection in grapevine. The aim of this study was to assess downy mildew severity in grapevine leaves using machine vision.

Methods and Results: Leaf disks of the cv Pinot Noir (*Vitis vinifera* L.) were placed in Petri dishes with the abaxial side up. *Plasmopara viticola* sporangia were collected from infected leaves in the vineyard and used for the experimental inoculation of the leaf disks in laboratory. Images of Petri dishes including different levels of downy mildew infection were taken using a digital RGB camera. Machine vision techniques were used to estimate downy mildew severity (percentage of pixels representing visual symptoms) on the leaves. The symptoms were evaluated by eight experts, visually estimating the percentage of area showing sporulation. Considering the average evaluation of the experts, the assessment obtained by the new developed algorithm based on computer vision was represented as a R^2 value of 0.82 and RMSE of 14.34%.

Conclusions: The results show a strong correlation between the severity computed by machine vision and the visual assessments, opening the possibility of the automated evaluation of downy mildew severity using non-invasive sensors.

Significance and Impact of the Study: The results indicated that machine vision can be applied for assessing and quantify visual symptoms of downy mildew in grapevine.

Keywords: Grapevine, downy mildew, non-invasive phenotyping tools, imaging, machine vision

Introduction

Downy mildew, caused by the oomycete *Plasmopara viticola,* is a key disease in world viticulture (Gessler *et al.,* 2011). Nowadays, the evaluation of disease severity is mostly based on visual assessments of leaves or histological laboratory analysis (Toffolatti *et al.,* 2016). However, these techniques to assess grapevine diseases are time-consuming, require trained personnel and almost all of them are destructive.

New technologies and artificial intelligence have been recently applied to plant disease detection (Oerke *et al.,* 2016). Machine vision, a non-invasive technology has been developed and used for diseases identification in grapevine and other fruit trees (Yang *et al.,* 2019; Zhu *et al.,* 2020). These tools are considered robust and reliable systems, capable to assess and quantify the symptoms caused by different pathogens in the vineyard.

The aim of this study was to use machine vision techniques to automatically assess downy mildew severity in grapevine leaves.

Materials and Methods

Leaf disks of the cv Pinot Noir (*Vitis vinifera* L.) were placed in 16 Petri dishes with the abaxial side up. Disks were inoculated with a suspension of *P. viticola* sporangia ($5x10^4$ sporangia/mL) obtained from infected leaves in the vineyard. At the end of the latency period, images of disks showing white sporulation were taken in the laboratory with a digital RGB camera.

Machine vision techniques were used to automatically estimate downy mildew severity in grapevine leaf disks (Figure 1). This methodology consists of three main steps: pre-processing of the image, application of a filter to visualize the downy mildew infection, and calculation of infected pixels per leaf disk using new algorithms.
For the validation, eight experts visually evaluated each leaf disk and assigned a percentage of downy mildew severity according to the visual area showing sporulation.

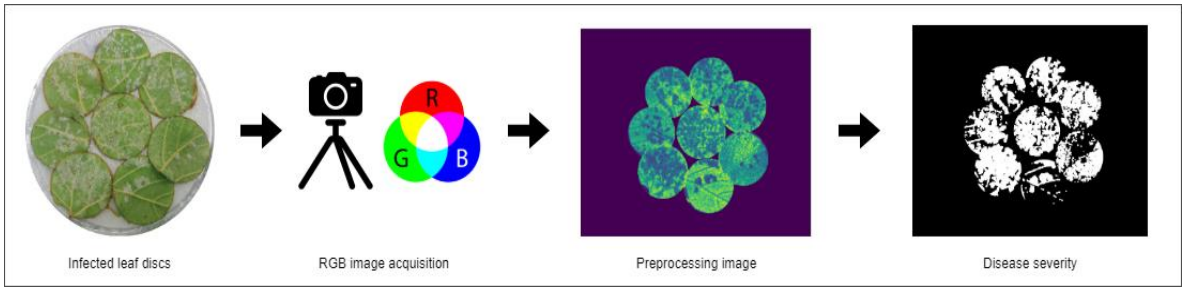

Figure 1: Computer vision process used to assess downy mildew severity in grapevine leaves.

Automatic evaluation of leaf disks was performed in two-stages, detection of pixels presenting downy mildew symptoms and disease severity calculation for each leaf disk. The first stage was divided into three steps, where different computer vision techniques were applied. First, the discs were located using the Hough Transformation (Yuen *et al.,* 1990). Then the images were processed, highlighting the disease symptoms represented in the images using the HSV (Hue-Saturation-Value) colour space, the median filter and the CLAHE equalization (Pizer *et al.,* 1987). Finally, each image was segmented by colour, using the multilevel threshold with the Otsu method (Liao *et al.,* 2001) to find the correct colour threshold to separate the pixels between the disease symptoms and the rest. By the other hand, the second stage consisted in calculating downy mildew severity on each disk considering the pixels of the disk labelled as disease symptom.

Automatic evaluation was compared with the average of the experts' visual evaluation using the metrics coefficient of determination (R^2) and Root Mean Squared Error (RMSE).

Results and Discussion

Computer vision techniques made it possible to quantify the symptoms of downy mildew in grapevine leaves (Figure 2). In most of the discs the evaluation provided by the experts was similar to the one obtained automatically (data not shown). Comparing the average evaluation of the experts with the one obtained automatically, an R^2 of 0.82 and an RMSE of 14.34% were obtained.

Figure 2: Example of automatic severity estimation and location by machine vision of downy mildew symptoms (light red areas) in grapevine leaf disks.

These results demonstrate a strong relationship between computer vision and visual downy mildew assessments in grapevine leaves. As automated disease detection using computer vision could be translated into faster assessments than human supervision, it could cover a wider range of applications, including the fast assessment of one or several plants in one image, or even on-the-go solutions.

Conclusions

Computer vision techniques can be used for the estimation of downy mildew severity in grapevine. Furthermore, these techniques offer the location of downy mildew symptoms in the leaves. These new technologies and data analysis have shown promising results for the automatic estimation of downy mildew disease severity in grapevine.

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