MONITORING OF OLIVE TREES TEMPERATURES UNDER DIFFERENT IRRIGATION STRATEGIES BY UAV THERMAL INFRARED IMAGERY

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ABSTRACT

With the continuous escalation of global warming and consequent water scarcity, techniques to optimize water use of irrigation in agriculture are needed. Thus, deficit irrigation strategies (DI) can be used for a sustainable water usage. However, it is necessary to recursively monitor plant response under DI to ensure their productivity and prevent from severe water stress. This study intends to evaluate canopy and soil surface temperatures of olive trees under different irrigation strategies, through thermal infrared images obtained by Unmanned Aerial Vehicle (UAV). The temperatures from the different irrigation strategies were analysed with three approaches using the difference between canopy and air temperatures (Tc-Ta). The use of UAV-based thermal infrared imagery has proven to be extremely useful to the estimation of olive canopy and soil surface temperatures, which allow to discriminate different irrigation treatments.

Index Terms— deficit irrigation, water stress, precision agriculture, unmanned aerial vehicles, remote sensing

1. INTRODUCTION

Nowadays, agricultural activities are responsible for about 70% of fresh water usage worldwide [1]. In a global warming scenario, irrigation management is important for optimization of water use in agriculture [2]. Adoption of deficit irrigation strategies (DI) allows to preserve water resources with a minimum impact in the yield being suitable for regions where water is scarce and improving water productivity is a goal [3]. DI is an irrigation strategy that water supply is below crops water needs, allowing a development of a certain level of water stress. This strategy can be applied either during a particular period or throughout the whole growing season [4]. Some authors reported that DI could increase net farm income [5, 6]. The potential returns of DI derive from the increased water productivity and diminished water costs of irrigation [4]. However, the adoption of DI implies appropriate knowledge of crop evapotranspiration (ET), its response to water deficits, including the identification of critical crop growth stages, and the economic impacts on yield reduction [7]. Therefore, it is extremely crucial to evaluate either physiological and agronomic plant response to a water deficit imposed by a DI strategy. The former can be performed by monitoring water stress indicators [8, 9]. Relative Water Content (RWC) and Leaf Water Potential (LWP) are wildly used to evaluate plant water status [10, 11]. However, these methods are laborious, time-consuming and destructive.

Thus, it is necessary to develop new expeditious and non-destructive methods to monitor plants water stress. With the emergence of UAVs, which are capable of carrying different types of sensors, many authors have investigated their potential in precision agriculture [12]. For the purpose of water stress monitoring, some authors proposed the use of aerial thermal infrared (TIR) imagery in vineyard [13], palm trees [14] and peach trees [15]. Nevertheless, TIR monitoring is strongly dependent on plant architecture and on environment [7].

Therefore, the aim of this study is to estimate olive canopy temperature by aerial thermal imagery under different irrigation strategies. The difference of canopy temperature and air temperature was used to establish correlations with measured plant water stress indicators.

2. MATERIAL AND METHODS

2.1. Study area description

This study was carried out in a commercial olive orchard (*Olea europaea* L. cv Verdeal) located at Lamas de Orelhão, Mirandela, Portugal (41°25'32.2" N; 7°17'16.8" W; Altitude: 313 m), a typical olive growing area of the northeast of Portugal. The olive orchard area is about 2 ha with olive tree spacing 7 m × 7 m apart, drip irrigated and was submitted to six irrigation regimes (Fig. 1): two well-watered (WI), irrigated with 120 and 100% of estimated ET; two sustained deficit irrigation (SDI), irrigated with 60 and 30% of ET; and two regulated deficit irrigation (RDI), irrigated with 100 and 60% of ET in sensible water deficit stage of olive and reducing to 15% or interruption of watering during fruit pit hardening (~1 month). Crop water requirements, was estimated according the approach described in [16].

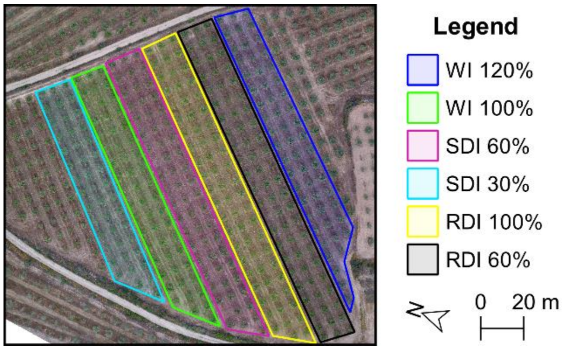

Fig. 1. Aerial overview of the studied olive orchard with the defined irrigation strategies.

2.2. Data acquisition and photogrammetric processing

Field measurements of shoot water potential (Ψ_F) and relative water content (RWC) were made according the methodology described in previous works [9]. Stomatal conductance (g_s) was also measured in leaves turning the sun at noon solar.

A fixed-wing UAV, the senseFly's eBee (senseFly SA, Lausanne, Switzerland) equipped with the sensor senseFly Thermomap was used for TIR imagery acquisition. For the planning and execution of the flight mission, the eMotion application (senseFly SA, Lausanne, Switzerland) was used. The flight was performed on 10 September 2019, with air temperature (Ta) of 35 °C, at 75 m height, with forward and side overlap of 90% and 75%, respectively, resulting in a spatial resolution of 17 cm. On this date, the phenology stage was phase III of the fruit development.

The acquired TIR imagery was processed using the Pix4Dmapper Pro software (Pix4D SA, Lausanne, Switzerland), being produced an orthorectified raster with the land surface temperature. Then, the temperature value of each pixel was subtracted by the air temperature (Ta) in the time of the flight, to obtain the Tc – Ta [17].

2.3. Data analysis

The difference between surface temperature and air temperature (Ta) was analysed through three approaches: (1) canopy temperature values (Tc); (2) drip lines temperature values (Tdl), which includes canopy and wet soil in the drippers zone; and (3) treatment blocks values (Ttb), considering the values of the canopy, wet and dry soil around the olive trees and shadows. As for the canopy approach, circles with 2 m of diameter were overlaid in the TIR imagery in the centre of each olive tree (mean diameter of ~3 m). This approach was selected in order to minimize soil temperature interference. In the second approach, a line with 100 m of the irrigation lines were selected and a buffer of 1.5 m was applied, covering the irrigation lines per treatment. Lastly, the treatment blocks were analysed using a polygon with an area of 1500 m, in each treatment.

3. RESULTS AND DISCUSSION

The orthorectified land surface temperature from the acquired TIR imagery for olive orchard is presented in Fig. 2.

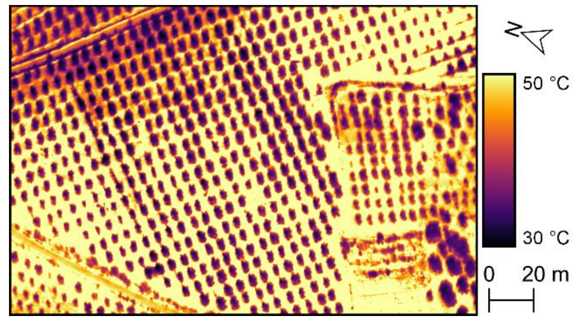

Fig. 2. Aerial thermal image of olive orchard

The mean value of the difference between surface temperature and air temperature (35 °C) of each treatment obtained for well-watered and deficit irrigation treatments were distinct in the three analysed approaches (Fig. 3).

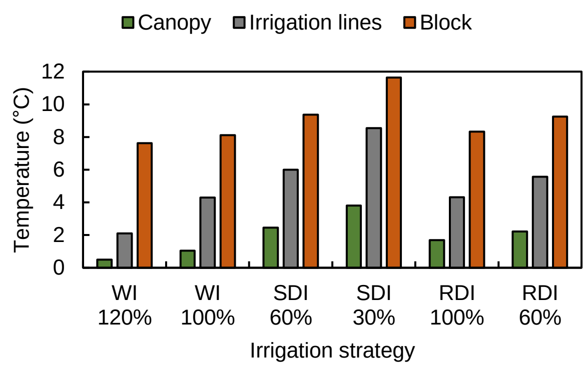

Fig. 3. Mean values of surface temperature difference and air temperature of the three approaches for different irrigation strategies

Regarding the canopy values (Tc-Ta), while the WI treatments 120% and 100% had a mean difference of 0.5 and 1.0 °C, respectively, the SDI 60% and 30% treatments had a difference of, respectively, 2.5 and 3.8 °C, an increase of 80% and 87% compared to WI 120%. Concerning the RDI treatments, the RDI 100% values was 1.7 °C and the RDI 60% had similar values to SDI 60% with 2.2 °C. The differences between RDI treatments and similar treatments are not considerable. When the UAV-based TIR data was acquired, the irrigation in the RDI treatments was already reestablished (after pit hardening phase) three weeks ago and the olive trees recovered the water deficit.

Considering the drip lines temperature values (Tdl – Ta), the differences between WI and deficit treatments were again noticeable. Whereas WI 120 and 100% had values of 2.1 and 4.3 °C, respectively, SDI 60 and 30% had 6.0 and 8.5 °C, an increase of 65% and 75% compared to WI 120%. These differences were less pronounced in this approach, since in the irrigation lines the temperature of the wet soil around the dripper zone was considered. As observed in the approach relying in canopy values, RDI 100 and 60% obtained similar values to WI 100% and SDI 60% with 4.3 and 5.6 °C, respectively.

Finally, the treatment blocks temperature values (Ttb – Ta), presented a less pronounced differences as in the irrigation lines, since the dry soil temperature of each treatment was admitted, thus standardizing the data. The WI 120 and 100% obtained values of 7.6 and 8.1 °C, while the SDI 60 and 30% obtained values of 9.4 and 11.6 °C, an increase of 19% and 34% compared to WI 120%. Once again, the RDI 100 and 60% obtained similar values to WI 100% and SDI 60% with 8.3 and 9.2 °C.

Midday values of g_s and Ψ_F were 18% and 22% lower in RDI, 55% and 56% in SDI 30% compared to those observed in WI 120%, $g_s = 272 \pm 19$ mmol $m^{-2}s^{-1}$ and Ψ_F = -1.3 ± 0.17 MPa.

4. CONCLUSION

In this study, the temperatures of olive trees under different irrigation strategies were analysed using TIR data acquired collected with a UAV. Three type of analysis of the Tc – Ta were performed: using values of the canopies, values of the irrigation lines and values of the treatment blocks. In general, it was possible to verify that the deficit treatments had higher values than the WI treatments in these three approaches. The most extreme case was verified in the canopy analysis, whereas the SDI 30% had 87% higher values than WI 120%.

As future work, it is intended to establish correlations between the analysed thermal data and water status indicators such as LWP, RWC and stomatal conductance, in order to assist growers. Moreover, automatic estimation of olives trees using UAV-based data from different sensors (RGB and multispectral) should be considered, bringing new automation levels and increasing data availability and improving the decision support.

5. ACKNOWLEDGMNETS

This work was funded by the European Agricultural Fund for Rural Development (FEADER) and the Portuguese State under Action 1.1 «Operational Groups», as part of Standard 1, «Innovation» of the PDR 2020 - Continent Rural Development Program, as part of the GO Project - Olive Oil Operational Group - SustentOlive: Improvement of irrigation and fertilization practices at olive farms in Trás-os-Montes for its sustainability, supported by the European Regional Development Fund (FEDER) through the Competitiveness and Internationalization Operational Program - COMPETE 2020 under the PORTUGAL 2020 Partnership Agreement with Financial support provided by the FCT-Portuguese Foundation for Science and Technology (PD/BD/150260/2019) to Pedro Marques, under the Doctoral Programme "Agricultural Production Chains – from fork to farm" (PD/00122/2012) and to Luís Pádua (SFRH/BD/19702/2018).

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