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Dendrometric evaluation of *Helianthus annuus* under water deficit conditions

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Abstract: Drought is characterised as a recurring climatic phenomenon with prolonged duration, affecting land through below-average rainfall and often accompanied by high temperatures. When the available water falls below the optimum level, water deficit or water stress arises, disrupting normal plant processes. This condition poses challenges for plant growth and development as it hampers the internal water transport, induces stomatal closure, and limits access to photosynthetic resources.

The study employed the annual sunflower as the experimental plant. The plants were cultivated in a controlled environment with a temperature ranging from 20 to 25°C and a humidity level of 55 to 60%, supplemented by MARS HYDRO artificial LED lighting set to a 12-h photoperiod. Radial changes in the plant stems were monitored using a DD-S type dendrometric sensor to measure radial fluctuations. The collected data were recorded in a dendrometric data logger DL 18. Data collection occurred at hourly intervals from February 20 to March 9, 2023. The nine plants were divided into three groups, each comprising three plants. All plants from groups 1 and 2 received irrigation at one-day intervals (group 1 – 80 cm^3 per plant, group 2 – 40 cm^3 per plant) and group 3 was not irrigated.

Based on these findings, visible water stress was evident in the plants under experimental conditions. Consequently, continuous monitoring throughout the growing season will be essential to adjust the irrigation rate to meet the requirements of the plants.

Keywords: dendrometer, drought, *Helianthus annus*, irrigation, water deficit, water stress

INTRODUCTION

Plants are susceptible to a variety of harsh environmental stressors. Several biotic and abiotic factors influence increased plant growth in field conditions. Drought is a key abiotic factor limiting agricultural crop yield (Podlaski *et al.*, 2017). Adequate water and nutrient delivery are critical variables in optimal plant growth and crop output. Water stress is one of the most serious constraints to crop growth, particularly in semi-arid and arid parts of the world, because it plays an important role in how plants develop and grow at all stages (Shamim *et al.*, 2009). Drought stress occurs when the water supply to the roots becomes problematic or when the rate of transpiration becomes too high (Ghobadi *et al.*, 2013). These two conditions frequently coexist in arid and semi-arid environments (Reddy, Chaitanya and Vivekanandan, 2004). Water scarcity, whether temporary or chronic, has a negative impact on plant morphological and physiological processes (Iqbal, Ashraf and Ashraf, 2008). Water deficit leads to the closure of stomata and decreased rates of transpiration, resulting in lowered water potential within plant tissues, reduced photosynthesis, and hindered growth. The viability of plants in arid conditions relies on the initiation and continuous maintenance of multiple physiological mechanisms (Fulda *et al.*, 2011). Drought is a multifaceted stress that affects plants at numerous levels of organisation (Yordanov, Velikova and Tsonev, 2000). Drought settings are distinguished by large differences in precipitation, precipitation quantity, and precipitation distribution within and between seasons (Rauf, 2008).

Sunflower, belonging to the *Asteraceae* family and *Helianthus* genus, is a concise duration plant encompassing over 70 species globally. Its name, “sunflower”, is derived from its resemblance to the sun in terms of size and appearance, as well as the rotational movement around the sun that inspired the name. Noteworthy features of sunflowers include their large, circular yellow inflorescence flower head (which gives rise to achenes maturing into seeds) directly facing the sun's rays, a lengthy taproot, stems covered in hair, broad and roughly toothed leaves. Native to temperate climates of North America, with temperatures ranging between 20 and 25°C, sunflowers were subsequently introduced to Europe by Spanish explorers during the sixteenth century. The botanical aspect of sunflowers reveals their aesthetic and ornamental value, characterised by a diverse range of sizes and colours, transitioning from cream to yellow across different cultivars (Vilvert *et al.*, 2018).

MATERIALS AND METHODS

Helianthus annuus L. constitutes one of the world's most widely grown oil crops (Flagella *et al.*, 2002). It is grown throughout the world, and the majority of its products are sold as culinary or livestock feed (Yegorov *et al.*, 2019). Sunflowers' tolerance to various climatic and soil conditions has increased their cultivation as an oilseed plant all over the world (Forleo *et al.*, 2018). Sunflower growth necessitates fertile soil, moderate rainfall, viable seeds, and so on. Among the world's three leading oilseed crops, namely soybean, rapeseed, and sunflower, sunflower has been identified as a key source of high-quality edible oil, particularly for culinary uses (Pal *et al.*, 2014). The seeds of sunflowers are used to obtain sunflower oil. Every environmental element that reduces the growth of the sunflower plant eventually leads to a reduction in seed production, oil yield, and industrial products. Sunflower is a deep-rooted crop that has been demonstrated to reduce soil water availability. As a result, sunflower is more resistant to short-term water stress (Karam *et al.*, 2007).

Due to the nature of our experiment, the plants were placed in indoor laboratory conditions to avoid external environmental influences that could affect the results, while we actively monitored the temperature and humidity in the laboratory to create optimal conditions for growth, which in our case represented a temperature range of 20–25°C and a humidity of 55–60%. For proper growth, in addition to temperature and humidity, it was necessary to provide a suitable light source, which is essential for proper photosynthetic activity in a laboratory-controlled environment. As lighting, we chose MARS HYDRO artificial LED lighting with a photoperiod of 12 h. A dendrometer is a tool used to measure the diameter of plant stems. There are two types of dendrometers: those that contact the stem and those that do not (Clark, Wynne and Schmoldt, 2000). Instruments that fall into the latter type include optical forks and prisms. High-resolution dendrometers can provide insights into plant growth and physiology, such as assessing stem daily water status and analysing rapid development responses to changing conditions in the environment (Podlaski *et al.*, 2017). This type of data is useful for irrigation scheduling, site quality assessment, and constructing models of the primary drivers of tree development at sub-diurnal precision. In our situation, we used dendrometers with electronic calipers, which is a straightforward and practical dendrometer method. Electronic calipers measure diameter or displacement by converting physical distance into an electrical signal with the use of moving jaws on opposing sides of the stem. Despite their widespread use in field studies and greenhouses, electronic calipers may be constrained in their usefulness due to jaw size limits, which restrict their use to smaller stem sizes (Drew and Downes, 2009). In the irrigated and non-irrigated groups, dendrometers were affixed to the stems of *Helianthus annuus*. These devices convert alterations in branch diameter into an electrical signal, providing a resolution of 4.4 μm per volt and an accuracy of 2 μm within the range of 0 to 11,000 μm. The dendrometers were securely fastened to the stems using rubber bands, without causing any harm to the tissue. The sensor exhibits a coefficient of thermal expansion of 0.2 μm K^{-1}. Hourly measurements of electrical resistance values were automatically collected and recorded using a DL 18 data logger. The obtained raw data was then converted from ohms to μm using the equation: μm = (raw data)·(4400 m) (Bárek *et al.*, 2021).

Soil moisture has an important role in regulating energy and mass exchange activities at the soil-atmosphere interface. It can affect air temperature and humidity, as well as precipitation regimes, the incidence of heat waves and droughts, the availability of water for plants, and the stability of mountain slopes on a local to global scale (Pellet *et al.*, 2016). In light of the necessity for optimal utilisation of limited water resources, the significance of sensing techniques for assessing soil moisture in the root zone is increasing, aiming to achieve efficiency and cost-effectiveness (Nieberding *et al.*, 2023). In the pursuit of understanding the spatio-temporal dynamics of soil water content, there has been a growing utilisation of low-cost electromagnetic sensors. Although these sensors offer a cost-effective solution, their accuracy falls short when compared to reference electromagnetic soil water content sensing methods like time domain reflectometry (Bogena *et al.*, 2017). To determine the dielectric constant of the soil, we employed the Truebner SMT100, a high-quality sensor based on electrical capacitance principles. With this advanced approach, we can acquire exact and quantitative measurements of soil moisture content, providing vital insights into water availability and dynamics within the soil profile.

RESULTS AND DISCUSSION

In light of the measurements and observations mentioned below, it is important to consider the implications of these findings about the reactions of sunflower plants to changing irrigation conditions. Taking into account the specific conditions under which the plants were observed, it is noteworthy that the smallest changes in stem diameter reduction were evident in group 1 (Fig. 1, 2). In fact, the diameter of the plant stem exhibited an increase of 1.4%, going from 6.92 to 7.01 mm. This growth indicates a potential compensatory response to the prevailing stressors within the experimental setup. Upon modifying the irrigation rate to 40 cm^3 in group 2, a slight but discernible decrease in stem diameter of 2.8% was observed. The measurements indicated a reduction from 5.86 to 5.70 mm, suggesting a limited impact on the plant's structural development under the altered irrigation conditions. In stark contrast, the absence of irrigation in group 3 resulted in a substantial decrease in stem diameter, reaching an alarming 39.6%. The measurements revealed a notable decline from 5.74 to 3.47 mm, indicating a significant impairment in the structural integrity of the plants exposed to prolonged water deficit. These findings highlight the

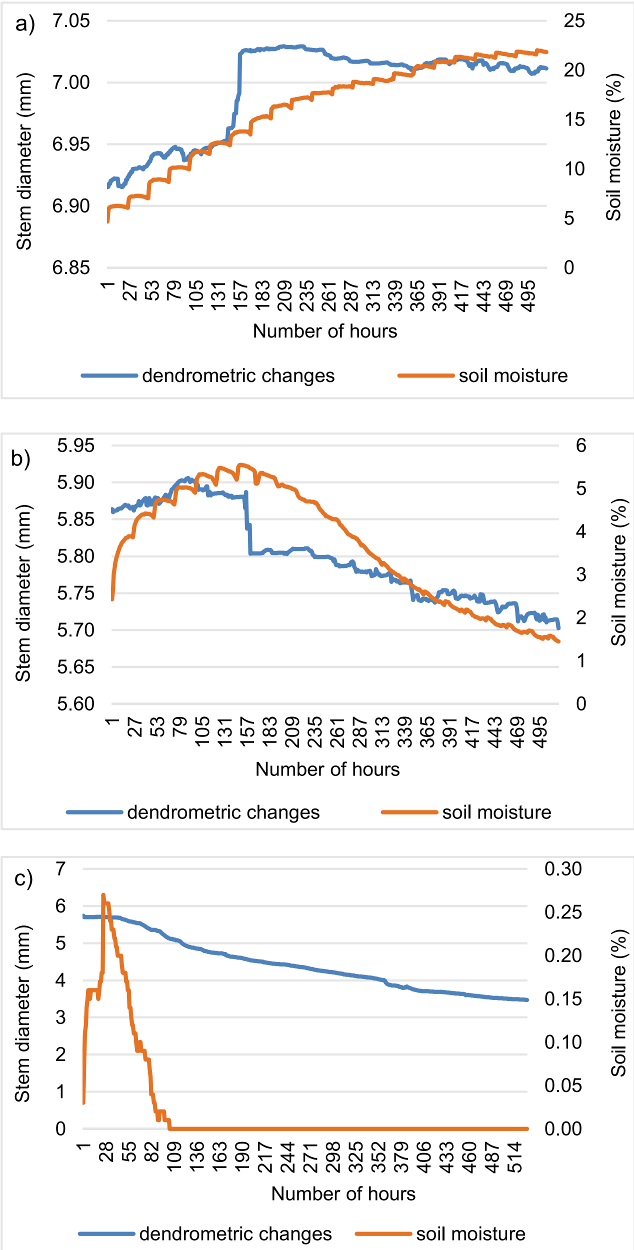

Fig. 1. Dendrometric and soil moisture measurements of plant irrigation groups: a) group 1 – 80 cm^3 per plant, b) group 2 – 40 cm^3 per plant, c) group 3 – no irrigation; source: own study

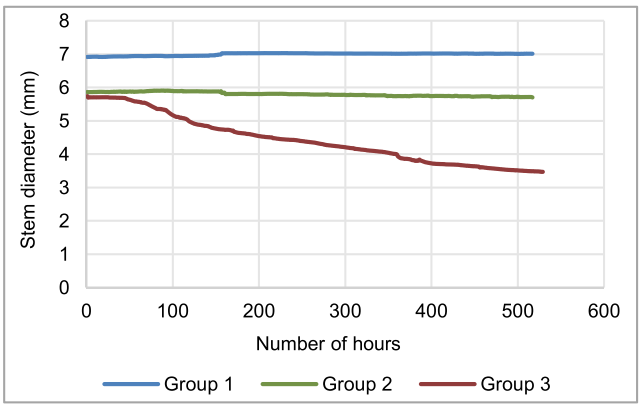

Fig. 2. Dendrometric comparison of all plant irrigation groups; groups 1, 2, and 3 as in Figure 1; source: own study

critical role of adequate water supply in maintaining the robustness and health of sunflower plants, as the lack thereof resulted in severe physiological repercussions.

Soil moisture measurements were correlated with data collected by dendrometers. For the group 1, we observed an increase in soil moisture from the original 4.68 to 21.84%. For the group 2, we observed a decrease in soil moisture from 2.43 to 1.45%. For the group 3, the maximum soil moisture value measured was 0.26%, which subsequently decreased to 0%.

CONCLUSIONS

The obtained results provide compelling evidence that the implementation of the DD-S dendrometer, in conjunction with the Truebner SMT 100 moisture meter, effectively identified stress indicators in plants subjected to suboptimal irrigation rates. These instrumental measurements exhibit high accuracy and precision, enabling us to reliably assess and monitor the stress symptoms associated with water deficit. Consequently, the utilisation of these measurement techniques holds significant promise for mitigating the adverse impacts of drought on plant productivity and overall agricultural yields. By leveraging the valuable data provided by these instruments, we can proactively intervene and implement preventive measures in the future, ensuring optimal water management practices to safeguard and enhance plant production in the face of challenging environmental conditions.

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