USO DE SENSORES PROXIMAIS PARA OBTENÇÃO DE NWSB EM VIDEIRAS

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RESUMO: Os Objetivos de Desenvolvimento Sustentável da ONU são um apelo para erradicar a fome e promover a agricultura sustentável; portanto, o uso eficiente da água na irrigação é essencial. Torna-se fundamental a utilização eficiente da água nos cultivos irrigados para a conservação do ambiente. As ferramentas de manejo e tomada de decisão para planejamento e monitoramento da irrigação vem sendo aprimoradas com as novas tecnologias advindas da agricultura digital. Entretanto, ainda é necessário monitorar continuamente por meio de sensores de solo e planta as condições hídricas das plantas para garantir boa precisão e servir de base para correlações com as novas tecnologias digitais como o uso de imagem termográfica digital. Este estudo tem como objetivo estimar a linha de base inferior (NWSB) do CWSI para uva fina de mesa no estádio de repouso fenológico. Foram avaliados dois pomares, um irrigado e outro não irrigado, localizados no município de São Miguel Arcanjo, SP. Nas duas áreas de estudo foram monitorados dados climáticos, bem como umidade do solo, temperatura do solo e temperatura da copa. Atualmente, as plantas encontram-se no estádio fenólogico, denominado repouso ou dormência, em que não é realizada a irrigação. Os resultados da NWSB indicam que a cultura está em estresse hídrico mesmo na área irrigada, haja vista que houve baixa precipitação.
PALAVRAS-CHAVE: Irrigação de precisão, Sustentabilidade, Tecnologia.

USE OF PROXIMAL SENSORS TO ESTIMATE NWSB IN GRAPEVINES

ABSTRACT: The United Nations Sustainable Development Goals call for eradicating hunger and promoting sustainable agriculture; therefore, efficient water use in irrigation is essential. Efficient water use in irrigated crops is vital for environmental conservation. New technologies from digital agriculture have enhanced management and decision-making tools for irrigation planning and monitoring. However, it is still necessary to continuously monitor plant water

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conditions through soil and plant sensors to ensure accuracy and provide a basis for correlations with new digital technologies, such as digital thermographic imaging. This study aims to estimate the non-water-stressed baseline (NWSB) of the CWSI for grapevines during the dormant phenological stage. Two orchards were evaluated—one irrigated and one non-irrigated—located in the municipality of São Miguel Arcanjo, SP. In both study areas, climate data, as well as soil moisture, soil temperature, and canopy temperature, were monitored. Currently, the plants are in the phenological stage known as dormant, during which irrigation is not applied. The NWSB results indicate that the crop is under water stress even in the irrigated area, due to low precipitation at this stage.

KEYWORDS: Precision Irrigation, Sustainability, Technology

INTRODUCTION

Grapes (*Vitis vinifera* L.) hold significant importance for human consumption, ranking among the most consumed fruits worldwide. According to Faostat (2022), global grape production reaches 8,761,547 tons annually. However, it is highly influenced by climate change, particularly temperature. Another critical factor affecting grapevine development is the spatial variability within vineyards, which can be impacted by efficient water use in irrigation, especially when the crop's water requirements are not adequately met.

Efficient water use is essential in grape production, given that the global area cultivated with grapevines exceeds that of most other fruits (FAO, 2011). Therefore, to enhance efficient water use in grapevines, it is necessary to implement technologies that enable real-time detection of the crop's water needs (Han et al., 2018).

The crop water stress index (CWSI) was developed as a normalized index to quantify stress and overcome the effects of other environmental parameters affecting the relationship between stress and plant temperature (Idso et al. 1981). The CWSI is based on relating the canopy–air temperature difference (Tc-Ta) to air vapor pressure deficit (VPD). This requires the estimation of Non-Water-Stressed Baseline (NWSB) and the upper baseline. Accurate estimation of the NWSB depends on well-irrigated, non-stressed plants.

Water stress affects grapevines in various ways, including reduced growth, lower yields, and increased susceptibility to pests and diseases. Monitoring the CWSI enables timely irrigation management decisions. This study aims to estimate the Non-Water-Stressed Baseline (NWSB) for grapes during the dormant phenological stage.

MATERIALS AND METHODS

The study was conducted in the Distrito Agrotecnológico of São Miguel Arcanjo, São Paulo State, Brazil, located at coordinates 23°52'42" S and 47°59'50" W, at 710 meters above sea level. According to the Köppen-Geiger classification, the predominant climate in the region is type Cfa temperate, without a dry season, and with hot summers. The average annual temperature is 19.2 °C, and the mean annual precipitation is 1,454 mm. The predominant soil types are Yellow-Red Argisol (42%) and Red Latosol (46%).

The study period spanned from March 28 to May 5, 2025. The phenological development of the grapevines cultivars 'Moscato' was divided into six stages based on days after pruning (DAP), as follows: bud break (15 to 25 DAP); bud break and flowering (26 to 75 DAP); fruit growth (76 to 116 DAP); berry softening (117 to 136 DAP); maturation and harvest (137 to 243 DAP); and phenological dormant (244 to 365 DAP), completing the crop cycle.

It is worth noting that in the region, pruning is commonly carried out in July or early August. The phenological stages of bud break, flowering, fruit growth, and berry softening are considered the most critical for production, during which irrigation plays a vital role.

The Crop Water Stress Index (CWSI) was determined using the method proposed by Idso et al. (1981), which requires estimation of the Non-Water-Stressed Baseline (NWSB) and the upper baseline. This methodology is based on the difference between canopy temperature (Tc), measured with an infrared thermometer, and air temperature (Ta), obtained from a meteorological station, recorded at 20-minute intervals.

An infrared radiometer sensor (IRR), model SIL411 by Apogee Instruments, was installed in each study area to record canopy temperature. The devices were connected to a data logger and mounted on March 11 and 12, 2025, oriented east-west, positioned 50 cm above the vine canopy, with a 30° field of view. Upper and lower baselines were established using data from the irrigated and non-irrigated experimental plots with table grapevines.

Climatic data were collected to determine the vapor pressure deficit (VPD), calculated from air temperature and relative humidity, sourced from the CIIAGRO and INMET meteorological stations located near the experimental sites. For fitting the NWSB, only data with VPD values greater than 0.5 kPa were selected. The time intervals analyzed for the linear regression behavior were 1:00 p.m., 2:00 p.m., 3:00 p.m., 4:00 p.m., and 5:00 p.m.

Real-time monitoring of soil moisture, temperature, and electrical conductivity (EC), as well as canopy temperature, is being performed, with data recorded every 20 minutes. To monitor soil temperature, moisture, and electrical conductivity (EC), five TEROS 12 sensors

(METER Group) were installed at both the irrigated and non-irrigated sites. Three sensors were placed at a 20 cm depth (one in the inter-row and two in the vine row), and two sensors were installed at a 40 cm depth in the vine row. All sensors were connected to a ZL6 4G data logger, which records and stores data in a cloud-based platform with remote access.

RESULTS AND DISCUSSION

The accumulated precipitation during the study period was 78.2 mm, while the potential evapotranspiration (ETp) reached 152.29 mm. The average temperature recorded in São Miguel Arcanjo, SP, was 20.95°C. Soil moisture monitoring data for the study areas are presented in Figure 1. In the irrigated area, volumetric water content at a depth of 20 cm was higher than at 40 cm, whereas in the non-irrigated area, the opposite was observed until a rainfall event occurred on April 24, 2025.

In the irrigated area (Figure 1A), the volumetric water content at 20 cm depth ranged from 0.261 to 0.363 $m^3\ m^{-3}$, while at 40 cm depth it ranged from 0.236 to 0.366 $m^3\ m^{-3}$. From March 24 onward, following a rainfall event of approximately 3.47 mm, the volumetric water content values at both depths (20 and 40 cm) became more similar. In the non-irrigated area (Figure 1B), volumetric water content at 20 cm depth ranged from 0.239 to 0.374 $m^3\ m^{-3}$, and at 40 cm depth, from 0.276 to 0.347 $m^3\ m^{-3}$.

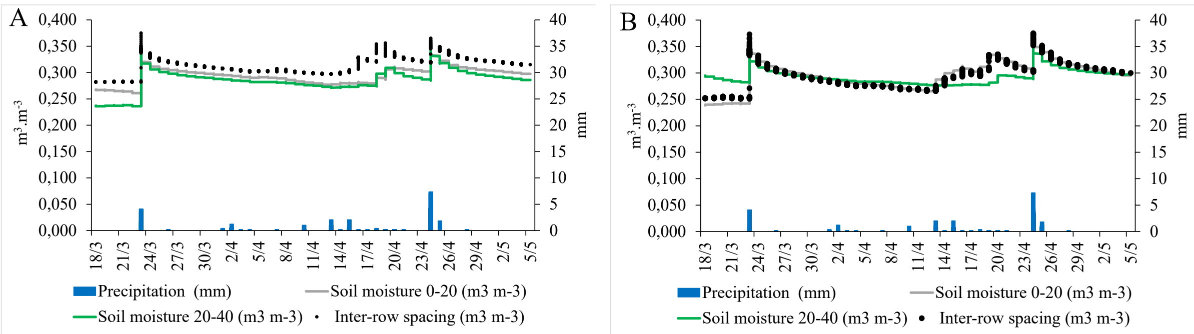

Figure 1. Soil moisture data at depths of 20 and 40 cm and precipitation: (A) Irrigated area and B) Non-irrigated area.

Figure 2 shows the Non-Water-Stressed Baseline (NWSB) at different times of day for both irrigated and non-irrigated areas. In Figure 2A, it can be observed that the slope of the regression lines varied considerably throughout the day, while the intercept values decreased progressively from 1:00 p.m. to 5:00 p.m. The expected behavior of the NWSB is a decreasing slope trend. Silveira et al. (2024) reported a decreasing slope from 2:00 p.m. to 5:00 p.m., which aligns with the expected pattern for NWSB. In Figure 2B, a predominance of decreasing slope is observed, except at 1:00 p.m., where the trend diverged.

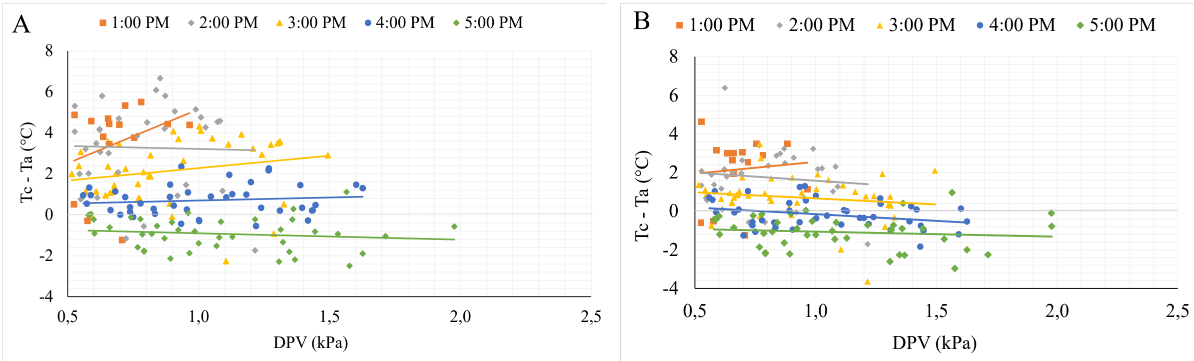

Figure 2. NWSB for grapevines: (A) Irrigated area and (B) Non-irrigated area.

It is important to note that in this study, the grapevines were in the phenological dormancy stage, during which no irrigation is applied. Therefore, the plants were under severe water stress, as evidenced by the high CWSI values observed at 1:00 p.m. and 3:00 p.m. in the irrigated area and at 1:00 p.m. in the non-irrigated area.

Figure 3 presents the regression of the lower baseline in the irrigated and non-irrigated areas, selecting data with a vapor pressure deficit (VPD) greater than 0.5 kPa. In the irrigated area (Figure 3A), the slope, intercept, and coefficient of determination were -0.658°C.kPa⁻¹, 0.8202°C, and 0.0157, respectively. In the non-irrigated area (Figure 3B), the slope, intercept, and coefficient of determination were -1.248°C.kPa⁻¹, 1.0518°C, and 0.0832, respectively. The dormant phenological stage is not the ideal phase for estimating NWSB, as this baseline represents the plant under optimal water conditions, i.e., well-irrigated.

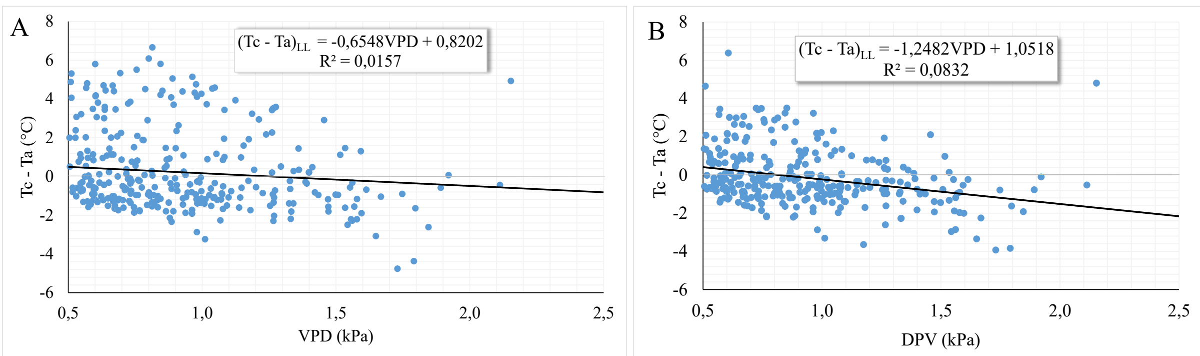

Figure 3. Estimating NWSB: (A) Irrigated area and (B) Non-irrigated area.

According to Idso (1981), the upper baseline represents a stressed plant, whereas the lower baseline represents a non-water-stressed plant under adequate moisture conditions. Therefore, during the phenological dormancy stage, plants are under severe water stress due to a dry period and reduced leaf area. Figure 4 presents the linear regression of the upper baseline for the irrigated and non-irrigated areas, considering Tc–Ta data against the saturation vapor pressure (SVP). In the irrigated area (Figure 4A), the slope, intercept, and coefficient of determination were –0.0316 °C kPa^{-1}, 2.4341 °C, and 0.0144, respectively, whereas in the non-irrigated area (Figure 4B), these values were –0.8649 °C kPa^{-1}, 2.4994 °C, and 0.0757, respectively. In the irrigated area, the slope was lower than in the non-irrigated area, indicating that plants in the irrigated area tended to experience greater water stress, although the expected behavior for the upper baseline would be an ascending trend.

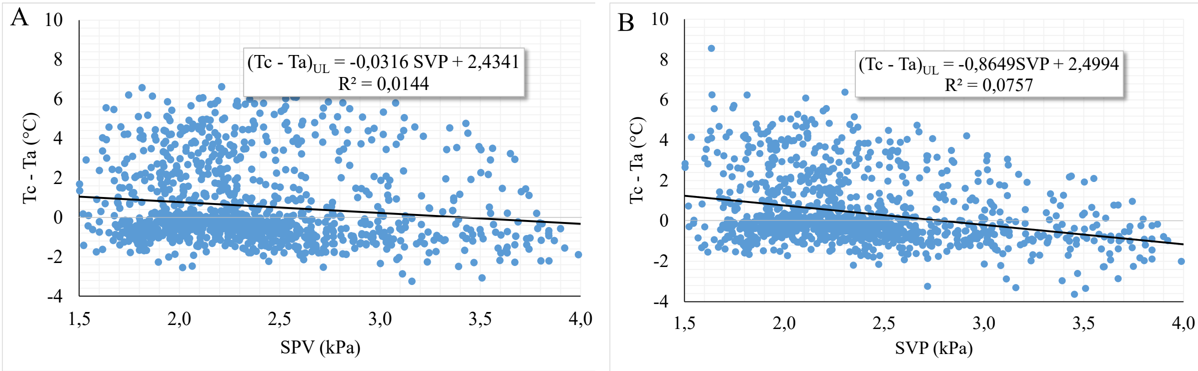

Figure 4. Estimating the upper limit: (A) irrigated area and (B) non-irrigated area

CONCLUSIONS

The current phenological stage of the grapevine is not considered ideal for estimating the Non-Water-Stressed Baseline (NWSB), as vines are subject to stress from prevailing climatic conditions and the absence of active irrigation, even in the irrigated plots. These factors likely compromise the accuracy of NWSB determination, emphasizing the need to conduct such estimations during phenological stages when the grapevine is physiologically active and well-irrigated. Therefore, this phenological stage is more appropriate for estimating the upper baseline. The next steps will involve determining the upper and lower baselines to obtain the water stress index (CWSI) for the grape cultivar 'Moscato' at each phenological stage. Subsequently, thermographic images will be captured to extract canopy temperature during the bud break, flowering, fruit growth, grain filling, and maturation stages to obtain specialized CWSI values that support more precise irrigation management.

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