Canopy temperature mapping with a vineyard robot

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Abstract. *The wine industry is a strategic sector in many countries worldwide. High revenues in the wine market typically result in higher investments in specialized equipment, so that producers can introduce disruptive technology for increasing grape production and quality. However, many European producers are approaching retirement age, and therefore the agricultural sector needs a way for attracting young farmers who can assure the smooth transition between generations; digital technology offers an opportunity to fulfill both needs in commercial vineyards. In this scenario, agricultural robots emerge as a novel approach to monitor key agronomical parameters and carry out specific agricultural operations. With the aim of reducing the breech between technology and grape growers, Europe is strongly supporting the practical application of new technologies and digital solutions in such a traditional crop as wine-producing vineyards. VineScout is an industry-driven consortium funded by the European Commission with the goal of industrializing previous prototypes developed under the EU project VineRobot. The Vinescout concept departs from a Technology Readiness Level (TRL) of 6/7, and is committed to yield a commercial prototype at TRL 9. The new robot is designed to be medium-size (100 kg), cost-efficient, and energy-saving with only electric drives, lithium batteries, and solar panels. This paper describes the advances carried out during the first year of the project, and how crucial challenges are being negotiated under a user-centered design. Assessing and mapping the spatial variability of vine water status in vineyards constitute a major challenge, especially in the current context of climate change. An effective, non-destructive, sampling system capable of providing a large amount of accurate observations is needed to define a sustainable irrigation scheduling. Field tests conducted over the summer in 2017 revealed the potential of automated monitoring for understanding water stress in vines. The VineScout robot was able to generate reliable temperature maps of the grapevine canopy in real time, non-invasively, and on-the-fly with a cost-efficient infrared radiometer.*

Keywords. *Water status, agricultural robots, autonomous navigation, infrared radiometers, real-time mapping, precision farming, on-the-fly temperature assessment.*

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Introduction

The wine industry is a strategic sector in many countries worldwide. High revenues in the wine market typically result in higher investments in specialized equipment, so that producers can introduce disruptive technology for increasing grape production and quality. However, many European producers are approaching retirement age (Mikio Umeda, personal communication in CIGR conference 2018), and therefore the agricultural sector needs a way for attracting young farmers who can assure the smooth transition between generations; digital technology offers an opportunity to fulfill both needs in commercial vineyards. In this scenario, agricultural robots emerge as a novel approach to monitor key agronomical parameters and carry out specific agricultural operations. With the aim of reducing the breech between technology and grape growers, Europe is strongly supporting the practical application of new technologies and digital solutions in such a traditional crop as wine-producing vineyards. VineScout is an industry-driven consortium funded by the European Commission. The Vinescout concept departs from a Technology Readiness Level (TRL) of 6/7, and is committed to yield a commercial prototype at TRL 9. Assessing and mapping the spatial variability of vine water status in vineyards constitute a major challenge, especially in the current context of climate change. Heterogeneous precipitation patterns and longer periods of drought are forecast due to climate change (IPCC, 2014). Water scarcity may result in severe plant water deficit stress, which may negatively impact vegetative growth, yield and wine composition (Chaves et al., 2007). In this context precise irrigation is nominated as the only choice to deal with limited water resources and to prevent grapevines from water deficit stress. Precision irrigation can be defined as the irrigation regime that fits, in timing, duration and amount, to the actual crop needs, at the smallest manageable scale, to achieve the aimed crop performance (Cohen et al. 2005). The plant water status (expressed in terms of water potential, Ψ) has been shown to significantly within a single vineyard plot (Taylor et al., 2010). Therefore, assessing and mapping the spatial variability of vine water status within vineyards constitute a major challenge (Bellvert et al., 2016). To achieve it, an effective sampling system, capable of providing a large amount of accurate observations is required to drive accurate irrigation decision-making. Infrared radiometry, also called thermography, refers to the technique of measuring radiant energy, specifically in that portion of the total electromagnetic spectrum lying within the infrared region (wavelengths between 3 µm and 13 µm). The recorded temperature of the object of interest, in this case, the grapevine leaves, is related to the plant water status, as demonstrated in previous works (Jones et al. 2002).

This paper describes the advances carried out during the first year of the project towards the development of an effective, non-destructive, vineyard monitoring system using a cost-efficient infrared radiometer capable of providing a large amount of data, being the final objective to acquire accurate observations to define a sustainable irrigation scheduling.

Materials and methods

VineScout prototype was tested during summer in a Portuguese commercial vineyard. The field trials took place in Quinta do Ataíde property of Symington Family Estates (Coordinates: 41.24484041 North, 7.114694504 West) on 29-30 August 2017. The robot went through the vineyard rows autonomously driven at a speed of approximately 1 km/h. The headland turns were done manually with a joystick linked to the robot through a wire. An infrared radiometer (Apogee Instruments, Inc., SI-421, Logan, Utah, USA) was located on the robot's pole, facing to the right side of the vineyard canopy (Fig.1).

(a) **(b)**

Fig 1. (a) VineScout robot during 2017 summer tests in Quinta do Ataíde (Portugal) commercial vineyard; (b) close up of the infrared radiometer installed and used for plant water status contactless monitoring.

The sensor took data while the robot was moving forward through the field. Once the robot scanned around great part of the field, temperature data were retrieved.

Results and discussion

Infrared thermography is a technique based on the relationship between leaf stomatal closure or aperture and its surface temperature (Jones et al. 2002). When leaf transpires, water is lost through stomata and leaf temperature decreases. However, if transpiration stops, leaf temperature increases as no heat dissipation occurs. Following this physiological rationale, for a given grapevine variety, the highest the leaf temperature, the highest the water deficit of the plant. The temperature map registered during the experimental session is shown in Fig. 2. Hence in the map of Fig. 2, where grapevine canopy temperatures ranged from 20 to 40 ºC, the upper and lower areas of the plot (denoted in orange color) exhibited higher leaf temperature (around 35 ºC on average) than the central part of the plot (in green), where average temperature values of 30ºC were recorded.

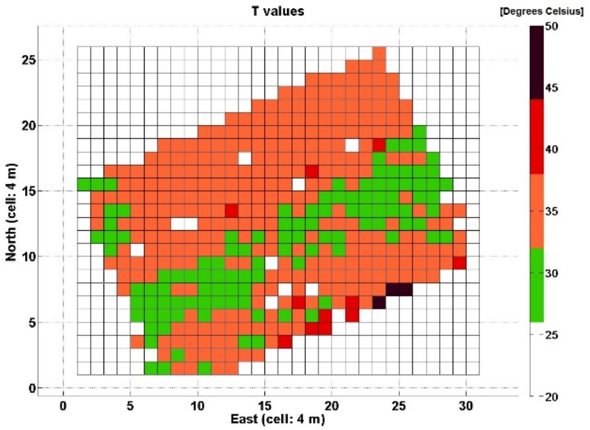
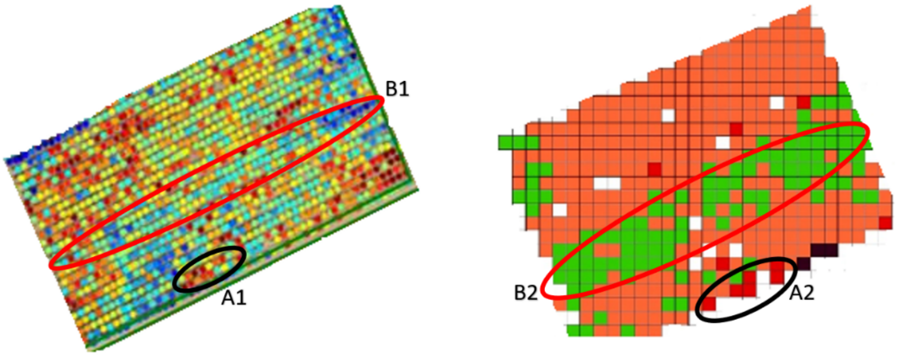


Fig 2. Canopy temperature in Quinta do Ataíde (Portugal) during August 2017 trials.

The vigor map in Fig. 3a was taken about 15 days before the tests with the robot of Fig 3b. This temperature map is the first test done from a robotic platform, and was registered in August 2017. Adjustments regarding map resolution should be made in the future to facilitate parameter correlation, but some conclusions can be derived from the maps. The thermal variation, indicated through color changes in Fig. 3, is probably related to zones of different vegetative vigor. For instance, the lowest vigor is found in the A1 zone of Fig 3a, which corresponds to zone A2 in Fig 3b. On the contrary, the high vigor zone represented by the blue area of the NDVI map labeled in Fig. 3a as B1 zone, is connected to the green part of B2 zone in Fig. 3b. The thermal variation is, therefore, related to the variation of vigor, as plants with high transpiration have lower temperature.



(a) (b)

Fig 3. Remote-sensed map vigor with NDVI (a), and ground robot-sensed temperature map (b), for the same area.

The autonomous monitoring of vines with the IR radiometer installed in the VineScout prototype has enabled the assessment of the spatial variability of the vineyard temperature status, displayed in the map of Fig. 2. This map will enable the delineation of zones with differentiated plant water status, hence the potential definition of different irrigation protocols, which eventually will contribute to a more sustainable, optimized and precise water management of the vineyard.

Conclusion

Field tests conducted over the summer in 2017 revealed the potential of automated field monitoring for understanding the variability of water stress in vines within a vineyard plot. The VineScout robot was able to generate reliable temperature maps of the grapevine canopy in real time, non-invasively, and on-the-fly with a cost-efficient infrared radiometer. Delineation of differentiated zones within the vineyard plot was achieved, and this information is valuable to define precise irrigation protocols towards a more sustainable and optimized water management in viticulture. Future tests will focus on improving the resolution and precision of field maps for a better ground-truth correspondence.

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