Evaluation of grapevines' physiological responses and productivity in relation to potassium fertigation and short drought stress periods

MSc Thesis by

Emilio Quintana Molina

September 2023

Water Resources Management group

WAGENINGEN UNIVERSITY & RESEARCH

Evaluation of grapevines' physiological responses and productivity in relation to potassium fertigation and short drought stress periods

Thesis Water Resources Management submitted in partial fulfillment of the degree of Master of Science in International Land and Water Management at Wageningen University and Research, the Netherlands

Emilio Quintana Molina

September 2023

Supervisors:

Gerardo E. van Halsema Ph.D.

Department of Environmental Sciences
Water Resources Management Group
Wageningen University & Research,
The Netherlands
www.wur.nl/en.htm

Alon Ben-Gal Ph.D.

Senior Researcher
Soil, Water & Environmental Sciences
Gilat Research Center, Agricultural
Research Organization, Israel
www.agri.gov.il

ACKNOWLEDGMENTS

I would like to emphasize my grateful and gratitude to my supervisors. First to Gerardo E. van Halsema Ph.D. to believe in my capacities and made the contact to be in Israel doing my thesis research. Secondly to Alon Ben-Gal Ph.D. to invite me to do my thesis in the Gilat Research Center, ARO-Volcani Institute for almost four months. Likewise, to Or Sperling Ph.D. and Uri Hochberg Ph.D. for their countless support during the experiment.

Also, I would like to thank Yonatan Ron, Chen Omer, Aviad Perry, Victor Akuku and Natalie Toren for their support during my time at Gilat. My experience in Israel was a great learning process and it was just what I was looking for as a thesis topic.

I thank Wageningen University & Research for the privilege of receiving me as a student and the Mexican National Council of Science and Technology (CONACYT) and Eramus+ program of the European Union for the financial support received for my studies and activities for the Master of Science in International Land and Water Management in the Netherlands.

With deep love, I thank and dedicate this thesis to my parents María Teresa Molina Guerra and Edgar Gerardo Quintana González and to my siblings Alan Gerardo Quintana Molina, Mariette Aracely Quintana Molina and José Rodolfo Quintana Molina for their unconditional support and always motivating me to fulfill my dream to study abroad. Aunque estemos lejos, nunca olviden que los amo y pienso en ustedes a diario, sepan que me esfuerzo a día a día para un futuro próspero.

This experience has made something clear to me: I will eventually study a PhD and will dedicate myself to research in water resources management in the future.

As Alon Ben-Gal once told me *"Science is fun"*.

Emilio Quintana Molina
September 2023

ABSTRACT

The uncertain effects of climate change pose drought-related challenges in grapevine-producing regions. Novel adaptation measures to climate change through experimental research must be explored for grapevine production in drought-prone areas. Studies indicate that abundant fertilization with potassium aids against harmful drought effects in crops. The objective of the present research was to evaluate the effects of potassium availability on grapevine (Vitis vinifera cv.) physiology and productivity under short but severe drought stress periods through an experimental setup with weighing lysimeters under six treatments based on three potassium levels (concentrations in irrigation water: 5, 15 and 60 mg K^+ L^{-1}) and two irrigation regimes (well-watered and water-deficit). The study hypothesized that abundant potassium levels enable grapevines' tolerance to drought periods, sustaining plant physiological development and improving yield under episodic drought stress. Whole-tree actual evapotranspiration during the growing season was calculated from water balance in the lysimeters. Midday stomatal conductance (g_s) and stem water potential (Ψ_{stem}) were measured during two drought trials, and leaf area index (LAI) before, during, and after each trial. Additionally, reference evapotranspiration (ET_0) and vapor pressure deficit (VPD) were monitored during trials. The study's results regarding physiological parameters indicate that plant dehydration had similar patterns in g_s among treatments in both trials. In contrast, g_s recovery was staggered between treatments, with the 60WD treatment the last to recover in both trials. Regarding Ψ_{stem}, its behavior during plant dehydration in the first trial was similar among treatments, while in the second trial, differences between treatments were noticeable. Lastly, Ψ_{stem} recovered in all treatments on the first day of rehydration in both drought events. Regarding ET_a, both drought events suffered a post-drought reduction without reaching similar values as the well-watered treatments. The ET_a rate patterns were different between well-watered and water-deficit treatments during severe water stress days. Furthermore, lysimeter coefficients (K_{lys}) were noticeably different regarding crop coefficients (K_c) from the second half of the growing season onwards. In terms of LAI, drought significantly impacted plant canopy development, mainly in consecutive days of severe water stress. Ultimately, short drought events did not affect grapevine yield, water productivity, number of clusters, and brix degrees of the grape juice among treatments. In contrast, it affected average berry and cluster weights mainly between K-5 and K-60 treatments. In sum, the study findings were against the proposed hypothesis.

Keywords: *Vitis vinifera cv.*, weighing lysimeter, potassium treatments, stomatal conductance, stem water potential, leaf area index, yield.

CONTENT

LIST OF ABBREVIATIONS

15WD	Water-deficit vine with 15 mg K^+ L^{-1}
15WW	Well-watered vine with 15 mg K^+ L^{-1}
5WD	Water-deficit vine with 5 mg K^+ L^{-1}
5WW	Well-watered vine with 5 mg K^+ L^{-1}
60WD	Water-deficit vine with 60 mg K^+ L^{-1}
60WW	Well-watered vine with 60 mg K^+ L^{-1}
D	Drainage (L day^{-1})
ET_0	Reference evapotranspiration (mm day^{-1})
ET_a	Actual evapotranspiration (L day^{-1} $tree^{-1}$)
ET_{accum}	Accumulated actual evapotranspiration in a defined day (L)
$ET_{a\ s}$	Seasonal actual evapotranspiration (m^3)
ET_{lys}	Lysimeter's actual evapotranspiration (mm day^{-1} $tree^{-1}$)
g_s	Stomatal conductance (mol H_2O m^{-2} s^{-1})
I	Irrigation (L day^{-1})
K_c	Single crop coefficient (mm mm^{-1})
K_S	Water stress coefficient (mm mm^{-1})
K_{lys}	Lysimeter coefficient (mm mm^{-1})
$K_{lys\ end}$	Lysimeter coefficient for the final stage of the crop season (mm mm^{-1})
$K_{lys\ ini}$	Lysimeter coefficient for the initial stage of the crop season (mm mm^{-1})
$K_{lys\ mid}$	Lysimeter coefficient for the mid stage of the crop season (mm mm^{-1})
LAI	Leaf area index (m^2 m^{-2})
T_{avg}	Average temperature (°C)
T_{max}	Maximum temperature (°C)
T_{min}	Minimum temperature (°C)
VPD	Vapor pressure deficit (kPa)
WP	Water productivity regarding yield (kg m^{-3})
ΔS	Change in soil water storage (L day^{-1})
Ψ_{stem}	Stem water potential (MPa)

LIST OF FIGURES

LIST OF TABLES

CHAPTER ONE

1.1. INTRODUCTION

Growers and researchers of grape vineyards are interested in how short drought stress periods impact vines' productivity in terms of quality and quantity (Cogato et al., 2022). The uncertain effects of climate change may negatively impact grapevine production regarding yield and berry attributes in grape-producing regions (Fraga, 2019). Projections of population growth coupled with climate change scenarios propose that it is only possible to meet future global food production demands if agricultural production improvement is stimulated and accelerated (Fahad et al., 2023).

Sustainable food production faces severe global challenges due to adverse environmental conditions and increasing demand for agricultural products, especially in developing countries and countries with limited natural resources (Fahad *et al.*, 2023). In arid and semi-arid regions, the objective of controlling water availability is oriented to achieve optimal yields in terms of quality and quantity and water use optimization in agriculture (Netzer *et al.*, 2019). Abiotic stresses such as drought and heat can affect plant growth, development, and productivity through plant morphological, physiological, biochemical, and molecular changes (Fahad *et al.*, 2023). Drought-prone areas expose plenty of food security challenges (Bitew, 2015).

After coffee and olive trees, the grapevine is one of the world's most cultivated perennial fruit crops, presenting approximately 6.75 to 7.1 million hectares and producing 66 to 80 Mt between 2010-2021 (FAO, 2023). According to Chaves *et al.* (2010), grapevine productivity ranges from 5 tons per hectare in rain-fed to 40 tons per hectare in well-irrigated vineyards. Water limitations directly affect water relations in grapevines, either due to its low availability or high environmental demand (Smart, 1974; Hochberg *et al.*, 2023).

Drought-prone areas where grapevines are cultivated expose plenty of food security challenges (Bitew, 2015). Resilience to droughts is critical in productive semi-arid and arid regions where food production is compromised under the uncertain climate change effects (Fahad *et al.*, 2023). Experiences from research indicate that potassium nutrition can improve tolerance to drought stress in annual crops and trees (Premachandra *et al.*, 1991; Gupta & Berkowitz, 1987; Battie-Laclau *et al.*, 2014). Therefore, in the present investigation, it was proposed that controlled levels of potassium supplementation would encourage grapevines' resilience to drought periods.

The present thesis is divided into six chapters. The first chapter presents the introduction, problem statement, and thesis objective. Then, the second chapter contains the concepts and research questions. Consequently, the third chapter refers to methods, the fourth to results, and the fifth to discussion. Finally, the sixth chapter integrates conclusions and recommendations.

1.2. PROBLEM STATEMENT

The Intergovernmental Panel on Climate Change (2022) indicated that climate change effects will aggravate drought events in arid and semi-arid regions, intensifying the use of irrigation (Gambeta *et al.*, 2020). Several climate change scenarios indicate that grapevine-producing regions will be prone to water stress conditions due to extreme weather conditions (Fraga, 2019). The drought effects, whether induced by humans or critical environmental conditions, are part of current and future food production and must be considered in the production and food security efforts (Fahad *et al.*, 2023). Therefore, it is urgent to explore new adaptation measures to climate change through experimental research on-field and consequently disseminate knowledge among agricultural producers (Fraga, 2019).

The grapevine (*Vitis vinifera* cv.) is one of the most important perennial fruit crops in the world in relation to economic terms (Alston & Sambucci, 2019; Gambeta *et al.*, 2020). Nowadays, grapevine is cultivated in over 90 countries for diverse purposes such as wine production, liquors, juice, table grapes, and raisins (FAO-OIV, 2016; Gambeta *et al.*, 2020).

Vineyards are often exposed to drought stress periods due to being widely cultivated in semi-arid areas. However, even well-irrigated grapevines occasionally experience drought stress periods between irrigation events, due to temporal irrigation failures, heat events, or during peak crop evapotranspiration periods (Sepúlveda & Kliewer, 1986; Hochberg *et al.*, 2016; Hochberg *et al.*, 2023).

As part of adequate agricultural management, the quality and quantity of grapes are influenced by the plant water status of the vines throughout its growing season (Smart *et al.*, 1990; Williams, 2000; Keller, 2010; Baert *et al.*, 2013).

Studies in maize and wheat (Premachandra *et al.*, 1991; Gupta & Berkowitz, 1987) and in eucalyptus trees (Battie-Laclau *et al.*, 2014) have reported that fertilization with potassium improved drought stress tolerance and osmotic adjustment and, consequently, its harmful effects. Potassium is an essential macroelement in plant nutrition as well as the most abundant cation in plant tissues. Plant growth and productivity demand high potassium doses for its consequent distribution throughout the plant (Marschner, 2011; Nieves-Cordones *et al.*, 2016). However, there is a large knowledge gap in understanding the role of potassium fertilization in relation to drought resiliency in grapevines.

The present research was driven by the hypothesis that abundant potassium levels enable grapevines' tolerance to drought periods, sustaining plant physiological development and improving yield under episodic drought stress.

1.3. OBJECTIVE

To evaluate the effects of potassium availability on grapevine (*Vitis vinifera cv.*) physiology and productivity under short but severe drought stress periods, estimating actual evapotranspiration and measuring physiological and canopy growing parameters.

CHAPTER TWO

2.1. CONCEPTS

This section presents the concepts used in this research and the detailed conceptual framework (Figure 1).

Plant physiology

Plant physiology studies plant behavior and functions in order to examine and interpret processes of growth, metabolism, reproduction, defense as well as communication between plants (Salisbury & Ross, 1992; Baluška *et al.*, 2006; Scott, 2008; Smith *et al.*, 2019). Due to most of the aforementioned processes occurring at the cell, tissue, and organ level, there is a strong association between plant physiology and plant anatomy. Understanding plant physiology requires basic knowledge of chemistry and physics (Smith *et al.*, 2019). Drought events directly affect plant physiology and water uptake. In the present investigation, short periods of drought are induced in grapevines to study the interactions of the whole-tree actual evapotranspiration in relation to the stomatal conductance, stem water potential, and the leaf area index in different fertigated potassium treatments. Likewise, the interactions between the whole-tree actual evapotranspiration regarding the yield per tree, number of clusters, average cluster and berry weight are studied, which may interact with grape juice brix degrees and pH (Figure 1).

Stomatal conductance to H_2O vapor (g_s)

Stomatal conductance (mol m^{-2} s^{-1}) is an indicator of the plant water status that defines the degree of stomata aperture. Using a porometer, plants' gas exchange rate (carbon dioxide uptake) and transpiration (water vapor losses) are measured. The water loss due to plant transpiration and photosynthesis are dominated by stomatal closure. Moreover, in grapevines, H_2O vapor diffusion out of vine leaves is less dependent on stomatal opening than CO_2 diffusion into leaves (Keller, 2020). The stomatal conductance with regard to plant transpiration is conditioned by the soil water availability, the plant phenological stage, and weather conditions. As long as the soil presents available water, the plant will meet its transpiration demand and maintain stomatal conductance and water potential levels close to well-watered conditions. However, when available water is reduced, the water potential will drop along with the plant transpiration, gradually decreasing the stomatal conductance by closing the stomata to maintain fundamental plant functions. In general, reductions in stomatal conductance prevent decreases in water potential by reducing transpiration. The stomatal conductance is related to leaf water potential (Giménez et al., 2013).

Stem water potential (Ψ_{stem})

Stem water potential (MPa) is a water status indicator that directly measures the water tension within the plant's xylem. It expresses the ability to convey water from the soil to the environment (Choné et al., 2001). According to Choné et al. (2001), Ψ_{stem} is “the most discriminating indicator for both moderate and severe water deficits" (p. 477), mainly on peach and plum orchards. Moreover, Ψ_{stem} is influenced by stomatal regulation, which is driven by climate and watering factors; reductions in water potential generate stomatal closure and, consequently, lower stomatal conductance values. The Ψ_{stem} is estimated through a pressure chamber instrument and measured in pressure units, always being a negative value (Blanco & Kalcsits, 2021; Naor, 2000).

Weighing lysimeters

Weighing lysimeters are devices that directly measure water quantities used by the combined effect of evaporation and transpiration in crops (actual evapotranspiration) by closing the water balance. Lysimeters measure the mass of the plant, soil, and container at defined times. The change in mass allows for calculating the actual evapotranspiration (Fisher, 2012; Payero & Irmak, 2008). These devices represent the most direct method of estimating actual crop evapotranspiration (Payero & Irmak, 2008; Dong & Hansen, 2023).

Reference evapotranspiration (ET_0)

The reference evapotranspiration (mm day^{-1}) (also called reference crop evapotranspiration) is a standard evapotranspiration parameter based on a reference surface assuming a well-watered virtual grass (as a reference crop) that is continually growing and covering the soil surface with a uniform height of 1.2 m, surface resistance of 70 s m^{-1} and albedo of 0.23. The method recommended by FAO to calculate the ET_0 is the Penman-Monteith method. It can be calculated using meteorological data of the area of interest, such as radiation, air temperature, air humidity, and wind speed (Allen *et al.*, 1998).

Actual evapotranspiration (ET_a)

Actual evapotranspiration (mm tree-^{1} day^{-1} or L tree-^{1} day^{-1}) is defined as the amount of water through vapor actually removed from the soil and plant surfaces into the atmosphere; it is the sum of the evaporated and transpired water by crops driven by ET_0 components, such as temperature, relative humidity, wind, radiation, etc. (Sepúlveda, 2021). Actual evapotranspiration is one of the most important and difficult-to-estimate components of the hydrological cycle in ecosystems and agroecosystems. In addition, the exchange of energy and water between the soil, land, and atmosphere is explained by the actual evapotranspiration (Ochoa-Sánchez *et al.*, 2019).

Water balance

The water balance is a valuable and straightforward approach to defining water inflows and outflows at specific time and area scales. The water balance computation considers irrigation, precipitation, and capillary rise as inflows parameters. Additionally, it considers crop evapotranspiration, deep percolation, and surface runoff as outflows, not to mention the change in soil water storage that can be a negative or positive value (Allen *et al.*, 1998;

Ochoa *et al.*, 2007). In the elemental water balance expression shown in Equation 1, the rootzone in a crop field is defined as the water balance threshold.

$$I + P + C_r - ET_a - D_p - R_o + \Delta S = 0 \quad (1)$$

Where:
I → Irrigation (mm)
P → Precipitation (mm)
C_r → Capillary rise (mm)
ET_a → Actual crop evapotranspiration (mm)
D_p → Deep percolation under crop root zone (mm)
R_o → Surface runoff (mm)
ΔS → Change in soil water storage (mm)

The water balance is normally used to indirectly estimate parameters that are difficult to measure in field conditions (e.g., evapotranspiration, deep percolation, capillary rise, among others). It is important to highlight that, for controlled experimental conditions, where the parameters C_r and R_0 are not important, Equation 1 can be modified for convenience and simplicity.

Leaf area index (LAI)

The leaf area index (m^2 m^{-2}) is an indicator that illustrates plant canopy, representing the projected leaves area in a unit of land. It represents an essential variable for understanding the biophysical vegetation in processes such as photosynthesis, respiration, and precipitation interception (Alton, 2016; Fang *et al.*, 2019). LAI can be easily estimated using a ceptometer.

Vapor Pressure Deficit (VPD)

The vapor pressure deficit (kPa) is defined as the difference in the saturation vapor pressure and the actual vapor pressure (Allen et al., 1998). VPD is an important parameter in plant-water relations and can be computed for defined periods of time for its analysis.

High VPD values encourage plant water stress when soil water availability is reduced by increasing plant transpiration rates and reducing the photosynthesis process (Franks et al., 1997; Grossiord et al., 2020). Furthermore, high VPD values usually induce the progressive closure of the stomata (impacting stomatal conductance) in order to reduce water loss due to the increase in plant transpiration, in addition to generating critical values of water tension in the plant xylem (impacting stem water potential) (Running, 1976; Grossiord et al., 2020). Moreover, high VPD values impact the accelerated water loss from the crop surface (Dai, 2013; Grossiord et al., 2020).

2.1.1. CONCEPTUAL FRAMEWORK

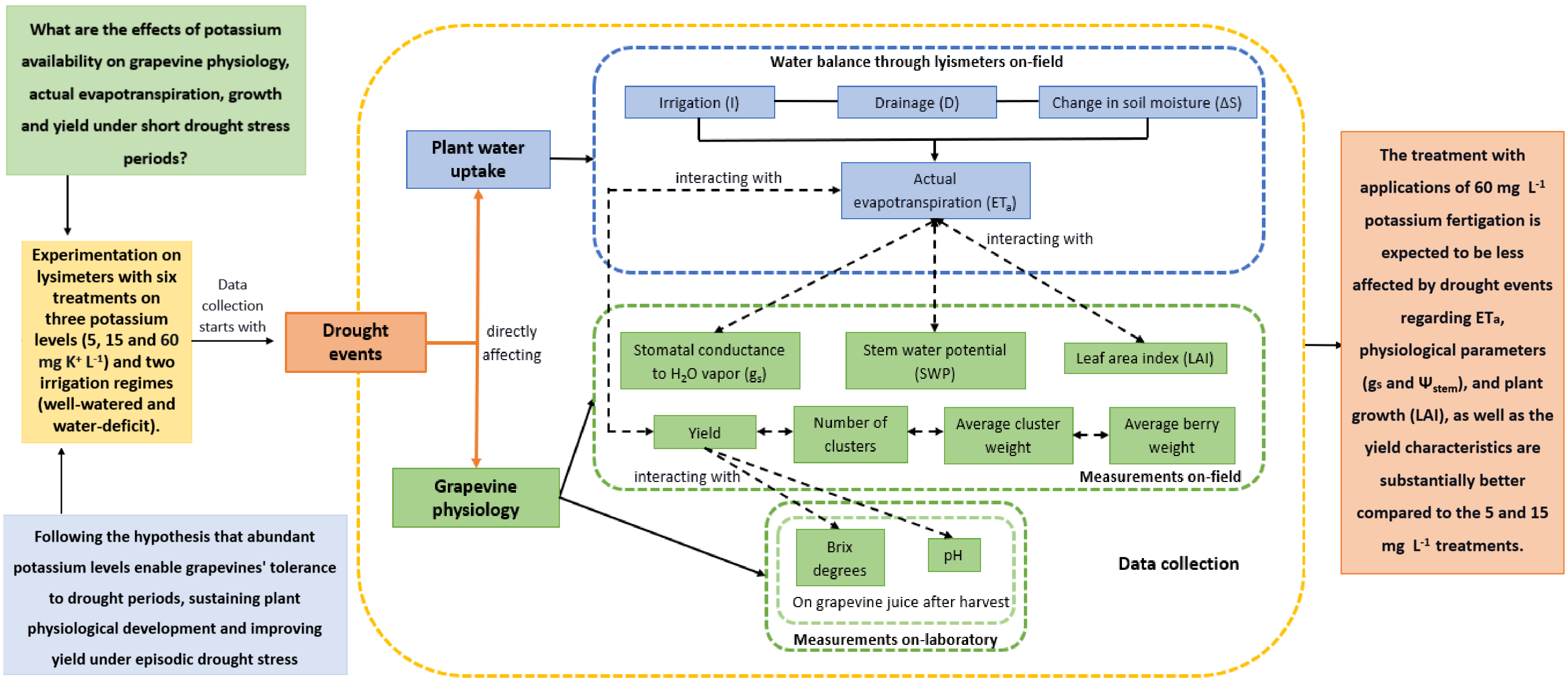

Figure 1. Conceptual framework of the thesis research.

2.2. HYPOTHESIS

Abundant potassium levels enable grapevines' tolerance to drought periods, sustaining plant physiological development and improving yield under episodic drought stress.

2.3. RESEARCH QUESTIONS

2.3.1. MAIN RESEARCH QUESTION

- What are the effects of potassium availability on grapevine physiology, actual evapotranspiration, growth, and yield characteristics under short drought stress periods?

2.3.1. SUB-QUESTIONS

- What is the behavior of the stomatal conductance and stem water potential during plant dehydration and recovery regarding potassium availability?
- What are the drought effects on grapevine actual evapotranspiration regarding potassium availability?
- What are the drought effects on tree canopy regarding potassium availability?
- What are the drought effects on grapevine yield characteristics regarding potassium availability?

CHAPTER THREE: METHODS

3.1. EXPERIMENTAL SITE

3.1.1. LOCATION

The experimental platform is located in the southern district of Israel, specifically in the northern region of the Negev desert at the Gilat Research Center for Arid & Semi-Arid Agricultural Research, Agricultural Research Organization— Volcani Institute of Israel's Ministry of Agriculture. The institution is situated at latitude 31° 20' N, longitude 34° 40' E, and approximately 150 m above sea level; Be'er Sheva city is 20 km away (Figure 2).

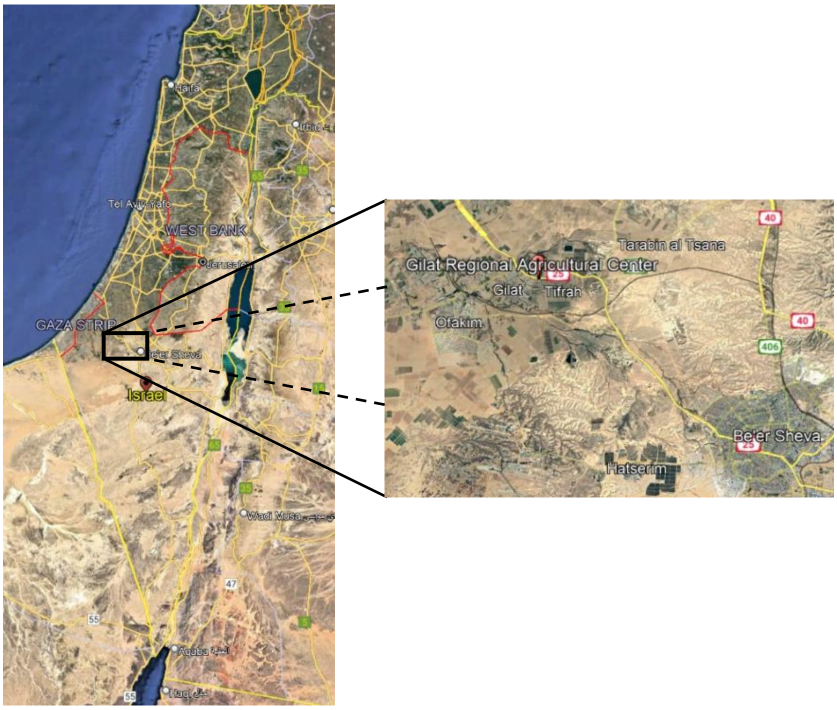

Figure 2. Location of the Gilat Research Center.

3.1.2. CLIMATE

The climate of the experimental site based on the Köppen climate classification is defined as BWh, hot and dry summers, and mild winters. Precipitation is mainly concentrated in the winter season, being rare in summer (Potchter & Ben-Shalom, 2013). According to historical meteorological data of the Land Conservation Division of Israel's Ministry of Agriculture, in the station Gilat during the period 2008-2022, the average maximum temperature was 27.8°C (range of 35-18.5°C), August being the hottest month with an average maximum temperature of 35°C and an average minimum of 21.7°C. Likewise, the average minimum temperature was 14.5°C (range of 21.7-7.8°C), January being the coldest month with an average maximum temperature of 18.5°C and an average minimum temperature of 7.8°C. The average annual temperature was 21.2 °C (Figure 3) (Agrometeo, 2023).

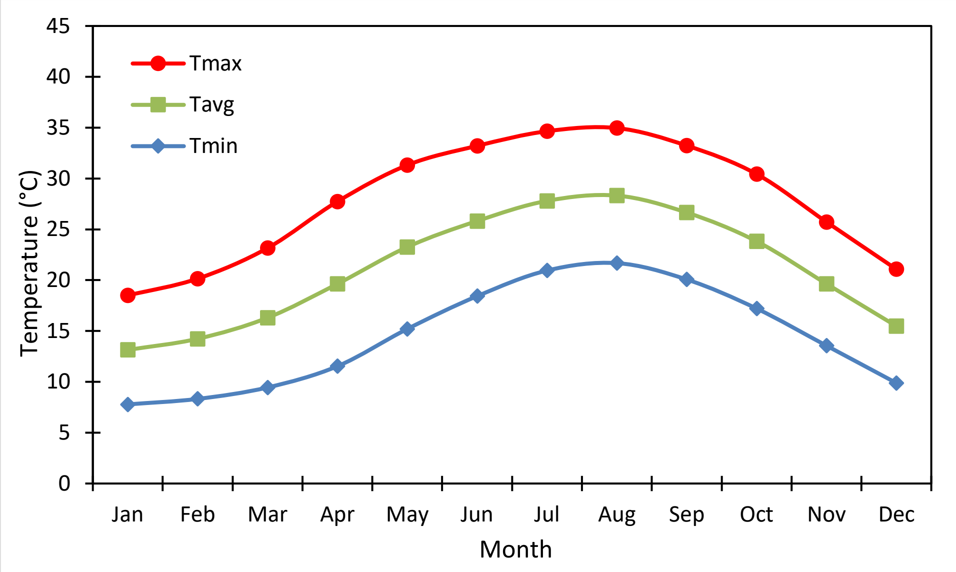

Figure 3. Monthly maximum, minimum, and average temperature in the experimental site (Gilat station, period 2008-2022).

Moreover, the average yearly precipitation was 221 mm. The rainy season was concentrated in winter, mainly between October and March. The rainiest month was January, and the driest was July. Precipitation in summer was scarce (Figure 4) (Agrometeo, 2023). During data collection, precipitation was insignificant and not considered in calculations.

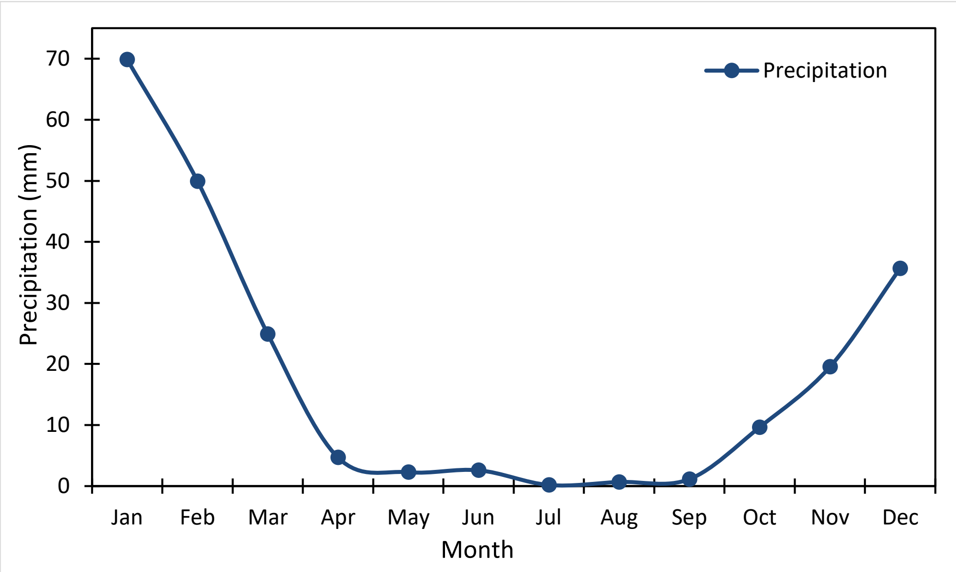

Figure 4. Average yearly precipitation in the experimental site (Gilat station, period 2008-2022).

Furthermore, the historical reference evapotranspiration calculated using meteorological data by the Penman-Monteith equation fluctuated approximately between 2 mm/day in January, increasing to 6.7 mm/day in July and decreasing to 2.3 mm/day in December (Allen et al., 1998) (Figure 5). However, during the data collection of the experiment, maximum values of up to 10 mm/day were reported (see results section).

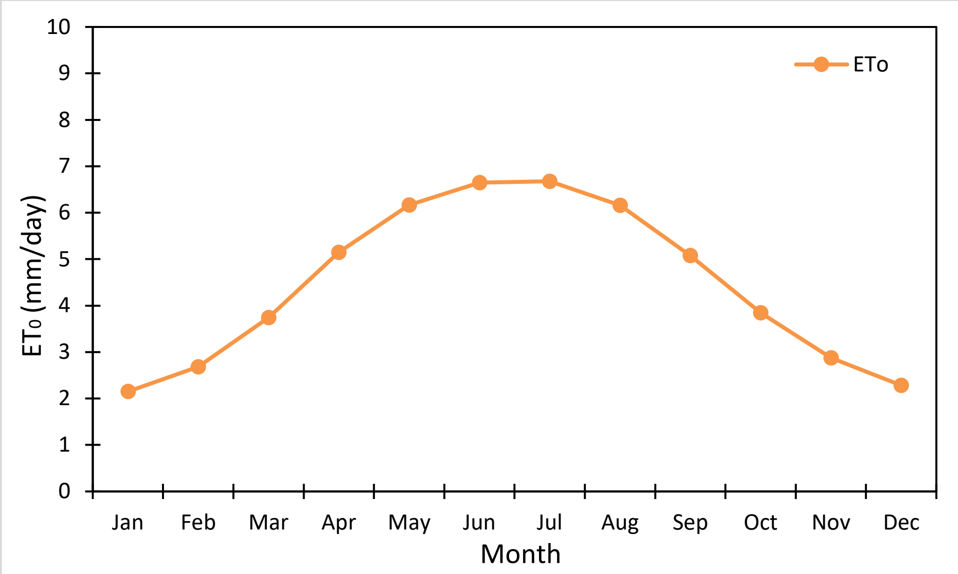

Figure 5. Average reference evapotranspiration in the experimental site (Gilat station, period 2008-2022).

3.2. EXPERIMENTAL DESIGN

The research comprised weighing lysimeter experimentation to evaluate potassium concentration effects in physiological development response under short drought stress periods in Early Sweet (var) grapevines (*Vitis vinifera cv.*). The experiment was conducted in an experimental set-up with twenty-eight weighing lysimeters, but just twenty-four were used (the remaining four were not necessary for the present research); every lysimeter contained a single grapevine.

In March 2018, the grapevines ("Early Sweet" grafted on "140 Ruggeri") were planted in 10L pots. In March 2020, they were transplanted to the weighing lysimeters (see lysimeter experimentation section). The trees were distributed homogeneously in four rows of seven lysimeters, the separation between trees was 2.5 m and between rows 5 m.

Six treatments with four replicates randomly allocated (twenty-four grapevines) were established based on three potassium levels and two irrigation regimes (Appendix 1), as described below:

1. Well-watered grapevine with 60 mg K^+ L^{-1} (60WW)
2. Well- watered grapevine with 15 mg K^+ L^{-1} (15WW)
3. Well- watered grapevine with 5 mg K^+ L^{-1} (5WW)
4. Water-deficit grapevine with 60 mg K^+ L^{-1} (60WD)
5. Water-deficit grapevine with 15 mg K^+ L^{-1} (15WD)
6. Water-deficit grapevine with 5 mg K^+ L^{-1} (5WD)

The well-watered treatments integrated approximately 130-140% water from last-day actual evapotranspiration. In contrast, in water-deficit treatments, the grapevines were dehydrated by interrupting irrigation during episodic drought trials until reaching critical physiological values in stomatal conductance and stem water potential (see drought trials and data collection sections).

Grapevines were fertigated daily with mineral fertilizers through drip irrigation, varying the potassium concentration depending on the experimental treatment (60-15-5 mg K L-1) at 40 mg N L-1, 10 mg P L-1, 35 mg Ca L-1, 15 mg Mg L-1, 0.025 mg Cu L-1, 0.6 mg Fe L-1, 0.3 mg Mn L-1, 0.016 mg Mo L-1, and 0.15 mg Zn L-1, following commercial vineyard management (Hochberg *et al.*, 2023).

3.3. LYSIMETER EXPERIMENTATION

Weighing lysimeters (Figure 6) were composed of polyethylene containers with a volume of 2 m^3 (1.4 m diameter and 1.3 m high), four load-cells brand Zemic Europe B.V model H8C-C3-2.0T-4B in parallel, and a metal platform (Hochberg *et al.*, 2023). The lysimeter's containers were filled with loamy sand soil (88-95% sand and 4-10% clay) (ibid.) The excess of water was drained by an inert rockwool extension to 50 L buckets at one meter below the soil container bottom (Ben-Gal & Shani, 2002; Hochberg *et al.*, 2023). Drainage water accumulated in the collection buckets was automatically emptied through an electric valve. As the bucket was connected to the weighing lysimeter, measurement of lysimeter mass before and after its emptying indicated volume of the drainage. A drip irrigation line was installed per lysimeter with 16mm pipeline diameter and eight pressure-compensated drip emitters of 2.0 L h^{-1} model PC online, brand Netafim Tel Aviv. Grapevines grew vertically to 1.2 m height supported by a commercial Y-shaped trellis with dimensions of 1.4 by 2.7 m (Figure 6) (Hochberg *et al.*, 2023). The group of lysimeters included an automatic water and fertilizer preparation and delivery system (Ben-Gal *et al.*, 2010).

Lysimeter mass data were collected and stored with a field-installed data logger and automatically downloaded to a comma-separated Excel file through a preprogrammed digital interface (LoggerNet 4.7, Campbell Scientific) using a main project PC located in the research center offices. Likewise, the lysimeters were calibrated on-field with a known mass (< 50 kg) before each drought trial through the mentioned interface and the project's main PC using the AnyDesk application and mobile data (in order to use the main PC remotely); the admissible percentage error in the calibration (known mass concerning measured mass) was defined as ± 2%.

The data collection system in the lysimeters was programmed to measure mass at five-minute intervals and considering the expected mass changes in a day (relative mass ranging from approximately -100 to 100 kg). The main objective of using weighing lysimeters was to calculate the actual daily evapotranspiration through a water balance, considering the mass of the irrigation, drainage, and change in water storage components (see data collection section) (Ben-Gal *et al.*, 2010). Appendix 2 shows schemes elaborated in AutoCAD 2023 that highlight the components of the weighing lysimeters used in the present investigation (front, side, and top view).

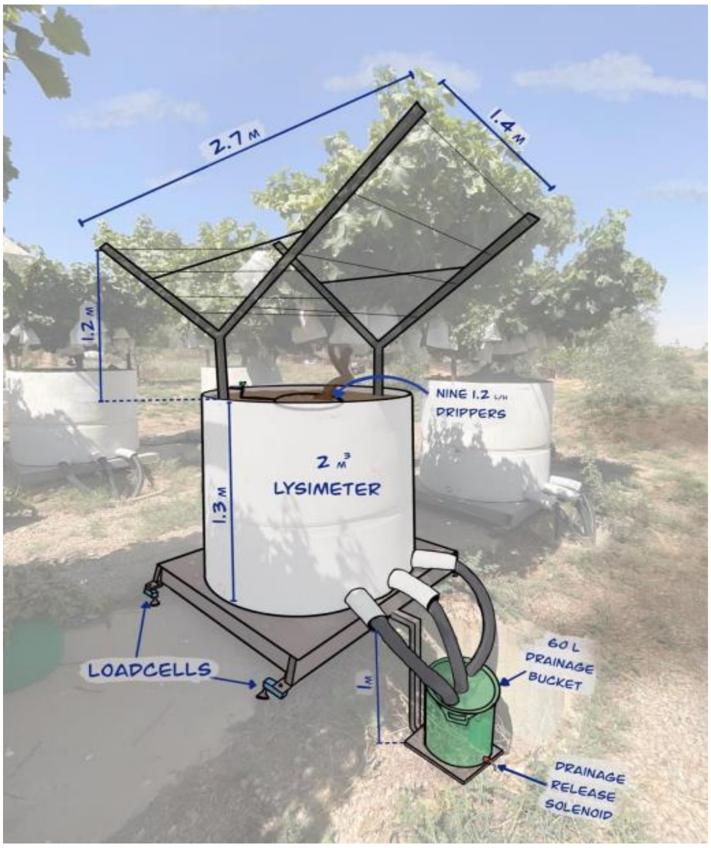

Figure 6. Lysimeter setup at Gilat Research Center, ARO-Volcani Institute, Israel (Hochberg *et al.*, 2023).

3.4. DROUGHT TRIALS

In the present investigation, two drought trials were carried out. The trials were monitored on a daily basis considering daily actual evapotranspiration and two physiological parameters: stomatal conductance and stem water potential (see data collection section). In the case of grapevines, a severe water deficit was defined when the midday stomatal conductance was approximately equal to or greater than 0.02 mol m^2 s^{-1} and stem water potential was approximately -1.0 to -1.2 MPa (Flexas *et al*., 2002; Hochberg *et al.*, 2023).

The drought trials comprised irrigation interruption, inducing the dehydration of the plant until reaching a severe water deficit based on the mentioned physiological parameters. The critical drought point was maintained for some days by supplying daily small amounts of water equal to the previous day's stress level ET_a. Subsequently, the irrigation was re-established for the vine recovery, and measurements continued until reaching the same values in both physiological parameters as the well-irrigated homologous treatments (Hochberg *et al.*, 2023).

The first drought trial was carried out from April 28 to May 11, and the second from June 8 to 18. The critical drought days in the first drought were May 10 and 11, while the second were from June 14 to 18. The vine rehydration (or recovery) in the first drought comprised from May 12 to 17 and the second from June 19 to 23.

3.4.1. DROUGHT VISUAL ASSESSMENT

A drought visual assessment on the water-deficit trees regarding their canopy appearance was carried out during the critical days of drought in each drought trial. According to the canopy status in relation to the effect of drought, values from 1 to 5 were assigned. The scoring was given between 11:30 and 14:00 hrs. The score 5, “high drought effects”, indicated that leaves have dropped and the existence of extreme curling leaves; the score 2.5, “medium drought effects”, expressed that leaves have not dropped and the presence of some curling leaves; and the score 0, “no drought effects” pointed out that leaves have not dropped and the inexistence of curling leaves.

In addition, two drone flights (model Mavic Mini 2, brand DJI) were carried out on June 22 and July 6 to define the impact of the fertilization levels on the trees' canopy at the end of the growing season.

Moreover, a visual assessment of berries comparing water-deficit trees concerning well-water trees was carried out. It was observed how potassium availability and drought events affected the berries' appearance in the clusters between the studied treatments. Likewise, pictures of the identified damage were taken.

3.5. DATA COLLECTION

3.5.1. METEOROLOGICAL PARAMETERS

3.5.1.1. REFERENCE EVAPOTRANSPIRATION

The daily reference evapotranspiration ET_0 (mm day^{-1}) was consulted from the Gilat meteorological station, which was calculated using the Penman-Monteith equation (Allen et al., 1998).

3.5.1.2. MIDDAY VAPOR PRESSURE DEFICIT

Vapor pressure deficit (VPD) is an important factor closely related to stomatal conductance and stem water potential. In the present investigation, the use of the midday vapor pressure deficit (VPD_{midday}) was established, which considers the maximum value of the VPD in 10-minute intervals between 11:30 and 14:00 hrs. (along with the data collection of the physiological parameters). The VPD was calculated using weather data from the Gilat meteorological station during the days of the drought trials and its plant recovery.

Firstly, the saturation vapor pressure (e°, kPa) was calculated through the average air temperature at 2m height in ten-minute intervals (T_{10min}, °C) (Equation 2) (Allen et al., 1998).

$$e^{\circ}_{10min} = 0.6108 exp^{\left(\frac{17,27 * T_{10min}}{T_{10min} + 237.3}\right)} \quad (2)$$

Subsequently, through the relative humidity in 10-minute intervals (RH_{10min}, %) and the saturation vapor pressure in 10-minute intervals ($e°_{10min}$, kPa), the VPD in ten-minute intervals (VPD_{10min}, kPa) was calculated (Equation 3) (Allen et al., 1998).

$$VPD_{10min} = (100 - RH_{10min})/e^{\circ}_{10min} \quad (3)$$

Finally, VPD_{midday} was defined as the maximum value of VPD_{10min}.

3.5.2. WATER BALANCE

3.5.2.1. ESTIMATION OF DAILY ACTUAL EVAPOTRANSPIRATION (ET_a)

The whole-tree daily actual evapotranspiration (henceforth referred to as actual evapotranspiration) (ET_a) was calculated through the water balance method throughout the growing season, specifically between April 20 (lysimeters calibration) and July 13 (three days after grapevines harvest), 2023 (Allen *et al.*, 1998). Although ET was measured, it is assumed that the evaporation portion tends to be insignificant due to mainly two factors: mulching of the soil with a permeable (for air entry) woven plastic sheet and vines' dense canopy over the relatively small wetted soil surface (more noticeable during mid and late-season).

Irrigation was supplied to the weighing lysimeters through drip irrigation approximately between 01:00 to 06:00 hrs., depending on the irrigation needs based on the day-before ET_a; note that the irrigation was stopped during drought trials. Accumulated drainage was measured and removed daily at 23:00 hrs. The twenty-four-hour change in soil water storage was measured through the difference in weight regarding the analyzed day with respect to the day before. Averages for thirty minutes intervals were used in the calculations.

Daily actual evapotranspiration (ET_a , L $tree^{-1}$ day^{-1}) was calculated per tree from irrigation (I, L), drainage (D, L), and change in soil water storage (ΔS, L) (Ben-Gal *et al.*, 2010; Hochberg *et al.*, 2023) (Equation 4). Figure 7 illustrates the water balance components, as well as the behavior of a weighing lysimeter during a typical day.

$$ET_a = I - D - \Delta S \quad (4)$$

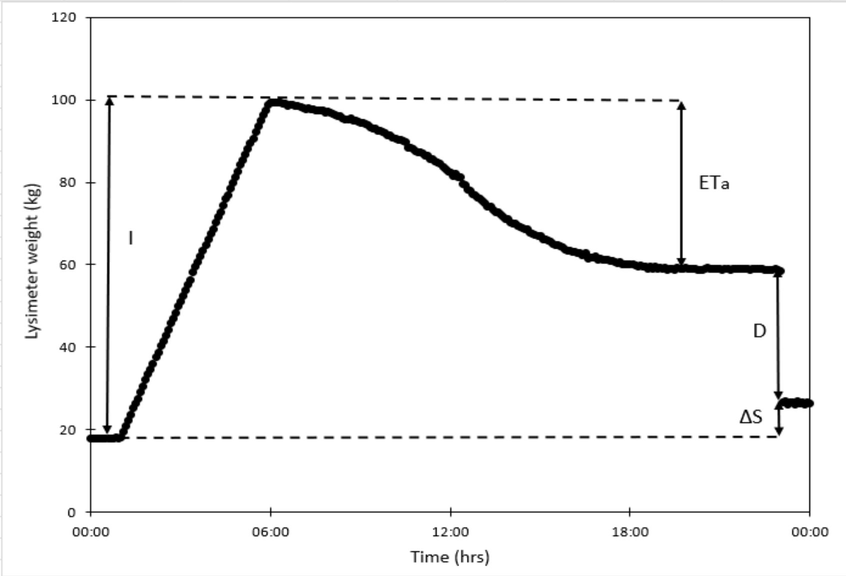

Figure 7. Water balance components throughout a day in an irrigated grapevine.

Moreover, the instantaneous evapotranspiration rate (L h^{-1}) was calculated in representative trees in order to analyze the daily patterns and ET_a peak rate between treatments during both drought trial and its recovery.

The actual evapotranspiration during the growing season was calculated and analyzed. Considering seasonal actual evapotranspiration ($ET_{a\,s}$, m^3) and yield (Y, kg), water productivity (WP, kg m^{-3}) per tree was calculated and analyzed (Equation 5) (van Halsema & Vincent, 2012).

$$WP = \frac{Y}{ET_{a\,s}} \tag{5}$$

It is important to mention that, due to a technical failure detected at the end of the growing season, ET_a data from lysimeter number 3 was not used (n=3 for K-15WD).

3.5.3. PHYSIOLOGICAL PARAMETERS

3.5.3.1. STOMATAL CONDUCTANCE

Midday stomatal conductance to H_2O vapor (henceforth referred to as stomatal conductance) (g_s) was measured in five sun-exposed, healthy, well-developed, and expanded leaves (normally located in the upper part of the tree canopy) approximately between 12:00 to 14:00 hrs. using a porometer model LI-600, brand LI-COR (Figure 8) (Hochberg *et al.*, 2023).

The g_s was measured once before and after the drought trial and daily during the drought and recovery of the grapevines (not measuring on Saturdays). During data collection, g_s data was stored in the instrument, assigning an identifier per tree through a bar code. Subsequently, the data was downloaded in an Excel file separated by commas using the LI-COR LI-600 2.0.0 application. A median g_s per tree was used for further analysis.

Figure 8. Porometer model LI-600, brand LI-COR.

3.5.3.2. STEM WATER POTENTIAL

Midday stem water potential (henceforth referred to as stem water potential, Ψ_{stem}) was measured in parallel to g_s measurements. One leaf per vine in the shade was covered in aluminum + plastic bags for approximately 30 minutes. The leaves were removed from the vine between 12:00 to 14:00 hrs and stored in a plastic bag and then in a polystyrene container for transport to the laboratory. The Ψ_{stem} measurements were done no more than one hour after the leaves excising using a pressure chamber model 600D, brand PMS instruments (Figure 9) (Hochberg et al., 2023; Hochberg, 2020).

Figure 9. Pressure chamber model 600D, brand PMS instruments.

3.5.4. CANOPY GROWTH

3.5.4.1. LEAF AREA INDEX

In order to track the plant growth leaf area index (LAI) was measured before, during a drought critical day and after each drought trial. LAI was measured around 12:00 to 14:00 hrs. using twenty positions (27 cm intervals) under the trellis' surface area (Figure 10A) with a ceptometer model LP-80, brand Decagon (Figure 10B). The vine canopy was allowed to grow only on the trellis; hence the excess was trimmed after drought trials. The first pruning was done on May 28, and the second on June 29, 2023. To account for the drought effect on the behavior of the canopy, the LAI was particularly studied during the critical days of drought in both drought trials.

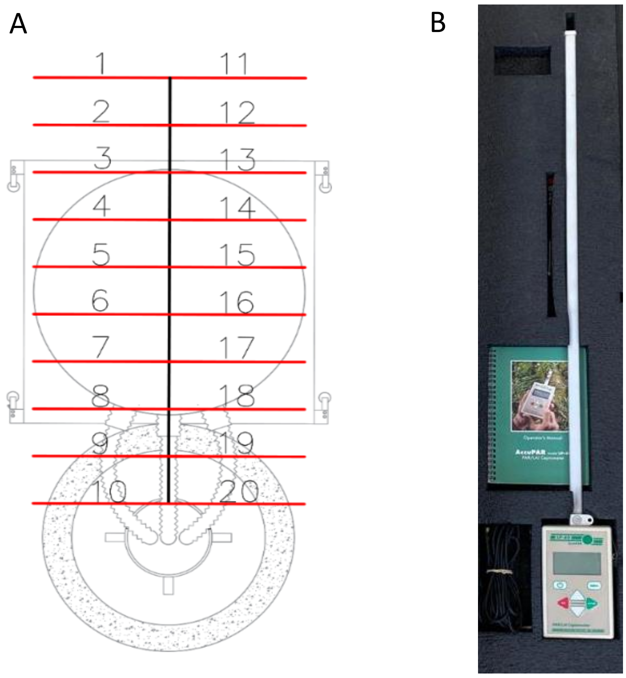

Figure 10. Leaf area index measurement set-up (A) and ceptometer model LP-80, brand Decagon (B).

3.5.5. HARVEST

Grapevines were harvested on July 10. The clusters per tree were counted and placed in containers for transport to the laboratory, where the yield per vine was measured with a digital scale model Mirav 6000, Shekel scales brand. The average cluster weight per vine was calculated based on the number of clusters and the yield per vine. Also, the average berry weight was estimated based on the weight of 50 randomly selected berries per vine using a precision digital scale model ENTRIS4202I-1S, brand Sartorius.

In the laboratory, twenty-five berries were squeezed to get the juice in order to measure the brix degrees using a refractometer model ATC-1, brand ATAGO (Figure 11A), and the pH using a potentiometer model pH 700, brand Eutech Instruments (Figure 11B).

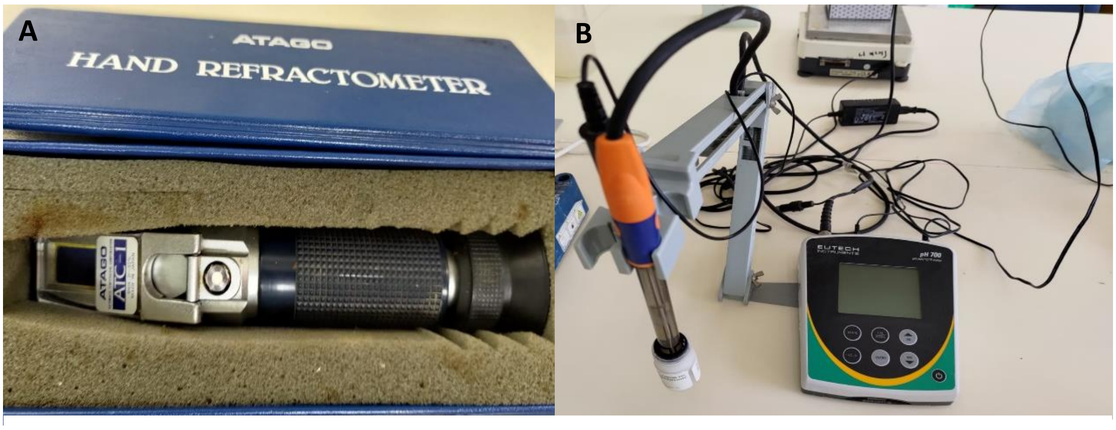

Figure 11. Refractometer (A) and potentiometer (B).

It is important to mention that, to achieve the harvest of the vines, agricultural management in terms of fungicides, insecticides, phytoregulators, and foliar fertilizers was performed based on commercial vineyard management; Appendix 3 shows the agrochemicals applied throughout the growing season to the trees and their purpose. A light thinning was done in the grapevines' clusters from May 22 to 24, 2023. Also, the clusters were covered with paper bags open at the bottom to avoid damage caused by birds from May 22 to 30, 2023.

3.6. LYSIMETER COEFFICIENT

The lysimeter coefficient (K_{lys}, mm mm^{-1}) was calculated based on the daily actual evapotranspiration per lysimeter (ET_{lys}, L day^{-1} tree^{-1}), the Penman-Monteith reference evapotranspiration (ET_0, mm day^{-1}), and the lysimeter area of influence (S; 2.5m * 5m) (Equation 6) (Hochberg et al., 2023).

$$K_{lys} = \frac{ET_{lys}}{ET_0 * S} \tag{6}$$

An analysis of the K_{lys}, based on grapevine's initial season stage ($K_{lys\ ini}$), mid-season stage ($K_{lys\ mid}$) and final season stage ($K_{lys\ end}$) for this specific experimental setup was carried out.

3.7. DATA STATISTICS

The data (g_s, Ψ_{stem}, LAI, daily ET_a, accumulated ET_a, normalized ET_a, K_{lys}, drought visual assessment scores and harvest components) were analyzed using one-way AVONA to evaluate statistically significant differences between the means of the treatments and if necessary, a Tukey's HSD test (post-hoc test) to evaluate statistically significant differences between pairs of treatments (Montgomery & Runger, 2018). The statistical analysis was done using the JMP Pro 16 software (SAS Institute, USA) and defining a statistical significance at $P \leq 0.05$ in both tests.

CHAPTER FOUR: RESULTS

4.1. PHYSIOLOGICAL CHANGES DURING PLANT DEHYDRATION AND RECOVERY

During the first drought trial (April 28 to May 11), the well-watered treatments and the drought treatments at all potassium levels did not present significant statistical differences during the first five days (April 28 to May 02) in the g_s (average value of 0.28 mol m^{-2} s^{-1}) and Ψ_{stem} (average value of -0.5 MPa) (Figure 12C and 12D) (Table 1). In the case of the second drought trial (June 8 to 18), the physiological parameters responded rapidly to the drought event due to the daily water demand of the plant. Unfortunately, due to the weekend, the second and third days of drought were not measured (June 9 and 10).

On the sixth day of the first drought trial (May 03), significant statistical differences in the physiological parameters between the treatments began to be observed. In the case of g_s, the 5WW treatment (average value of 0.30 mol m^{-2} s^{-1}) significantly differed from 5WD and 15WD treatments (average values from 0.22 to 0.23 mol m^{-2} s^{-1}). At the same time, 15WW, 60WW, and 60WD treatments (average values from 0.25 to 0.28 mol m^{-2} s^{-1}) had no significant differences regarding 5WW, 5WD, and 15WD treatments (average values from 0.22 to 0.30 mol m^{-2} s^{-1}) (Table 1). Concerning Ψ_{stem}, the 5WW and 60WW treatments (average values around -0.38 MPa) had significant differences with 5WD and 15WD treatments (average values from -0.51 to 0.52 MPa). In contrast, the 15WW and 60WD treatments (average values from -0.41 to -0.44 MPa) did not have significant differences with respect to the remaining treatments (Figures 12C and 12D) (Table 2).

In the case of the second drought trial, significant statistical differences from the fourth day of drought were observed (June 11). Concerning g_s, the well-watered treatments (average value of 0.55 mol m^{-2} s^{-1}) and water-deficit treatments (average value of 0.35 mol m^{-2} s^{-1}) were significantly different, regardless of the potassium levels (Table 1). About the Ψ_{stem}, there were significant differences between the 15WD and 60WD treatments (average values from -0.79 to -0.84 MPa) concerning 5WW, 15WW, and 60WW treatments (average values from -0.57 and -0.61 MPa). Contrary, 5WD (average value of 0.72 MPa) did not have significant differences from the remaining treatments (Figures 13C and 13D) (Table 2).

The physiological parameters gradually decreased from May 3 in the first drought trial and June 11 in the second drought until they reached severe water deficit levels on May 10 and June 14, respectively (g_s under 0.02 mol m^{-2} s^{-1} and Ψ_{stem} of -1.0 MPa) (Figure 12C, 12D, 13C, and 13D) (Table 1 and 2).

On the tenth day of dehydration of the first drought trial (May 7), the g_s had significant differences between the well-watered treatments (average value of 0.38 mol m^{-2} s^{-1}) and water-deficit treatments (average value of 0.20 mol m^{-2} s^{-1}), no matter potassium levels (Table 1). Regarding Ψ_{stem}, the 5WW and 60WW treatments (average values from -0.41 to -0.42 MPa) had significant differences concerning the 5WD, 15WD, and 60WD treatments (average values from -0.61 to -0.65 MPa). Additionally, the 15WW treatment (average value of 0.52 MPa) had no significant differences from the remaining treatments (Figures 12C and 12D) (Table 2).

Plant dehydration during the second drought trial was quicker than the first trial (seven days compared to fourteen days) (Figures 12 and 13). On the fifth day of dehydration of the second trial (June 12), the g_s had significant differences between the 5WW and 15WW treatments (average values from 0.49 to 0.50 mol m^{-2} s^{-1}) compared to the 60WW treatment (average value of 0.53 mol m^{-2} s^{-1}), 15WD treatment (average value of 0.095 mol m^{-2} s^{-1}) and 60WD treatment (average value of 0.06 mol m^{-2} s^{-1}). In contrast, the 5WD treatment (average value of 0.09 mol m^{-2} s^{-1}) was statistically similar to the 15WD and 60WD treatments (Table 1). Regarding Ψ_{stem}, there were significant differences between the 5WW, 15WW, and 60WW treatments (average values from -0.48 to -0.52 MPa), 15WD and 60WD treatments (average values from -0.94 to -0.98 MPa), and the 5WD treatment (average value of -0.72 MPa) (Figures 13C and 13D) (Table 2). It is important to highlight, during the second drought trial, June 13 was abnormal since it was cloudy and rained slightly. For that reason, it was impossible to measure the g_s because the leaves were wet; fortunately, Ψ_{stem} was measured. The rain was neglected since the weather station measured 0 mm at the Gilat Research Center.

The critical days in the first drought trial were on May 10 and 11 (Figure 12C and 12D), while the second drought were from June 14 to 18 (Figure 13C and 13D) (Table 1 and 2). In order to maintain drought stress, in the first drought trial, 10L liters of water were manually irrigated to each tree in water-deficit conditions on May 10. Similarly, in the second drought trial, ±30 L were irrigated on June 15 and ±15L on June 16 and 17 through drip irrigation (Appendix 4).

During the two critical days of drought in the first drought trial, there were significant statistical differences in g_s between the 5WW, 15WW, and 60WW treatments (average values from 0.32 to 0.37 mol m^{-2} s^{-1}) and the 5WD, 15WD, and 60WD treatments (average values from 0.022 to 0.032 mol m^{-2} s^{-1}) (Table 1). Likewise, there were significant differences in Ψ_{stem} between the 5WW, 15WW, and 60WW treatments (average values from -0.48 to -0.64 MPa) and the 5WD, 15WD, and 60WD treatments (average values from -1.0 to -1.12 MPa) (Figure 12C and Figure 12D) (Table 2).

Concerning the critical days of drought in the second drought trial, on June 14, there were significant differences in g_s between the 60WW treatment (average value of 0.59 mol m^{-2} s^{-1}), 5WW and 15WW treatments (average values from 0.52 to 0.53 mol m^{-2} s^{-1}) and 5WD, 15WD and 60WD treatments (average values from 0.0087 to 0.01 mol m^{-2} s^{-1}) (Table 1). Regarding Ψ_{stem}, there were significant differences between the 5WW, 15WW, and 60WW treatments (average values from -0.57 to -0.66 MPa) and 5WD, 15WD, and 60WD treatments (average values from -0.91 to -1.08 MPa) (Table 2). On June 15, it was observed that Ψ_{stem} reacted rapidly due to the 30L irrigation on June 15, varying from approximately - 1.0 MPa to - 0.8 MPa; however, the g_s values remained as severe water-deficit. On June 16, there were significant differences in g_s between the 5WW treatment (average value of 0.5 mol m^{-2} s^{-1}), 15WW and 60WW treatments (average values from 0.58 to 0.63 mol m^{-2} s^{-1}) and 5WD, 15WD, and 60WD treatments (average values from 0.011 to 0.13 mol m^{-2} s^{-1}) (Table 1). In relation to Ψ_{stem}, there were significant differences between the 5WW, 15WW, and 60WW treatments (average values from -0.7 to -0.75 MPa) concerning 5WD, 15WD, and 60WD treatments (average values from -1.05 to -1.15 MPa) (Table 2). On June 17, no physiological parameters were measured (Saturday). On June 18 (the last day of critical drought), the physiological parameters were slightly higher than the previous days; there were significant differences in g_s between the 60WW treatment (average value of 0.59 mol m^{-2} s^{-1}), 5WW and 15WW treatments (average values from 0.46 to 0.49 mol m^{-2} s^{-1}) and 5WD, 15WD, and 60WD treatments (average values from 0.34 to 0.35 mol m^{-2} s^{-1}) (Table 1). Considering the Ψ_{stem}, there were significant differences between the 5WW, 15WW, and 60WW treatments (average values from -0.43 to -0.51 MPa) with regard to the 5WD, 15WD, and 60WD treatments (average values from -0.82 to -0.91 MPa) (Figure 13C and 13D) (Table 2).

In general, during the critical drought days, the g_s values were lower in the second drought trial than in the first one (Table 1). Likewise, in both drought trials, the Ψ_{stem} values were not less than -1.2Mpa; the 60WD treatment had the lowest values, while 5WD had the highest (Table 2). In both drought events, g_s and Ψ_{stem} presented an inversely proportional relationship regarding the midday vapor pressure deficit for well-watered treatments (Figures 12E and 13E). Finally, irrigation was reestablished on May 11 in the first drought trial and June 18 in the second drought trial.

Concerning the plant recovery of the first drought trial in terms of g_s (May 12 to 17), on May 15, the 5WD treatment reached statistically similar levels with respect to the 5WW treatment (average value of 0.425 mol m^{-2} s^{-1}), while the 15WD and 60WD were statistically different from 15WW and 60WW, respectively. On the other hand, on May 16, the 15WD treatment recovered levels statistically similar to the 15WW treatment (average value of 0.533 mol m^{-2} s^{-1}); the 60WD treatment was the only one remaining to recover compared to the 60WW treatment. Finally, on May 17, the 60WD treatment reached levels statistically similar to 60WW (average value of 0.506 mol m^{-2} s^{-1}) (Figure 12C) (Table 1).

Similarly, in the plant recovery of the second drought trial regarding g_s (June 19 to June 23), on June 21, the 15WD treatment recovered at statistically similar levels as the 15WW treatment (average value of 0.518 mol m^{-2} s^{-1}) and the 5WD and 60WD treatments were statistically different from the 5WW and 60 WW treatments, respectively. Subsequently, on June 22, the 5WD treatment reached statistically similar levels to the 5WW treatment (average value of 0.508 mol m^{-2} s^{-1}), while the 60WD treatment was statistically different from the 60WW treatment. Ultimately, on June 23, the 60WD treatment statistically recovered the same values as 60WW (average value of 0.586 mol m^{-2} s^{-1}) (Figure 13C) (Table 1).

On the other hand, in both drought trials, the Ψ_{stem} recovered statistically similar values to the well-watered treatments in all water-deficit treatments (average value of -0.57 MPa) on the first day of recovery (May 12 in the first drought event and June 19 in the second) (Figures 12D and 13D) (Table 2). Data collected from all experimental days regarding g_s and Ψ_{stem} are show in Appendix 4 and 5.

Table 1. Average per treatment of g_s (mol m^{-2} s^{-1}) analyzed in both drought trials during plant dehydration and rehydration. The letters in brackets represent the statistical report where levels not connected by the same letter are significantly different (n=4, α= 0.05).

Event	Date	Treatment					
		5WD	**5WW**	**15WD**	**15WW**	**60WD**	**60WW**
1st dehy-dration	**May 02**	0.229 (A)	0.274 (A)	0.233 (A)	0.261 (A)	0.260 (A)	0.265 (A)
	May 03	0.234 (B)	0.307 (A)	0.224 (B)	0.282 (AB)	0.252 (AB)	0.280 (AB)
	May 07	0.228 (B)	0.374 (A)	0.209 (B)	0.388 (A)	0.186 (B)	0.371 (A)
	May 10	0.032 (B)	0.373 (A)	0.023 (B)	0.33 (A)	0.024 (B)	0.329 (A)
	May 11	0.022 (B)	0.330 (A)	0.024 (B)	0.378 (A)	0.022 (B)	0.358 (A)
1st rehy-dration	**May 15**	0.428 (B)	0.424 (B)	0.394 (C)	0.443 (A)	0.359 (C)	0.418 (B)
	May 16	0.474 (B)	0.489 (B)	0.539 (A)	0.528 (A)	0.388 (C)	0.506 (A)
	May 17	0.508 (A)	0.521 (A)	0.494 (A)	0.509 (A)	0.499 (A)	0.514 (A)
2nd dehy-dration	**June 08**	0.500 (A)	0.499 (A)	0.492 (A)	0.497 (A)	0.496 (A)	0.522 (A)
	June 11	0.298 (B)	0.503 (A)	0.306 (B)	0.486 (A)	0.306 (B)	0.520 (A)
	June 12	0.092 (CD)	0.501 (B)	0.095 (C)	0.494 (B)	0.063 (D)	0.533 (A)
	June 14	0.009 (C)	0.52 (B)	0.010 (C)	0.528 (B)	0.01 (C)	0.596 (A)
	June 15	0.009 (C)	0.514 (B)	0.012 (C)	0.538 (B)	0.01 (C)	0.598 (A)
	June 16	0.012 (C)	0.504 (B)	0.013 (C)	0.585 (A)	0.011 (C)	0.629 (A)
	June 18	0.035 (C)	0.462 (B)	0.034 (C)	0.496 (B)	0.034 (C)	0.593 (A)
2nd rehy-dration	**June 21**	0.399 (D)	0.475 (C)	0.521 (B)	0.515 (B)	0.452 (C)	0.583 (A)
	June 22	0.513 (B)	0.503 (B)	0.523 (B)	0.508 (B)	0.435 (C)	0.618 (A)
	June 23	0.493 (B)	0.516 (B)	0.59 (A)	0.591 (A)	0.586 (A)	0.587 (A)

Table 2. Average per treatment of Ψ_{stem} (MPa) analyzed in both drought trials during plant dehydration and rehydration. The letters in brackets represent the statistical report where levels not connected by the same letter are significantly different (n=4, α= 0.05).

Drought event	Date	Treatment					
		5WD	5WW	15WD	15WW	60WD	60WW
1st dehy-dration	May 02	-0.517 (A)	-0.455 (A)	-0.503 (A)	-0.477 (A)	-0.448 (A)	-0.493 (A)
	May 03	-0.503 (B)	-0.388 (A)	-0.510 (B)	-0.410 (AB)	-0.448 (AB)	-0.385 (A)
	May 07	-0.613 (B)	-0.428 (A)	-0.635 (B)	-0.518 (AB)	-0.653 (B)	-0.418 (A)
	May 10	-1.038 (B)	-0.643 (A)	-1.023 (B)	-0.488 (A)	-1.123 (B)	-0.590 (A)
	May 11	-1.005 (B)	-0.595 (A)	-1.055 (B)	-0.610 (A)	-1.118 (B)	-0.605 (A)
1st rehy-dration	May 12	-0.573 (A)	-0.588 (A)	-0.573 (A)	-0.593 (A)	-0.563 (A)	-0.550 (A)
2nd dehy-dration	June 08	-0.605 (A)	-0.610 (A)	-0.578 (A)	-0.585 (A)	-0.555 (A)	-0.593 (A)
	June 11	-0.718 (AB)	-0.578 (A)	-0.795 (B)	-0.595 (A)	-0.840 (B)	-0.610 (A)
	June 12	-0.728 (B)	-0.485 (A)	-0.988 (C)	-0.528 (A)	-0.943 (C)	-0.525 (A)
	June 14	-0.915 (B)	-0.660 (A)	-1.033 (B)	-0.583 (A)	-1.078 (B)	-0.575 (A)
	June 15	-0.713 (AB)	-0.553 (A)	0.720 (AB)	-0.558 (A)	-0.770 (B)	-0.608 (AB)
	June 16	-1.055 (B)	-0.703 (A)	-1.135 (B)	-0.730 (A)	-1.145 (B)	-0.750 (A)
	June 18	-0.820 (B)	-0.460 (A)	-0.863 (B)	-0.433 (A)	-0.910 (B)	-0.515 (A)
2nd rehy-dration	June 19	-0.558 (A)	-0.560 (A)	-0.570 (A)	-0.575 (A)	-0.645 (A)	-0.570 (A)

4.3. DROUGHT EFFECTS ON ACTUAL EVAPOTRANSPIRATION

4.3.1. DAILY ACTUAL EVAPOTRANSPIRATION

During the first drought trial, the daily actual evapotranspiration (ET_a) had no statistically significant differences between treatments from April 28 to May 4 (first seven days of the drought event) (average values from 18.16 to 27.61 L tree^{-1} day^{-1}) (Figure 12B) (Table 3). Similarly, the physiological parameters did not differ significantly during the mentioned days. On May 5 (8th day of drought), there were statistically significant differences in daily ET_a between the treatments 15WW (average value of 42.57 L tree^{-1} day^{-1}), 15WD (average value of 34.07 L tree^{-1} day^{-1}), and 60WD (average value of 25.96 L tree^{-1} day^{-1}) treatments, while there were no differences between the 5WW, 15WW and 60WW treatments (average values from 37.40 to 42.58 L tree^{-1} day^{-1}), the 5WW, 60WW and 15WD treatments (average values from 34.08 to 39.55 L tree^{-1} day^{-1}), the 60WW, 15WD and 5WD treatments (average values from 31.12 to 37.4 L tree^{-1} day^{-1}), and the 5WD and 60WD treatments (average values from 25.96 to 31.12 L tree^{-1} day^{-1}) (Table 3). On May 11 (a critical day of drought), there were significant differences in the 5WW, 15WW, and 60WW treatments (average values from 37.24 to 41.24 L tree^{-1} day^{-1}) concerning the 5WD, 15WD, and 60WD treatments (average values from 9.9 to 11.6 L tree^{-1} day^{-1}) (Table 3). Subsequently, on May 15 (middle of the plant recovery), there were significant differences in the 5WW and 15WW treatments (average values from 37.98 to 40.03 L tree^{-1} day^{-1}) in relation to the 5WD and 60WD treatments (average values from 26.75 to 29.17 L tree^{-1} day^{-1}). Parallelly, there were no significant differences between the 5WW, 15WW, and 60WW treatments (average values from 36.82 to 40.03 L tree^{-1} day^{-1}), 60WW and 15WD treatments (average values from 31.39 to 36.82 L tree^{-1} day^{-1}), and 5WD, 15WD, and 60WD treatments (average values from 26.75 to 31.39 L tree^{-1} day^{-1}) (Figure 12B) (Table 3).

Finally, on May 18, when the physiological parameters in the water-deficit treatments reached statistically the same values as the well-watered treatments, the daily ET_a was significantly different in the 15WW (average value of 39.44 L tree^{-1} day^{-1}) concerning the 5WD (average value of 27.94 L tree^{-1} day^{-1}), while there were no statistical differences between 5WW, 15WW, 60WW and 15WD treatments (average values from 32.64 to 39.44 L tree^{-1} day^{-1}), 5WW, 60WW, 15WD and 60WD treatments (average values from 28.59 to 34.87 L tree^{-1} day^{-1}) and 5WW, 5WD, 15WD and 60WD treatments (average values from 27.94 to 34.07 L tree^{-1} day^{-1}) (Figure 12B) (Table 3).

In general, based on the daily actual evapotranspiration average, during the drought and recovery days, the 60WD and 60WW treatments were the lowest values, while the 15WD and 15WW were the highest in water-deficit and well-watered cases, respectively. Surprisingly, after the plant recovery, the 5WD and 5WW treatments were the lowest values, and the 15WD and 15WW treatments were the highest (Figure 12B) (Table 3).

In the case of the second drought trial, on June 8 (the first day of drought), there were no significant differences in daily ET_a between all treatments (Table 3). Consequently, significant differences were observed on June 9 (the second day of drought) in the 15WW treatment (average value of 60.75 L tree^{-1} day^{-1}) regarding the 5WD treatment (average value of 48.04 L tree^{-1} day^{-1}), while there were no significant differences between the 15WW, 60WW, 15WD, and 60WD treatments (average values from 52.39 to 60.95 L tree^{-1} day^{-1}), 5WW, 60WW and 60WD treatments (average values from 51.49 to 57.73 L tree^{-1} day^{-1}) and 5WW and 5WD treatments (average values from 48.04 to 51.5 L tree^{-1} day^{-1}) (Table 3). Subsequently, on June 11, there were significant differences between the 5WW, 15WW, and 60WW treatments (average values from 51.44 to 57.59 L tree^{-1} day^{-1}) concerning 5WD, 15WD, and 60WD treatments (average values from 37.41 to 39.91 L tree^{-1} day^{-1}) (Table 3). Similarly, on June 15 (a critical day of drought), there were significant differences between the 5WW, 15WW, and 60WW treatments (average values from 48.67 to 55.54 L tree^{-1} day^{-1}) regarding 5WD, 15WD, and 60WD (average values from 15.58 to 17.24 L tree^{-1} day^{-1}), while on June 18 (last critical day of drought) there were similar trends between treatments as June 15 (for 5WW, 15WW, and 60WW average values from 51.31 to 59.52 and for 5WD, 15WD, and 60WD average values from 17.24 to 19.27) (Table 3). On the other hand, on June 21 (middle of the plant recovery), there were significant differences between the 15WW and 60WW treatments (average values from 60.14 to 63.2 L $tree^{-1}$ day^{-1}) with respect to 5WD treatment (average value of 38.87 L $tree^{-1}$ day^{-1}), while there were statistical similarities in the 5WW, 15WW, and 60WW treatments (average values from 54.97 to 63.2 L $tree^{-1}$ day^{-1}), 5WW, 15WD, and 60WD treatments (average values from 44.74 to 54.97 L $tree^{-1}$ day^{-1}), and 5WD, 15WD, and 60WD treatments (average values from 38.87 to 47.09 L $tree^{-1}$ day^{-1}) (Figure 13B) (Table 3).

Ultimately, on June 23, there were significant differences between the 15WW and 60WW treatments (average values from 61.01 to 66.9 L $tree^{-1}$ day^{-1}) concerning the 5WD treatment (average value of 43.64 L $tree^{-1}$ day^{-1}), existing statistical similarities in the 5WW, 15WW, 60WW, 15WD, and 60WD treatments (average values from 50.12 to 66.89 L $tree^{-1}$ day^{-1}) and 5WW, 5WD, 15WD, and 60WD treatments (average values from 43.64 to 60.09 L $tree^{-1}$ day^{-1}) (Figure 13B) (Table 3).

Analogously, based on the daily actual evapotranspiration average, in the first four days of drought, the 15WD treatment had the highest values, followed by the 5WD treatment until the recovery of physiological parameters. Similarly, during the first four days of drought, the 5WD treatment was the one that presented the lowest values, the following four days it was the 60WD treatment, and later it was the 15WD treatment until the recovery of the physiological parameters. During plant recovery (and even after), the 5WD treatment presented the lowest values, while the 60WD treatment presented the highest values. In the case of the well-irrigated treatments, the 15WW treatment was the one that consistently showed the highest values, while 5WW the lowest (Figure 13B) (Table 3).

It is important to highlight that, even after plant recovery in both drought events, the daily ET_a did not reach the same levels in the water-deficit treatments compared to the well-watered treatments (Figure 12B and 13B). Daily ET_a values were statistically similar in both cases only after tree pruning (Figure 14). The daily components of the water balance used to calculate the daily ET_a throughout the growing season are shown in Appendix 6.

Table 3. Average per treatment of ET_a (L $tree^{-1}$ day^{-1}) analyzed in both drought trials during plant dehydration and rehydration. The letters in brackets represent the statistical report where levels not connected by the same letter are significantly different (n=4 except for 15WD where n=3, α= 0.05).

Drought event	Date	Treatments					
		5WD	5WW	15WD	15WW	60WD	60WW
1st dehy-dration	April 28	18.13 (A)	17.68 (A)	18.78 (A)	19.41 (A)	17.22 (A)	17.90 (A)
	May 04	26.20 (A)	26.64 (A)	29.45 (A)	31.09 (A)	26.19 (A)	26.59 (A)
	May 05	31.12 (CD)	39.55 (AB)	34.08 (BC)	42.58 (A)	25.96 (D)	37.4 (ABC)
	May 11	11.2 (B)	39.57 (A)	11.61 (B)	41.24 (A)	9.90 (B)	37.24 (A)
1st rehy-dration	May 15	29.17 (C)	37.98 (A)	31.34 (BC)	40.03 (A)	26.75 (C)	36.81 (AB)
	May 18	27.94 (C)	34.07 (ABC)	32.64 (ABC)	39.44 (A)	28.59 (BC)	34.87 (AB)
2nd dehy-dration	June 08	35.17 (A)	35.21 (A)	40.33 (A)	40.81 (A)	42.30 (A)	39.97 (A)
	June 09	48.04 (C)	51.5 (BC)	60.95 (AB)	60.75 (A)	57.73 (AB)	52.39 (ABC)
	June 11	37.41 (B)	51.44 (A)	39.91 (B)	57.59 (A)	37.68 (B)	54.00 (A)
	June 15	17.24 (B)	48.67 (A)	15.58 (B)	55.54 (A)	16.01 (B)	54.19 (A)
	June 18	19.27 (B)	51.31 (A)	17.24 (B)	59.52 (A)	18.20 (B)	55.31 (A)
2nd rehy-dration	June 21	38.87 (C)	54.97 (AB)	44.75 (BC)	63.20 (A)	47.09 (BC)	60.14 (A)
	June 23	43.65 (B)	60.09 (AB)	50.12 (AB)	66.9 (A)	53.67 (AB)	61.01 (A)

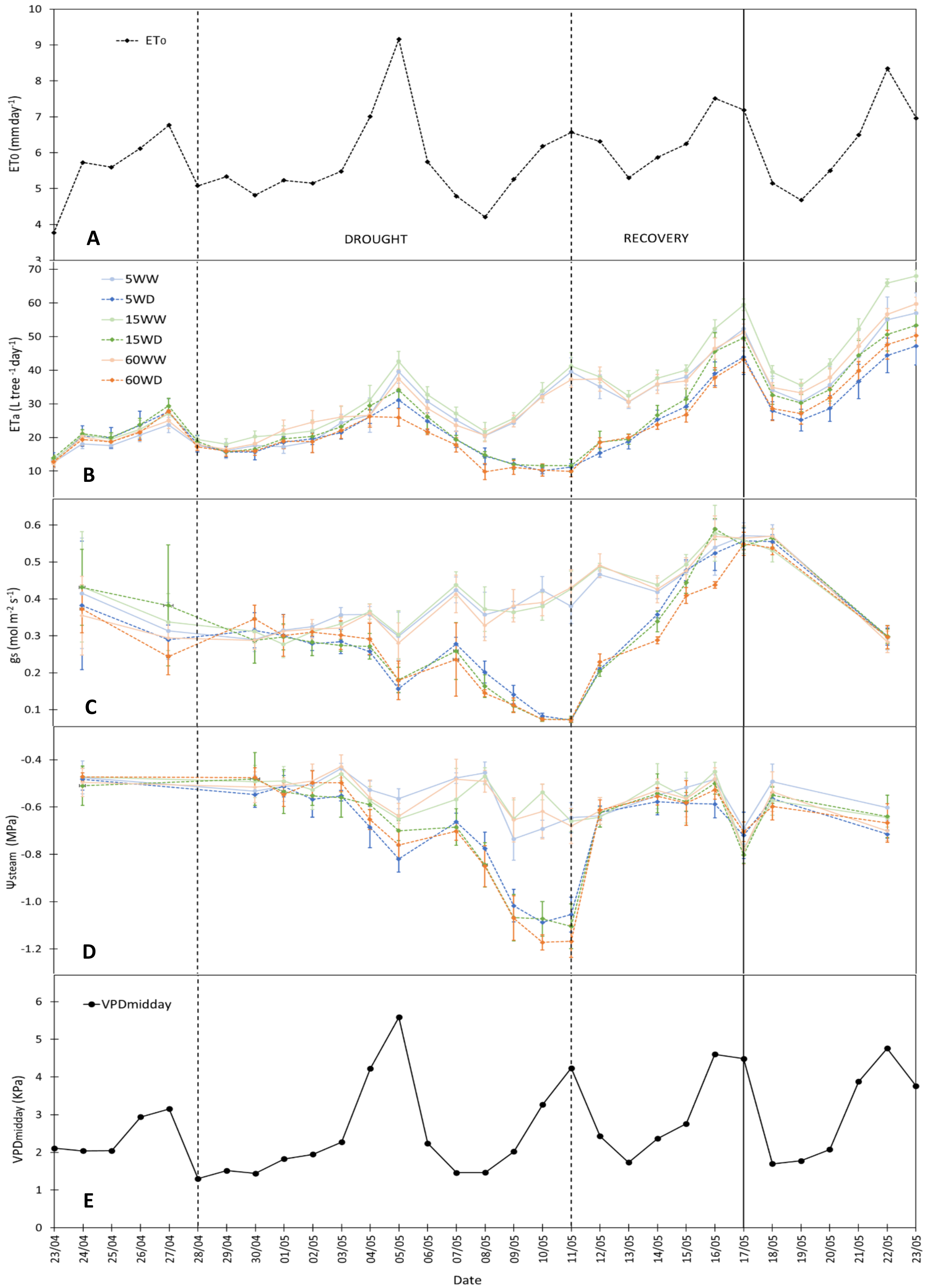

Figure 12. First drought trial measurements. (A) Reference evapotranspiration (ET_0), (B) Whole-tree actual evapotranspiration (ET_a), (C) Midday stomatal conductance (g_s), (D) Midday stem water potential (Ψ_{stem}), (E) Midday vapor pressure deficit (VPD_{midday}). Vertical dotted lines comprise the beginning and end of the drought event, while the solid line indicates the end of the plant recovery in all treatments. Points represent averages and error bars standard deviations (n=4, excluding 15WD in ET_a where n=3).

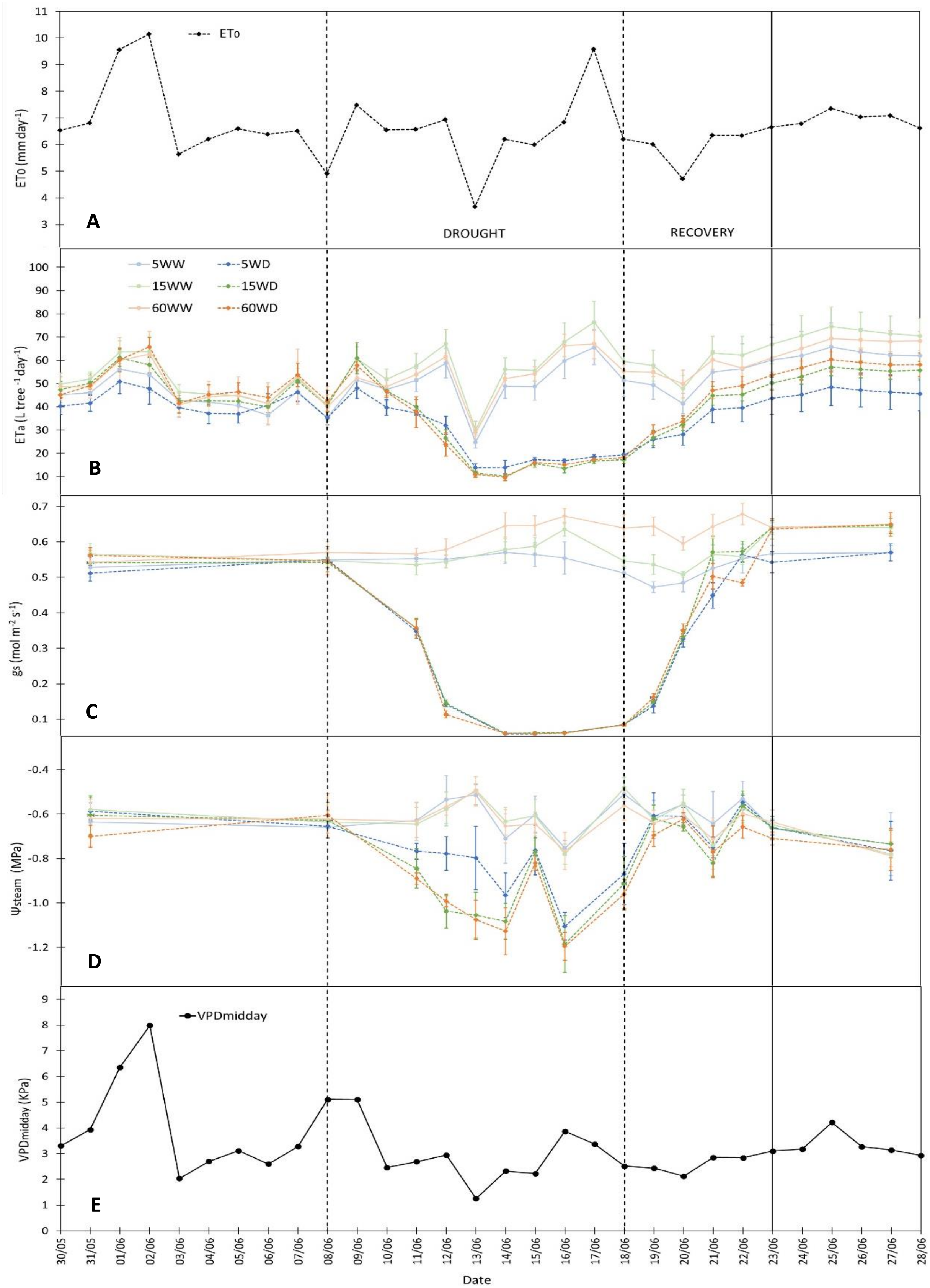

Figure 13. Second drought trial measurements. (A) Reference evapotranspiration (ET_0), (B) Whole-tree actual evapotranspiration (ET_a), (C) Midday stomatal conductance (g_s), (D) Midday stem water potential (Ψ_{stem}), (E) Midday vapor pressure deficit (VPD_{midday}). Vertical dotted lines comprise the beginning and end of the drought event, while the solid line indicates the end of the plant recovery in all treatments. Points represent averages and error bars standard deviations (n=4, excluding 15WD in ET_a where n=3).

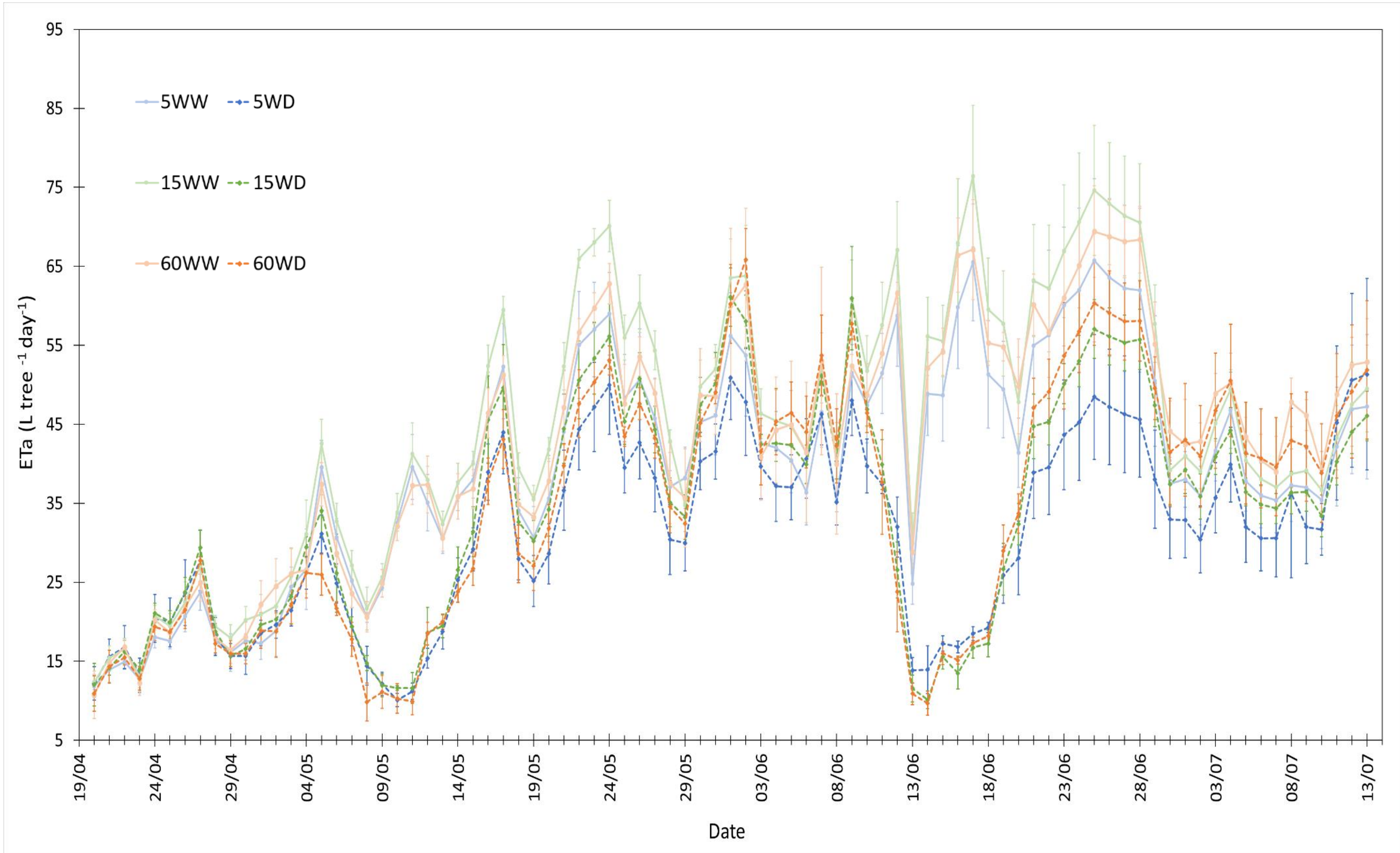

Figure 14. Daily actual evapotranspiration throughout the season.

4.3.2. ACCUMULATED EVAPOTRANSPIRATION DURING GROWING SEASON

The accumulated actual evapotranspiration (ET_a) per tree had no significant differences between treatments from April 20 to May 7 (Figure 15). During the first drought trial, on May 8, there were statistically significant differences in accumulated ET_a between the 15WW (average value of 428.68 L $tree^{-1}$ day^{-1}) and 60WD (average value of 351.21 L $tree^{-1}$ day^{-1}) treatments, while there were no significant differences between the 5WW, 60WW, 5WD, and 15WD treatments (average values from 374.63 to 402.56 L $tree^{-1}$ day^{-1}) (Table 4). Likewise, during the critical day of drought on May 11, there were significant differences between the 15WW treatment (average value of 529.45 L $tree^{-1}$ day^{-1}) concerning the 5WD and 60WD treatments (average values from 382.51 to 408.06 L $tree^{-1}$ day^{-1}); there were no significant differences between the treatments 5WW, 15WW and 60WW (average values from 484.38 to 529.45 L $tree^{-1}$ day^{-1}), 5WW, 60WW and 15WD (average values from 423.64 to 496.77 L $tree^{-1}$ day^{-1}) and 5WD, 15WD and 60WD (average values from 382.51 to 423. 64 L $tree^{-1}$ day^{-1}) (Table 4).

On the first day of the second drought trial, June 8, there were significant differences in accumulated ET_a between the 15WW treatment (average value of 1910.61 L $tree^{-1}$ day^{-1}) with respect to the 5WD treatment (average value of 1436.8 L $tree^{-1}$ day^{-1}), while there were no significant differences between the 5WW, 15WW, and 60WW treatments (average values from 1701.82 to 1910.61 L $tree^{-1}$ day^{-1}), 5WW, 60WW, 15WD, and 60WD treatments (average values from 1525.65 to 1775.27 L $tree^{-1}$ day^{-1}) and 5WD, 15WD, and 60WD treatments (average values from 1436.8 to 1600.9 L $tree^{-1}$ day^{-1}) (Table 4).

Moreover, during the critical day of drought on June 15, there were significant differences in the 15WW and 60WW treatments (average values from 2127.1 to 2289.43 L $tree^{-1}$ day^{-1}) concerning 5WD and 60WD treatments (average values from 1638.96 to 1727.89 L $tree^{-1}$ day^{-1}) but without significant differences between the 5WW, 15WW, and 60WW treatments (average values from 2033.24 to 2289.44 L $tree^{-1}$ day^{-1}), 5WW and 15WD treatments (average values from 1812.47 to 2033.24 L $tree^{-1}$ day^{-1}) and 5WD, 15WD, and 60WD treatments (average values from 1638.96 to 1812.47 L $tree^{-1}$ day^{-1}) (Table 4).

Finally, the accumulated ET_a on the day of harvest on July 10 presented significant differences in the 15WW and 60WW treatments (average values from 3478 to 3652.67 L $tree^{-1}$ day^{-1}) in relation to 5WD treatment (average value of 2505.45 L $tree^{-1}$ day^{-1}), while there were no significant differences between the 5WW, 15WW, and 60WW treatments (average values from 3256.75 to 3652.67 L $tree^{-1}$ day^{-1}), 5WW, 15WD, and 60WD treatments (average values from 2793.2 to 3256.75 L $tree^{-1}$ day^{-1}) and 5WD, 15WD, and 60WD treatments (average values from 2505.45 TO 2801.3 L $tree^{-1}$ day^{-1}) (Table 4).

It is important to highlight that during the late season (June and July), the ET_{accum} line slope of the 60WD treatment increased substantially, while the slope of 15WD remained relatively constant, observing similar values of ET_{accum} between the aforementioned treatments. Similarly, this occurred in the 60WW treatment compared to the 15WW treatment (to a lesser extent), observing a slight increase in the slope in the 60WW line. The K-5 treatments were consistently observed below the K-15 and K-60 treatments, maintaining slopes of their ET_{accum} lines relatively constant, even with canopy damages due to potassium deficiency (Figure 15).

The recovery of the 60WD treatment in terms of increase in ET_a was evident in the late season, although without statistically significant differences in relation to the 15WD treatment (Figure 15 and Table 4).

As can be seen in Table 4 and Figure 15, throughout the growing season, the treatment that consistently presented the highest ET_{accum} was 15WW, while the consistently lowest treatment was 5WD.

Table 4. Average per treatment of ET_{accum} (L) analyzed in diverse days during growing season. The letters in brackets represent the statistical report where levels not connected by the same letter are significantly different (n=4 except for 15WD where n=3, α= 0.05).

Date	Treatment					
	5WD	**5WW**	**15WD**	**15WW**	**60WD**	**60WW**
May 08	374.63 (AB)	387.95 (AB)	388.47 (AB)	428.68 (A)	351.21 (B)	402.56 (AB)
May 11	408.06 (C)	484.38 (AB)	423.64 (BC)	529.45 (A)	382.51 (C)	496.77 (AB)
June 08	1436.80 (C)	1701.82 (AB)	1600.91 (BC)	1910.61 (A)	1525.65 (BC)	1775.27 (AB)
June 15	1638.96 (C)	2033.24 (AB)	1812.46 (BC)	2289.44 (A)	1727.89 (C)	2127.1 (A)
July 10	2505.45 (C)	3256.75 (AB)	2793.20 (BC)	3652.67 (A)	2801.33 (BC)	3478.01 (A)

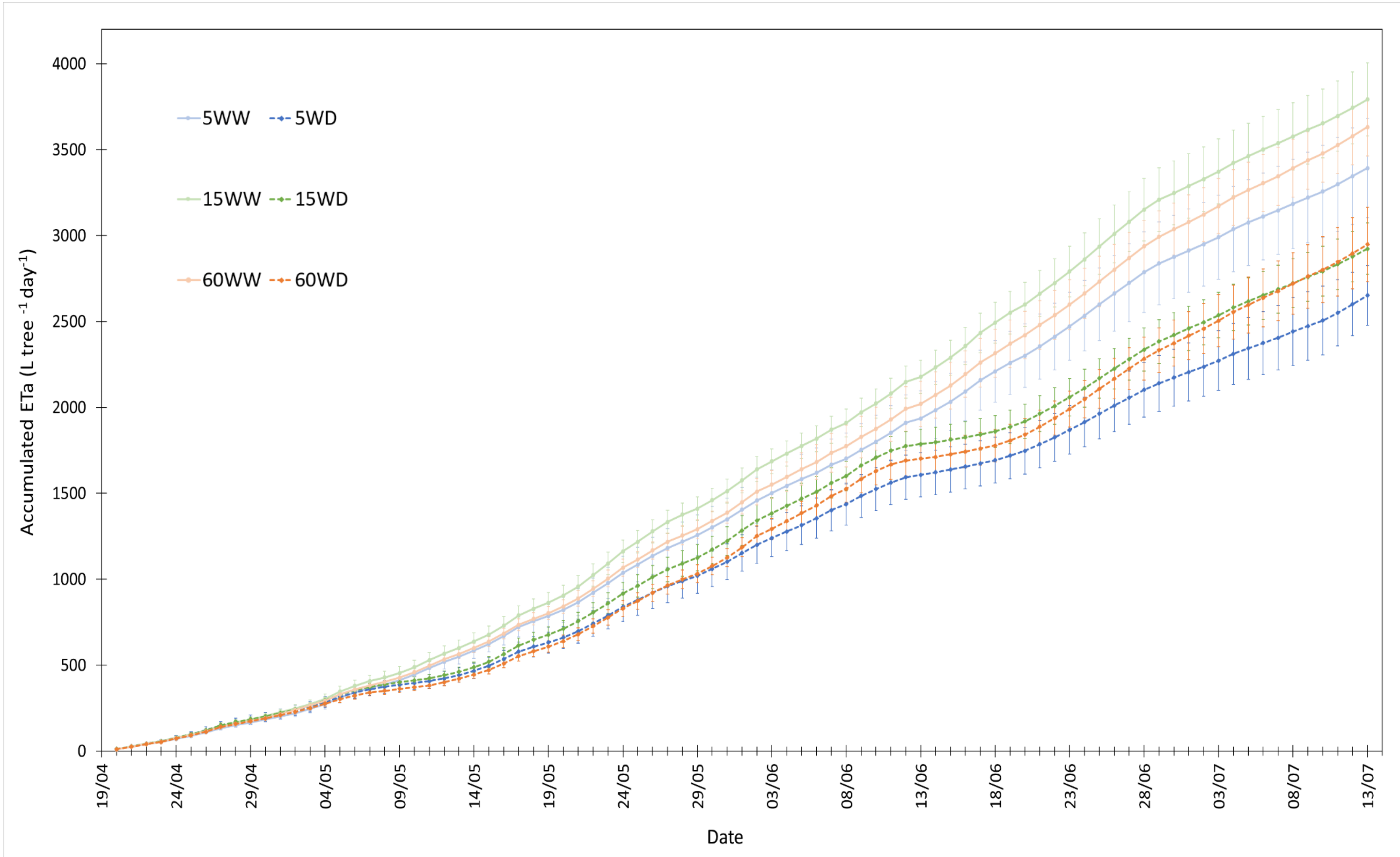

Figure 15. Accumulated actual evapotranspiration.

4.3.3. ACTUAL EVAPOTRANSPIRATION RATE DURING DROUGHT TRIALS

Vine-scale hourly actual evapotranspiration rates were calculated for the drought and recovery days per trial based on a single but representative lysimeter per treatment (5WW represented by lysimeter 17, 5WD lysimeter 19, 15WW lysimeter 7, 15WD lysimeter 15, 60WW lysimeter 8, and 60WD lysimeter 12) (Figure 16 and 17). No statistical analysis was elaborated due to the lack of repetitions per treatment.

On one hand, during the first drought trial, the daily ET_a patterns were similar between well-watered and water-deficit treatments during the first six days of drought (D1-D6). Subsequently, from the seventh to the twelfth drought day (D7-D12), the ET_a rates in the water-deficit treatments decreased progressively. Likewise, the daily ET_a patterns in the water-deficit treatments were gradually below the well-watered treatments. In the case of the water-deficit treatments, a noticeable trend was observed in which the highest peak ET_a rates corresponded to the 5WD treatment, followed by the 15WD treatment, and finally, the 60WD treatment. On the critical days of drought (D13-D14), the trend mentioned above was observed in the peak ET_a rates (5WD treatment was the highest and 60WD the lowest). Finally, after the irrigation re-introduction for the plant recovery (R1-R6), the rates of ET_a increased gradually in the water-deficit treatments but without reaching the same values as the well-watered treatments. Throughout the trial, in terms of peak ET_a rates, the well-watered treatments were not noticeably different (Figure 16).

On the other hand, in the second drought trial, the daily patterns and ET_a rates were similar in both water regimes during the first three days of the trial (D1-D3), but with the difference that the ET_a rates in the K5 treatments were lower compared to K15 and K60 treatments. Consequently, from the fourth to the fifth drought day (D4-D5), the water-deficit treatments decreased abruptly concerning the well-watered treatments in terms of ET_a rate; also, the daily ET_a patterns in the water-deficit treatments were significantly below well-watered treatments. Subsequently, from the sixth to the tenth drought day (D6-D10), the ET_a rate values of the water deficit treatments were consistently below the well-watered treatments, with no visible differences among them. Similarly to the first trial, during the plant recovery (R1-R6), the rates of ET_a in the water-deficit treatments increased progressively but without reaching similar values to the well-watered treatments; the 5WD treatment had visibly lower ET_a rates than the 15WD and 60WD treatments at the end of the plant recovery. Regarding the well-watered treatments, the ET_a rate was consistently higher in the 15WW treatment, followed by 60WW, and finally 5WW (Figure 17).

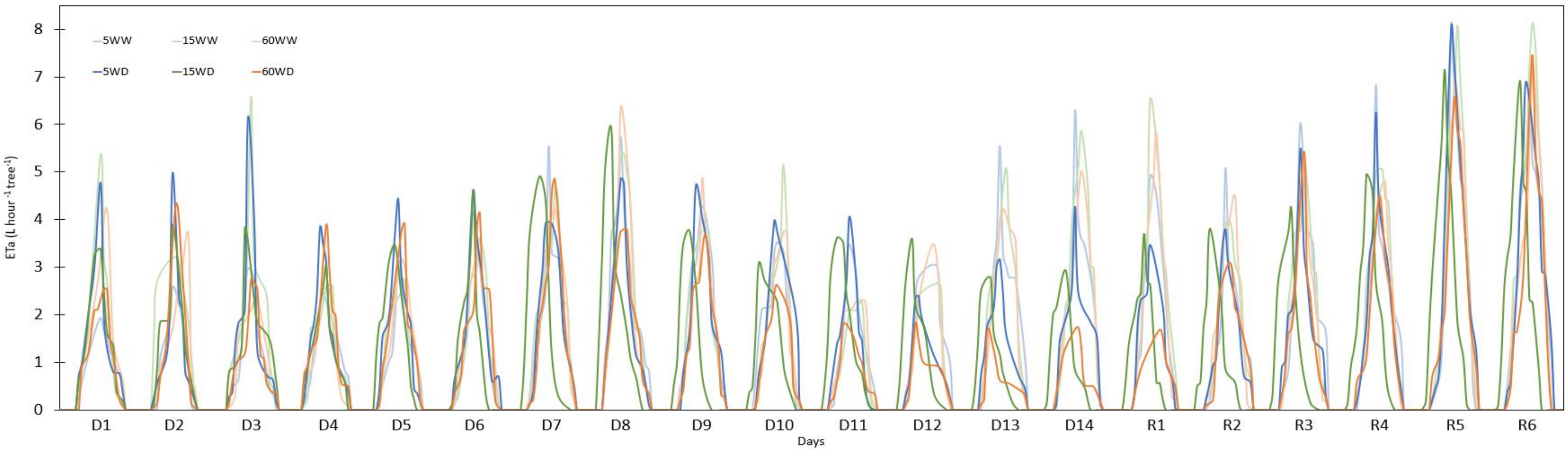

Figure 17. Actual evapotranspiration rate during first drought and recovery. The X-axis represents the days of drought (D) and recovery (R) (April 28 to May 17). 5WW is lysimeter 17, 5WD is lysimeter 19, 15WW is lysimeter 7, 15WD is lysimeter 15, 60WW is lysimeter 8, and 60WD is lysimeter 12.

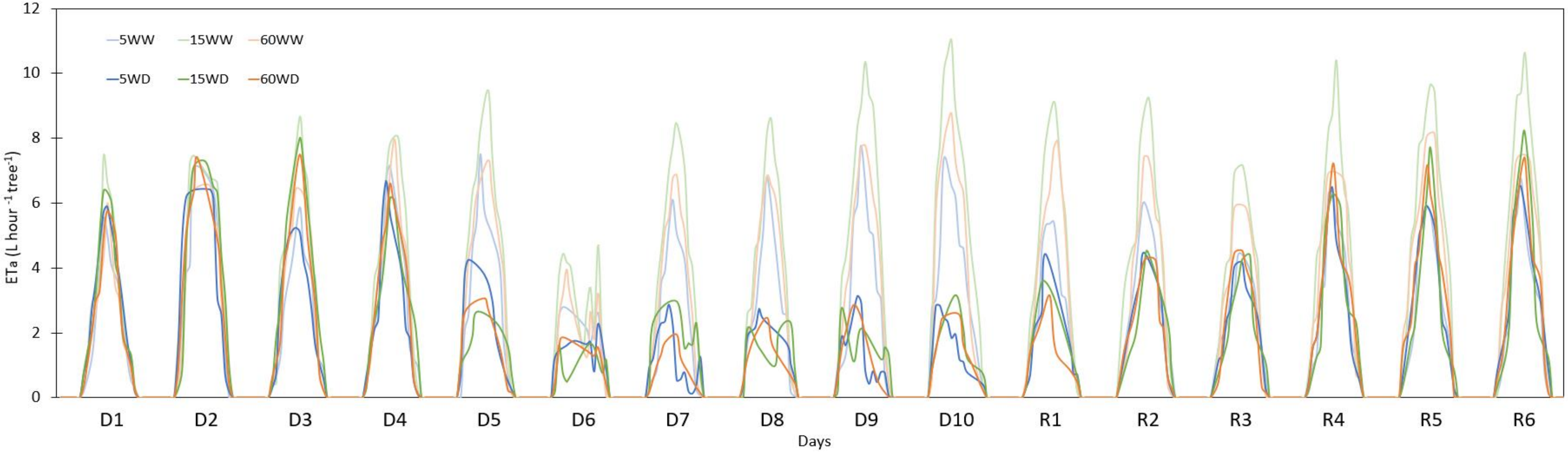

Figure 16. Actual evapotranspiration rate during second drought and recovery. The X-axis represents the days of drought (D) and recovery (R) (June 8 to June 23). 5WW is lysimeter 17, 5WD is lysimeter 19, 15WW is lysimeter 7, 15WD is lysimeter 15, 60WW is lysimeter 8, and 60WD is lysimeter 12.

4.4. DROUGHT EFFECT ON CANOPY

4.4.1. DROUGHT EFFECT ON LEAF AREA INDEX

In the first drought trial, during the critical day of drought on May 5, statistically significant differences were found in the leaf area index (LAI) in the 15WW treatment (average value of 3.23 m^2m^{-2}) compared to the 5WD treatment (average value of 2.49 m^2m^{-2}), while there were no significant differences between the 5WW, 15WW, 60WW, 15WD and 60WD treatments (average values from 2.59 to 3.23 m^2m^{-2}) and the 5WW, 60WW, 5WD, 15WD and 60WD treatments (average values from 2.49 to 2.95 m^2m^{-2}) (Figure 18).

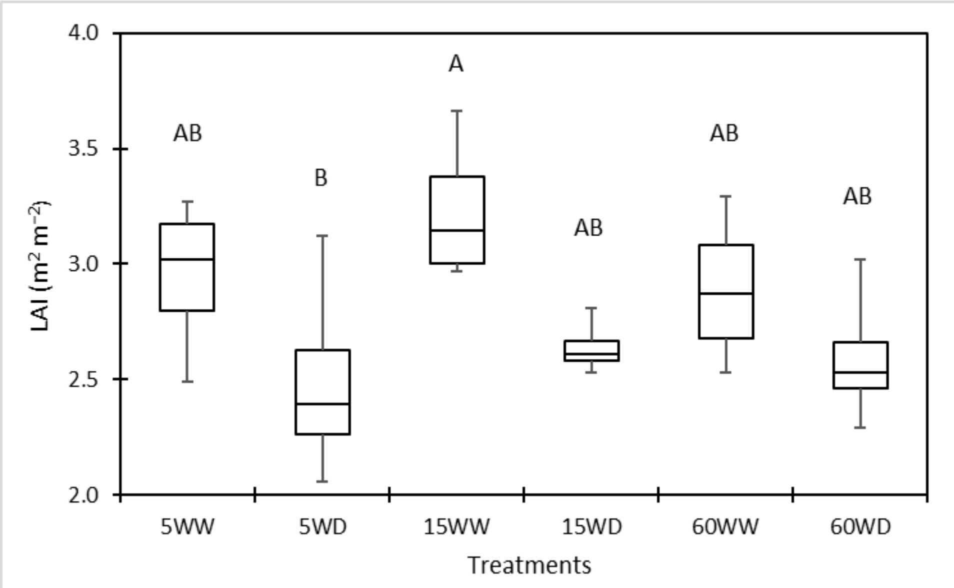

Figure 18. LAI in the first drought trial during a drought critical day (May 5) (n=4, α= 0.05)

Concerning the second drought trial, in the critical day of drought on June 15, there were statistically significant differences in LAI between the 5WW and 15WW treatments (average values from 4.5 to 4.51 m^2m^{-2}) with respect to the 15WD and 60WD treatments (average values from 3.56 to 3.62 m^2m^{-2}), but there were no significant differences between the 5WW, 15WW, and 60WW treatments (average values from 4.29 to 4.51 m^2m^{-2}), the 60WW and 5WD treatments (average values from 3.73 to 4.29 m^2m^{-2}) and the 5WD, 15WD, and 60WD treatments (average values from 3.56 to 3.73 m^2m^{-2}) (Figure 19).

Data collected regarding LAI before and after drought trials are show in Appendix 7, while LAI values per critical drought day for both trials are presented in Appendix 8.

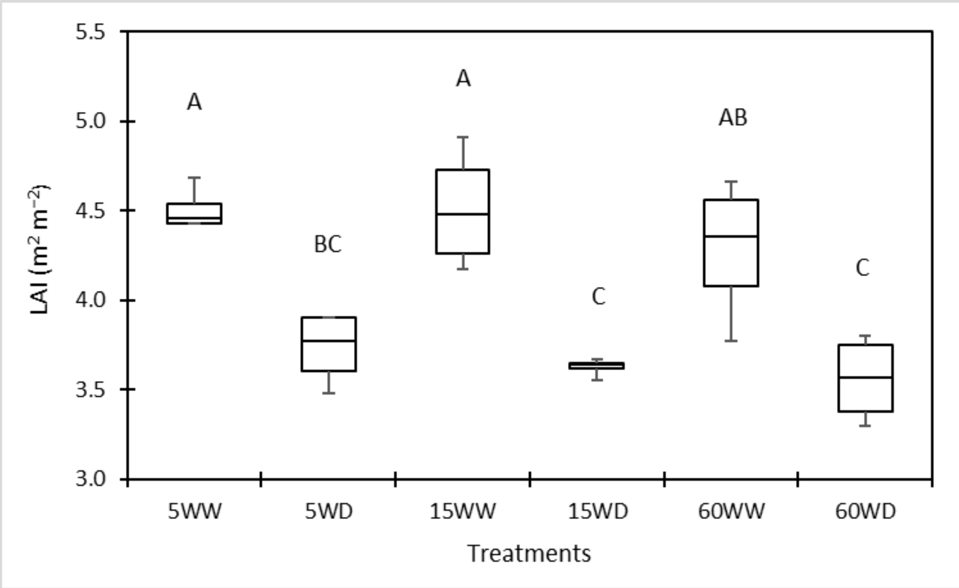

Figure 19. LAI in the second drought trial during a drought critical day (June 15) (n=4, α= 0.05).

4.4.2. DROUGHT VISUAL ASSESSMENT

The drought visual assessment carried out on critical drought days of the first drought trial (May 11) and second drought trial (June 14, 15, 16, and 18) indicates that there were no significant differences between the six treatments in terms of visible affectation due to drought in the appearance of the trees canopy. Appendix 9 shows the scores associated with each drought trial, critical day of drought, lysimeter number, and treatment.

Furthermore, through drone images, it was observed that potassium availability had an effect on the appearance of the grapevines' leaves, showing necrosis and chlorosis. Approximately in mid-May, considerable portions of the trees' canopy in the 5WW and 5WD treatments adopted and maintained a yellowish hue and intervening diffuse discoloration on leaves (chlorosis) and small brown lesions on the edges and sun-exposed portions of the leaves (necrosis) compared to the 15WW, 15WD, 60WW, and 60WD treatments. In addition, the edges of some leaves acquired a curved behavior. Appendix 10 illustrates the affectation of potassium availability in the different treatments on two dates.

Following heat events (June 1 and 2), a change in appearance of the clusters in the form of rot and brown spots in the berries was observed. The affectation was present mainly in the 5WD treatment and slightly in the 5WW treatment; likewise, the affectation was visually negligible in the 15WW, 15WD, 60WW, and 60WD treatments. Although the mentioned problem was not studied in detail in the present investigation, a variety of images regarding the clusters' affectation per treatment are shown in Appendix 11.

4.5. LYSIMETER COEFFICIENT THROUGHOUT GROWING SEASON

The lysimeter coefficient (K_{lys}) per treatment is shown in Figure 20. In particular, an analysis of the K_{lys} for the established grapevines corresponding to the initial season stage ($K_{lys\ ini}$) (from April 20 to May 18), the mid-season stage ($K_{lys\ mid}$) (from May 19 to June 16), and the final season stage ($K_{lys\ end}$) (from June 17 to July 13) for well-watered conditions was carried out. Similarly, an analysis regarding the K_{lys} during the critical day of drought for each drought trial was done (May 11 for the first trial and June 15 for the second trial). In order to elaborate statistical analyses and further discussion, a representative day per stage was chosen: before the first drought trial for $K_{lys\ ini}$, between the drought trials for $K_{lys\ mid}$, and after the second drought trial for $K_{lys\ end}$.

On April 26, in the case of $K_{lys\ ini}$, there were no statistically significant differences between the treatments; the average value considering all treatments was 0.29. Similarly, on June 3, for the case of $K_{lys\ mid}$, there were no significant differences between the treatments; the average value was 0.60. Finally, on July 3, in the case of $K_{lys\ end}$, there were significant differences between the 60WW and 60WD treatments (average values from 0.53 to 0.56) concerning the 5WD treatment (average value of 0.41); there were no significant differences between the 5WW, 15WW, 60WW, 15WD, and 60WD treatments (average values from 0.47 to 0.56) and between the 5WW, 15WW, 5WD, and 15WD treatments (average values from 0.41 to 0.52) (Table 5).

Furthermore, in the first drought trial, on the critical day of drought on May 11, there were statistically significant differences in K_{lys} between the 5WW, 15WW, and 60WW treatments (average values from 0.45 to 0.50) with regard to the 5WD, 15WD, and 60WD treatments (average values from 0.12 to 0.14). Similarly, in the second drought trial, on the critical day on June 15, there were significant differences between the 5WW, 15WW, and 60WW treatments (average values from 0.65 to 0.74) with respect to the 5WD, 15WD, and 60WD treatments (average values from 0.21 to 0.23) (Table 5).

Table 5. Average per treatment of K_{lys} (mm mm^{-1}) analyzed in diverse days during growing season. The letters in brackets represent the statistical report where levels not connected by the same letter are significantly different (n=4 except for 15WD where n=3, α= 0.05).

Date	Treatment					
	5WD	**5WW**	**15WD**	**15WW**	**60WD**	**60WW**
May 11	0.14 (B)	0.48 (A)	0.14 (B)	0.50 (A)	0.12 (B)	0.45 (A)
May 26 ($K_{lys\ ini}$)	0.31 (A)	0.27 (A)	0.31 (A)	0.29 (A)	0.28 (A)	0.29 (A)
June 03 ($K_{lys\ mid}$)	0.56 (A)	0.61 (A)	0.60 (A)	0.66 (A)	0.59 (A)	0.58 (A)
June 15	0.41 (B)	0.48 (AB)	0.47 (AB)	0.52 (AB)	0.53 (A)	0.56 (A)
July 03 ($K_{lys\ end}$)	0.23 (B)	0.65 (A)	0.21 (B)	0.74 (A)	0.21 (B)	0.72 (A)

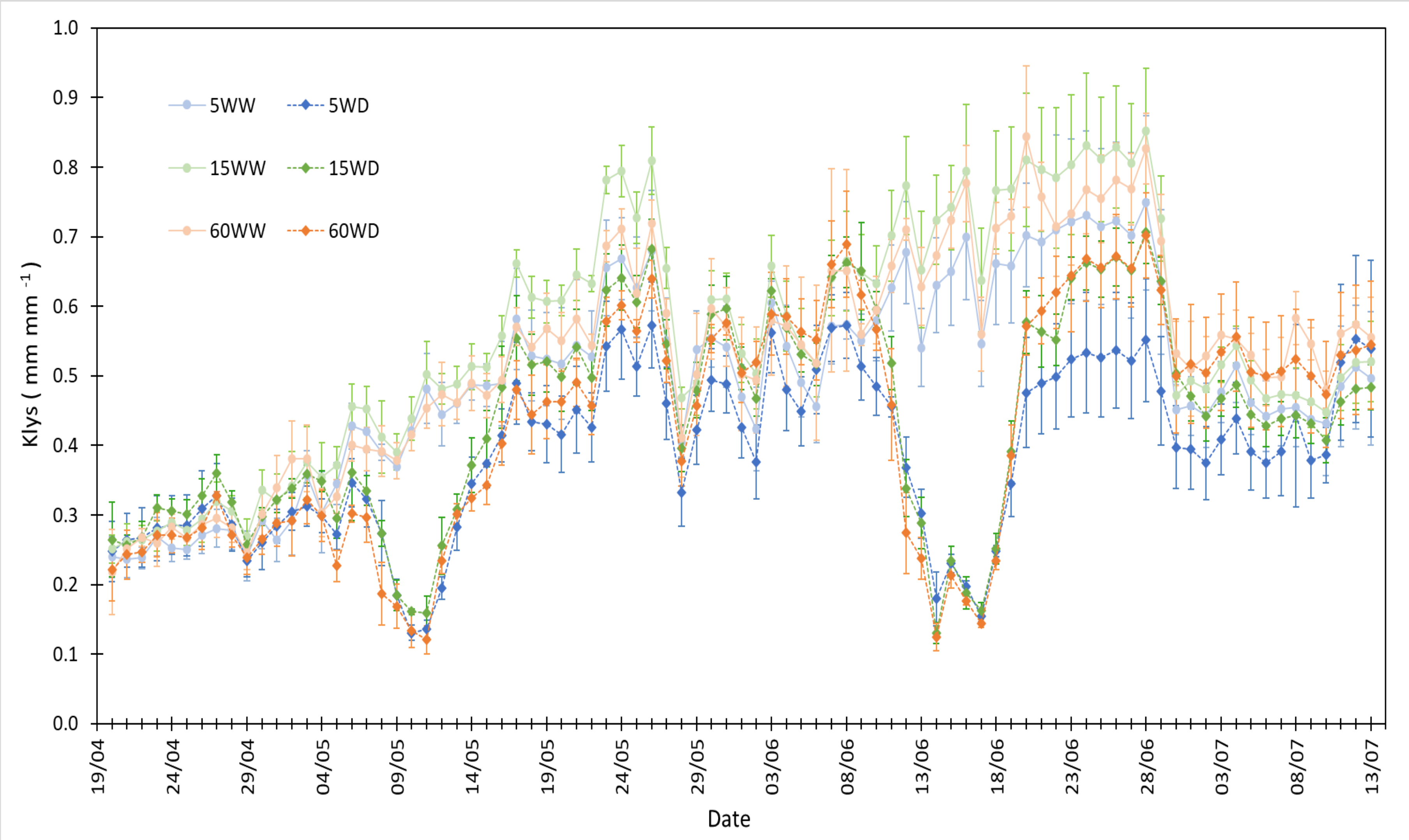

Figure 20. Lysimeter coefficient (K_{lys}) throughout growing season considering daily actual evapotranspiration per lysimeter (ET_{lys}, L day^{-1} tree^{-1}), Penman-Monteith reference evapotranspiration (ET_0, mm day^{-1}), and lysimeter area of influence (S; 2.5m * 5m) (April 20 to July 13).

4.6. DROUGHT EFFECTS ON HARVEST

4.6.1. YIELD

According to the data collected, no significant statistical differences among all treatments regarding the yield per tree were found (Figure 22). Concerning the 5WW treatment, the yield ranged from 3.64 to 22.74 kg/tree, while the 5WD treatment ranged from 5.32 to 16.03 kg/tree. Regarding the 15WW treatment, the yield fluctuated from 9.53 to 29.73 kg/tree, while the 15WD treatment ranged from 12.53 to 18.79 kg/tree. Finally, in the 60WW treatment, the yield ranged from 17.15 to 21.32 kg/tree, while the 60WD treatment ranged from 11.08 to 23.73 kg/tree (Appendix 12).

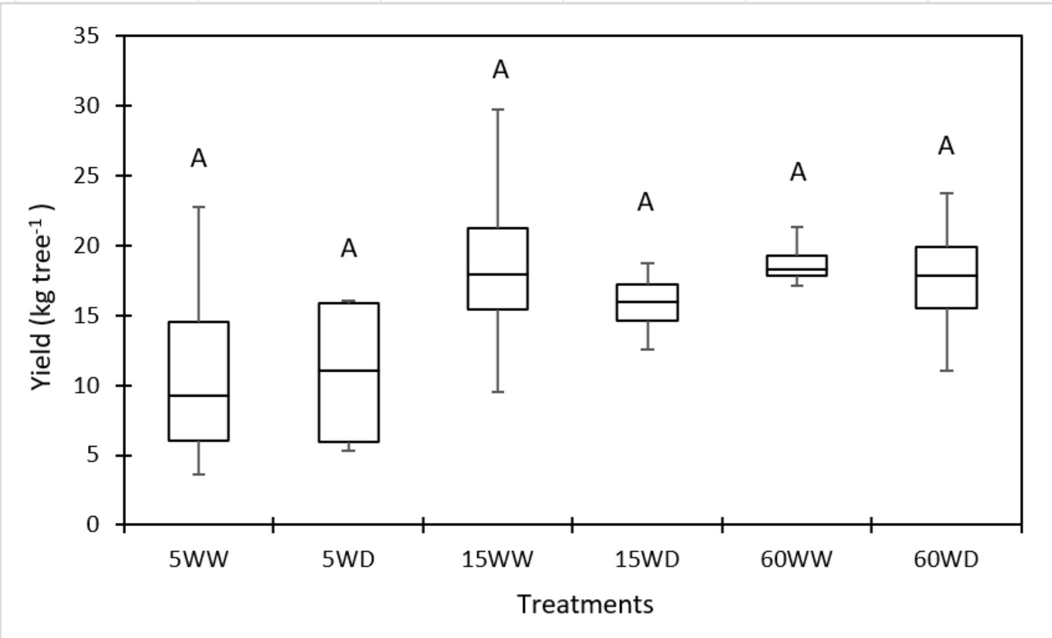

Figure 21. Yield per treatment (n=4, α= 0.05)

4.6.2. WATER PRODUCTIVITY

In order to relate the seasonal whole-tree actual evapotranspiration with the grapevine yield, the water productivity was calculated. It was found that there are no significant statistical differences in water productivity among all treatments (Figure 23). About the 5WW treatment, the water productivity ranged between 1.09 and 7.95 kg/m^3, while the 5WD treatment ranged from 2.04 to 7.03 kg/m^3. Concerning the 15WW treatment, the water productivity fluctuated from 2.47 to 8.80 kg/m^3, while the 15WD treatment ranged from 5.64 to 6.35 kg/m^3. Ultimately, in the 60WW treatment, the water productivity ranged from 4.96 to 6.25 kg/m^3, while the 60WD treatment ranged from 4.35 to 8.59 kg/m^3 (Appendix 12).

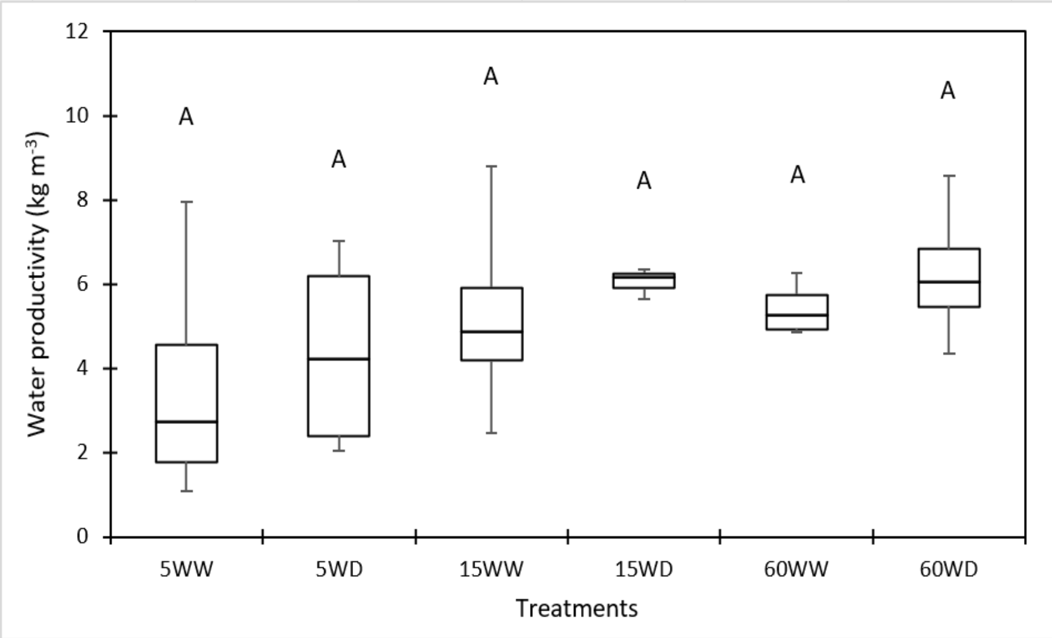

Figure 22. Water productivity per treatment (n=4, except for 15WD where n=3; α= 0.05).

4.6.3. NUMBER OF CLUSTERS

Concerning the number of clusters per grapevine, no significant statistical differences among all treatments were found (Figure 24). Regarding the 5WW treatment, the number of clusters fluctuated from 11 to 83, while the 5WD treatment ranged from 21 to 68. About the 15WW treatment, the number of clusters ranged from 32 to 77, while the 15WD treatment varied from 31 to 60. Finally, in the 60WW treatment, the number of clusters ranged from 41 to 54, while the 60WD treatment varied from 33 to 59 (Appendix 12).

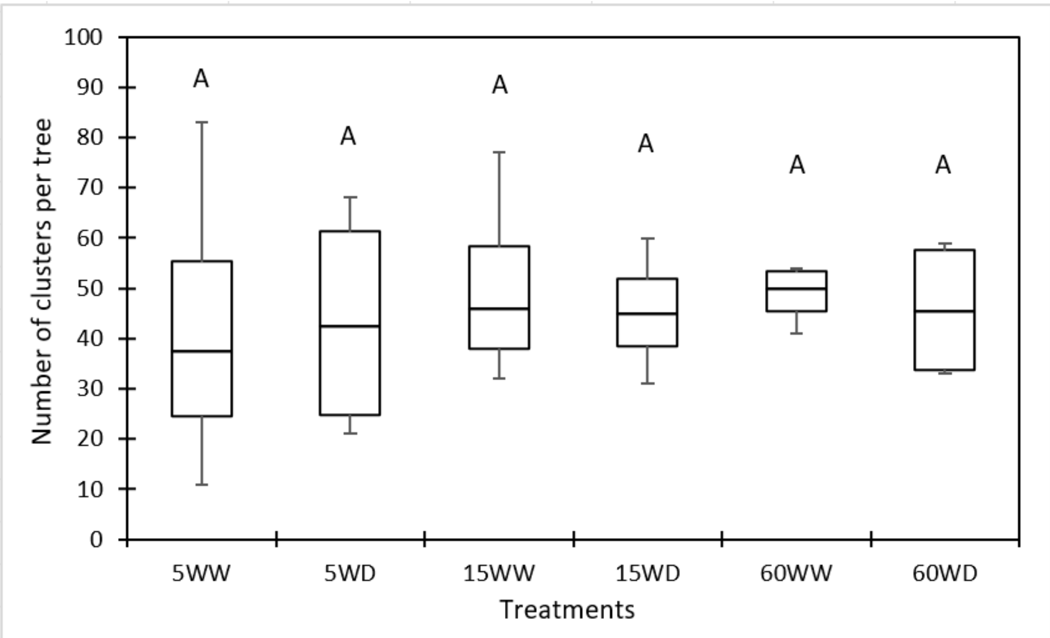

Figure 23. Number of clusters per treatment (n=4, α= 0.05).

4.6.4. AVERAGE CLUSTER WEIGHT

Concerning the average cluster weight, no significant statistical differences between 5WW, 15WW, 15WD, 60WW, and 60WD treatments, and 5WD, 15WW, and 15WD treatments were found. In contrast, there are significant statistical differences between 5WD with respect to 60WW and 60WD treatments (Figure 25). In relation to the 5WW treatment, the average cluster weight ranged from 0.234 to 0.331 kg, while the 5WD treatment ranged from 0.233 to 0.272 kg. About the 15WW treatment, the average cluster weight fluctuated from 0.298 to 0.462 kg, while the 15WD treatment varied from 0.313 to 0.404 kg. Ultimately, in the 60WW treatment, the average cluster weight varied from 0.341 to 0.454 kg, while the 60WD treatment ranged from 0.326 to 0.517 kg (Appendix 12). On the whole, the 5WD treatment presented the smallest average cluster weight.

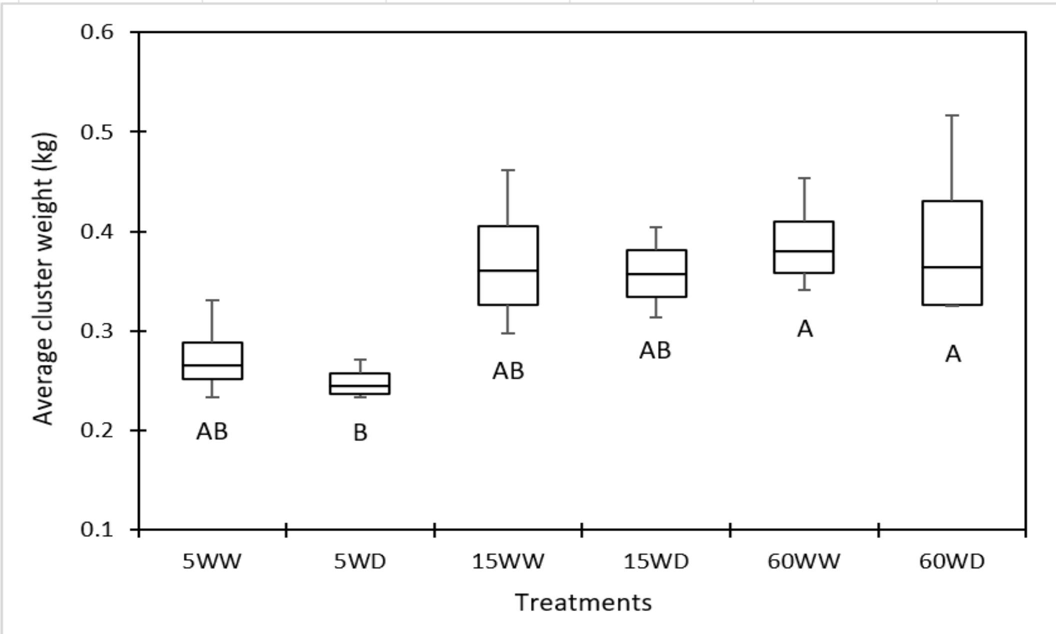

Figure 24. Average cluster weight per treatment (n=4, α= 0.05)

4.6.5. AVERAGE BERRY WEIGHT

Regarding the average berry weight, there were significant statistical differences between the 5WW and 5WD treatments with respect to the 15WD, 60WW, and 60WD treatments. Moreover, the 15WW treatment did not present significant statistical differences concerning the other treatments (Figure 26). About the 5WW treatment, the average berry weight ranged between 4.68 and 4.94 gr, while the 5WD treatment varied from 4.34 to 5.78 gr. In relation to the 15WW treatment, the average berry weight fluctuated from 5.31 to 6.58 gr, while the 15WD treatment ranged from 6.28 to 7.27 gr. Ultimately, in the 60WW treatment, the average berry weight ranged from 5.49 to 7.30 gr, while the 60WD treatment fluctuated from 6.43 to 7.75 gr (Appendix 12). In other words, 5WW and 5WD treatments had the smallest berry weights than the remaining treatments.

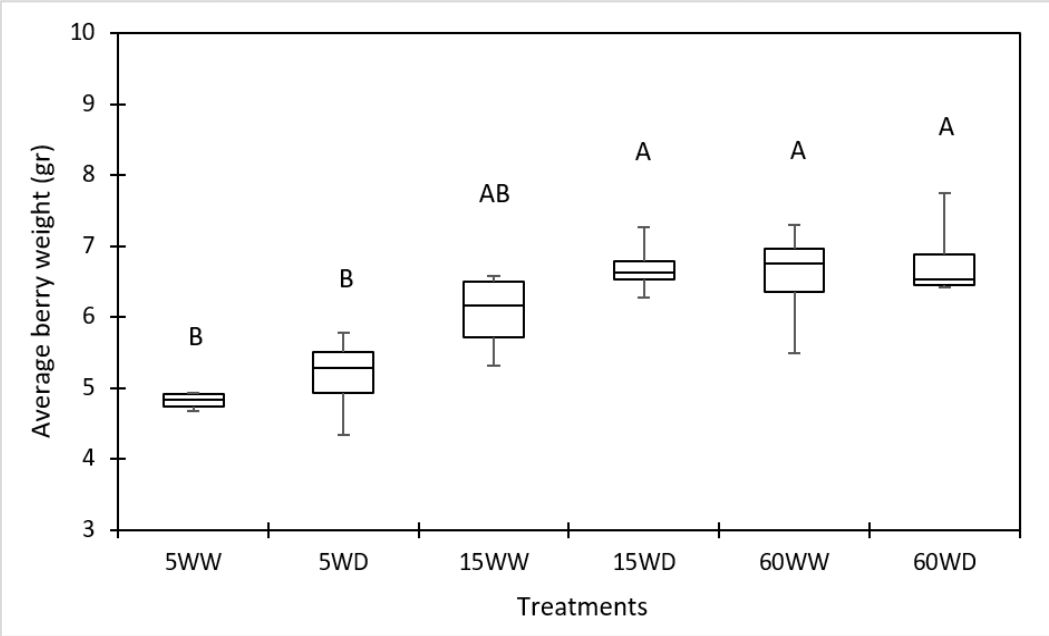

Figure 25. Average berry weight per treatment (n=4, α= 0.05).

4.6.6. BRIX DEGREES OF THE GRAPE JUICE

Considering the brix degrees of the grape juice, no significant statistical differences among all treatments were found (Figure 27). Regarding the 5WW treatment, the brix degrees ranged from 13.0 to 16.1 °Bx, while the 5WD treatment fluctuated from 11.0 to 17.2 °Bx. About the 15WW treatment, the brix degrees ranged from 15.0 to 16.2 °Bx, while the 15WD treatment varied from 12.5 to 15.0 °Bx. Finally, in the 60WW treatment, the brix degrees ranged from 13.5 to 17.2 °Bx, while the 60WD treatment varied from 12.5 to 15.5 °Bx (Appendix 12).

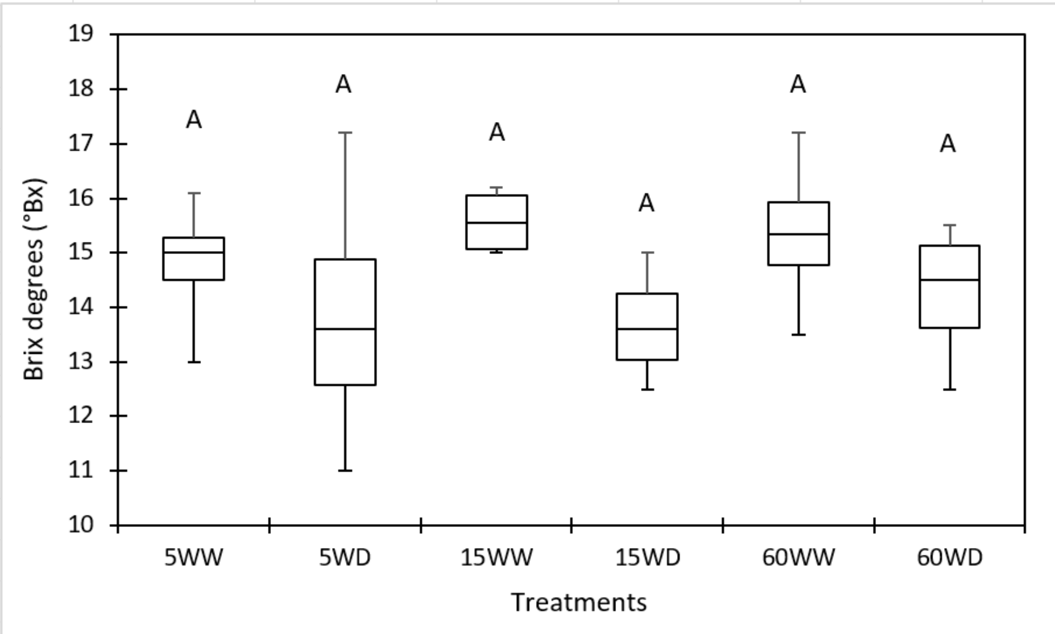

Figure 26. Brix degrees of the grape juice per treatment (n=4, α= 0.05).

4.6.7. GRAPE JUICE pH

Finally, considering the pH of the grape juice, there were significant statistical differences between the 5WW and 5WD treatments compared to the 60WW and 60WD treatments. In turn, there were no significant differences in the pH in the 15WW and 15WD treatments regarding the remaining treatments (Figure 28). In the 5WW treatment, the pH ranged between 3.34 and 3.58, while the 5WD treatment fluctuated from 3.37 to 3.51. Regarding the 15WW treatment, the pH varied from 3.44 to 3.74, while the 15WD treatment ranged from 3.45 to 3.75. Ultimately, in the 60WW treatment, the pH ranged from 3.64 to 3.88, while the 60WD treatment varied from 3.62 to 3.85 (Appendix 12). Overall, 5WW and 5WD treatments had the smallest pH values, and 60WW and 60WD were the highest.

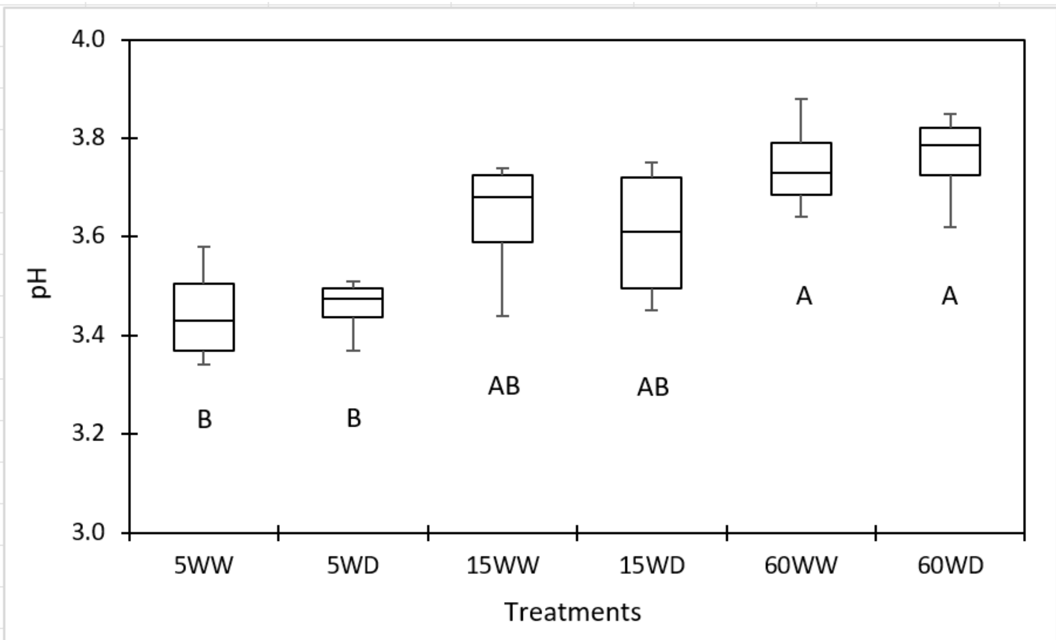

Figure 27. pH of the grape juice per treatment (n=4, α= 0.05).

CHAPTER FIVE: DISCUSSION

5.1. PHYSIOLOGICAL CHANGES DURING DROUGHT TRIALS AND PLANT RECOVERY

Exceedingly negative stem water potential, reduced photosynthetic rate, and stomatal conductance denote stress to grapevine water status (Romero *et al.*, 2010; Netzer *et al.*, 2019). The phenological stage, fruit load, weather factors, and the degree of water stress play a role in the stomatal responses during the grapevine's growing season (Wu et al., 2021; Hochberg et al., 2023). In the first drought trial, the behavior of the g_s during plant dehydration in the drought-exposed treatments showed that all treatments had similar patterns throughout dehydration and during the critical days of drought (Figure 12C). Similarly, in the second drought trial, the behavior of the g_s during plant dehydration and critical days of drought was statistically similar between the water-deficit treatments (Figure 13C).

According to Ghaderi et al. (2011), plant recovery in terms of g_s would not be significantly delayed considering values above 0.05 mol m^2 s^{-1} (approximately above Ψ_{stem} values of -1.0MPa; Hochberg et al., 2023). However, g_s values below 0.02 mol m^2 s^{-1} were reached in both drought events (Figures 12C and 13C). Generally, the recovery of g_s due to drought events can take days to weeks (Lovisolo et al., 2008; Belfiore et al., 2021; Herrera et al., 2021; Hochberg et al., 2023). In the present research, the recovery of g_s to drought stress in both trials took up to six days, considering all treatments. Likewise, g_s recovery was staggered between treatments in both drought events (Figures 12C and 13C).

On the one hand, the first treatment to recover in g_s in the first drought trial was 5WD (fourth day), possibly because trees still did not show leaves yellowing and to the slightly low LAI levels compared to the 15WD and 60WD treatments (Appendix 7). On the other hand, in the second drought trial, the first treatment to recover was the 15WD treatment (third day), which presented slightly lower LAI values than the 60WD treatment and without affectations on the trees' canopy due to the potassium availability as in the 5WD treatment. Furthermore, the second treatment to recover in the first trial was the 15WD treatment (fifth day), which presented moderately lower LAI values than the 60WD treatment. In contrast, in the second trial, the second treatment to recover was the 5WD treatment (fourth day), which even presenting consistent yellowing in the trees' canopy, recovered before the 60WD treatment. Finally, the 60WD treatment was the last to recover in both drought events (six days in the first trial and five in the second) (Figures 12C and 13C). As a consequence, it is evident that the plant recovery in terms of g_s was mainly driven to a greater extent by the vegetative vigorousness of the trees (estimated through the LAI) and, to a lesser extent, by the affectation caused by the potassium availability in the vines. However, collected data of LAI in the present study was limited.

Although the second drought trial had more critical days of drought than the first (five days compared to two days), the time in which the last treatment recovered in g_s did not differ considerably (one day of difference). In general, g_s values were lower in the second drought trial than in the first one (Figures 12C and 13C); however, that can be coincidental due to g_s being influenced by climate factors, such as VPD (Ben-Gal et al., 2010; Grossiord et al., 2020).

The Ψ_{stem} recovered on the first day of rehydration in both drought events in all treatments (Figures 12D and 13D); similar results were reported by Hochberg et al. (2023) in vines subjected to drought stress with potassium concentrations of 60 mg L^{-1}. During the plant dehydration of the first drought trial, the behavior of the Ψ_{stem} was similar between the water-deficit treatments (Figure 12D). In the second trial, the Ψ_{stem} behavior in the 15WD and 60WD treatments was statistically similar, while the 5WD treatment was the least affected by drought, having higher values than previously mentioned treatments, possibly due to its higher actual evapotranspiration compared to 15WD and 60WD treatments (Figure 13B and 13D). Nevertheless, the Ψ_{stem} variation in the critical days of drought in the second trial due to soil wetting through small irrigation doses was remarkably high, reaching values even higher than those delimited as severe water deficit (Figure 13D) (Hochberg et al., 2023). At least concerning to Ψ_{stem}, it was challenging to maintain critical drought levels through controlled irrigation doses. Contrary, g_s did not change with irrigation, being a reliable parameter in the effort to maintain critical drought levels (Figure 13C).

In addition, Ψ_{stem} values were higher in the second drought trial than in the first trial during plant dehydration (Figures 12D and 13D). Similarly, as stomatal conductance, Ψ_{stem} would also be influenced by climate factors so that difference can be attributed to weather conditions that are time and place-specific (Ben-Gal et al., 2010; Grossiord et al., 2020). The values of g_s and Ψ_{stem} were similar between drought trials during critical days of drought, so the weather's influence was less at severe water stress levels (Figures 12C, 12D, 13C and 13D) (Ben-Gal et al., 2010).

5.2. DROUGHT EFFECTS ON ACTUAL EVAPOTRANSPIRATION

The plants' evapotranspiration responses are closely related to the soil (or substrate) moisture at the drought onset, as well as the duration and harshness of the drought (Paulson, 1991). Kool et al. (2016) estimated that soil evaporation in commercial vineyards (without fertilization deficiencies) irrigated by drip irrigation systems is at most 12% of the seasonal actual evapotranspiration, even being ignored after the full development of the grapevine canopy. However, the conservative parameter "actual evapotranspiration (ET_a)" to account for the plant transpiration and soil surface evaporation was adopted in the present study (Ben-Gal et al., 2010), mainly due to differences in LAI between treatments driven by K levels.

The ET_a decrease depended on the total available water (TAW) in the lysimeter soil, the vine phenological stage, the canopy conditions of the vine and the weather conditions in the study area (Hochberg et al., 2023). The water demands of the vine were higher in the second drought trial (average values of 45 L $tree^{-1}$ day^{-1} at the beginning of the trial) compared to the first trial (average values of 18 L $tree^{-1}$ day^{-1} at the beginning of the trial), so the TAW was depleted faster in the second trial than in the first (Figures 12B and 13B).

In the first drought trial, the 60WD treatment dehydrated faster, presenting significantly lower daily ET_a values from the second half of the drought compared to the other drought-stressed treatments; this can be explained by the fact that the LAI was slightly higher in the 60WD treatment than the 5WD and 15WD treatments (Appendix 7). However, daily ET_a was similar between the water-deficit treatments during the severe water deficit days. Surprisingly, daily ET_a was significantly similar between treatments in the first half of plant recovery and similar during the second half of plant recovery between the 5WD and 60WD treatments but higher in the 15WD treatment (Figure 12B). In the case of the second drought trial, the daily ET_a pattern during the first half of plant dehydration showed that the 5WD treatment had lower values compared to the 15WD and 60WD treatments. During the second half of the plant dehydration, the 5WD treatment dehydrated slowly with respect to the other treatments, having higher values than the 15WD and 60WD treatments. Similar to the first trial, the daily ET_a values were similar during the critical days of drought among water-deficit treatments. Subsequently, during plant recovery, the 5WD treatment had the lowest daily ET_a (due to the canopy affectations by fertilization deficiencies), while the 15WD and 60WD treatments had significantly similar higher data (Figure 13B).

Both drought events suffered a reduction in post-drought ET_a without recovering similar levels as the well-watered treatments (Figures 12B and 13B). Actual evapotranspiration losses after plant recovery have been reported, additionally to in grapevines (Hochberg et al., 2023), in olives (Ben-Gal et al., 2010), and peach trees (Ferreira et al., 1996) and in annual crops such as wheat (Wu et al., 2021) and barley (Wraith et al., 1995). Consequently, Ben-Gal et al. (2010) claimed that ET_a reduction in olive trees "was due simply to reduced growth during the drought itself and to the subsequent lower growing capacity" (p. 131). Moreover, based on several studies, Keller (2020) states that even mild water stress can reduce shoot growth and therefore canopy development, "because a reduction in cell expansion usually occurs before the stomata begin to close" (p. 288). In the present research in the case of vines, the LAI values denote that post-drought ET_a reductions may also be mainly due to the growth capacity of the drought-affected trees (Ben-Gal et al., 2010; Keller, 2020) (Appendix 7). However, it is important to highlight that the trees' pruning may have impacted LAI values, not to mention that it induced a re-set of the evapotranspiration (Figure 14).

Furthermore, ET_a reduction was noticeable in the ET_{accum} through pronounced slope changes approximately parallel to the x-axis (Figure 15). The recovery of the 60WD treatment in terms of ET_{accum} was notably observed during the late season, reaching similar values to the 15WD treatment (and increasing the ET_{accum} line slope regarding 15WD treatment). Also, 60WD treatment presented slightly higher g_s values compared to the 15WD treatment and considerably higher than the 5WD treatment (notable on the last day of g_s measure on June 27 in Appendix 4); the Ψ_{stem} did not differ between treatments (based on June 27 in Appendix 5). However, the late recovery in the 60WD treatment did not have significant beneficial effects on yield. The treatment with the highest ET_{accum} was 15WW, while the lowest was 5WD. The effects on plant water uptake when trees are subjected to drought episodes should be considered for estimating water use in vineyards (Hochberg et al., 2023).

Ultimately, the actual evapotranspiration rate patterns during both drought events had noticeable differences between the well-watered and water-deficit treatments; the differences were most visible during severe water stress days (Ben-Gal et al., 2010). Midday actual evapotranspiration rate normally represented the peak ET_a rates in both irrigation regimes (Figures 16 and 17).

5.3. DROUGHT EFFECT ON CANOPY

Prolonged drought stress can cause reductions in shoot and axial branch growth and stem thickening (Buesa et al., 2017; Munitz et al., 2016; Intrigliolo & Castel, 2007; Netzer et al., 2019), as well as lower hydraulic conductivity and xylem cross-sectional area (Gerzon et al., 2015; Hochberg et al., 2015; Netzer et al., 2019) that directly impacts trees growing capacity.

The effect of drought episodes on LAI was appreciable during severe water deficit days in both drought trials. In the case of the first trial, the differences were evident between the 5WD and 15WW treatments (Figure 18). In contrast, in the second trial, the differences were notorious between the 5WD treatment compared to the 15WW and 60WD treatments (Figure 19). Hence, the 5WD treatment was consistently the most affected on LAI during critical days of drought, although highly varying in daily ET_a, g_s, and Ψ_{stem}. In general, low LAI values coupled with low g_s values led to ET_a reductions during and after plant recovery (Hochberg et al., 2023; Ohana-Levi et al., 2022) (Appendix 7).

Furthermore, the drought visual assessment was not a reliable technique to describe the drought effect on trees, possibly due to the defined range of scores and the scoring procedure. Contrarily, potassium availability affected the appearance of the grapevines' canopy, presenting necrosis and chlorosis in some leaves of the K-5 treatments (James et al., 2023). Likewise, the K-5 treatments were the most affected by berry damage following extreme heat events, possibly aggravated due to the drought events to which trees were subjected. Unfortunately, the effects of potassium availability on leaves and heatwaves' effects on grapevines were not deeply investigated in the present investigation. This illustrative analysis was included mainly due to the influence that may have existed during the g_s data collection.

5.4. LYSIMETER COEFFICIENT

The conditions in which the lysimeter coefficients (K_{lys}) were obtained differ from commercial vineyards, mainly due to the canopy growth control during the experiment, but also due to the relatively small soil surface to canopy area ratio, the vines' boundary conditions since their soil surface is 1.5 meters above the actual soil surface, and the relatively large spacing between rows. That said, the analysis may assume that relative differences between the K_{lys} values due to treatments would reflect similar differences in vineyard single crop coefficients (K_c). The K_c presented by Allen et al. (1998) are defined for well-managed and non-stressed crops in subhumid areas. In the case of table grapes, values of $K_{c\ ini}$, $K_{c\ mid}$, and $K_{c\ end}$ are 0.30, 0.85, and 0.45, respectively, in trees with a maximum height of 2m.

In periods with no drought, the $Kl_{ys\ ini}$ coefficient (average value of 0.29) was similar to the $K_{c\ ini}$ coefficient. Similarly, the $K_{lys\ mid}$ coefficient (average value of 0.60) considerably underestimates the $K_{c\ mid}$ coefficient, mainly due to controlled vegetative development and the large plant spacing in the present experiment. Finally, the $K_{lys\ end}$ coefficient overestimates the $K_{c\ end}$ coefficient in the 5WW, 15WW, 60WW, 15WD, and 60WD treatments (average values from 0.47 to 0.56). At the same time, it underestimates the $K_{c\ end}$ coefficient in the 5WD treatment (average value of 0.41) (Allen et al., 1998). At the end of the growing season, the effects due to potassium deficiency (necrosis and chlorosis) were notorious in the K-5 treatments, so the difference between the K_{lys} values was evident. Consequently, K_{lys} is an approximation under controlled conditions to the K_c, which would be valid for similar conditions as the present experiment (Allen et al., 1998). It is important to highlight that the K_{lys} alone is not representative during the drought trials. Although it helps calculate the water stress coefficient (Ks) to understand the drought effects on the plant transpiration capacity, according to Hochberg et al. (2023), modeling actual evapotranspiration in grapevines under episodic drought events is inaccurate. That was the reason why the mentioned approach was not studied in the present investigation.

5.5. DROUGHT EFFECTS ON HARVEST

Drought stress has been found to significantly affect grapevine berry diameter, leading to a reduction in berry and cluster weight (Lauer, 2012). However, within the same K level, there were no significant differences in average berry and cluster weights regarding well-watered and water deficit treatments in the present study. In contrast, there were significant differences between treatments, mainly between K-5 and K-60 (Figures 25 and 26). Similarly, in the case of pH, the same was found as the mentioned harvest components (Figure 28). Conversely, the short drought events did not significantly affect the yield, water productivity, number of clusters, and brix degrees of the grape juice among treatments, possibly due to the duration and number of drought events.

In general, even though potassium is known to contribute to the proper functioning of physiological responses such as stomatal regulation and osmotic adjustment (Marschner, 2011) and yield quality and quantity (James et al., 2023), the results obtained in the present research go against the proposed hypothesis since abundant potassium levels did not enable grapevines' tolerance to drought periods regarding plant physiological and productivity parameters.

5.6. LIMITATIONS OF THE STUDY

An important limitation to highlight is that the experimental setup used in the present investigation demanded abundant maintenance, mainly in relation to failures in the loadcells and drainage valves. The reliability of the data is strongly dependent on maintenance, which must be monitored on a daily basis.

Data collected from LAI were few and far between time periods, making it challenging to compare them between treatments. In that sense, the LAI was likely not the most appropriate parameter to attribute the drought effects on grapevines, which is variable depending on the season of the year and the measurement time.

Furthermore, irrigation was the most variable parameter within treatments in the lysimeter water balance, even with new drippers (up to 20% difference; reason unknown). Although it was not an obstacle in well-watered treatments, it was problematic in water-deficit treatments during critical days of drought. Despite efforts to provide tailored supplemental irrigation in the water-deficit treatments, maintaining severe water stress in physiological parameters was challenging, mainly regarding stem water potential.

The selection of healthy leaves following the methodology used by Hochberg et al. (2023) for g_s measurement, even though it was random, directly influenced and stimulated a bias in the results obtained. Additionally, the number of data collected and the decision to use the average or median of g_s for data analysis impacted in the results (in the present research was used the median of five g_s data collected). Likewise, although an attempt was made to measure g_s at consistent times (12:00 to 2:00 p.m.), due to the various field activities, it was sometimes measured around 12:00 hrs. and other times around 14 hrs.; hence, there may be variations that are not considered among measurement days. Regarding Ψ_{stem}, the decision to collect a single value per tree and day could have influenced the data in case of an erroneous measurement.

Moreover, the canopy condition had a role in the research results, in the second half of the growing season, the trees of the 5WW and 5WD treatments became affected in their canopy in the form of consistent yellowing due to the potassium availability. The g_s turned out to be a challenging parameter to measure due to the affectation above mentioned, varying considerably between healthy and affected leaves. As mentioned before, in the present investigation, only healthy leaves were considered; however, this decision could have affected the results concerning the order of plant recovery.

CHAPTER SIX: CONCLUSIONS AND RECOMMENDATIONS

The main research question of this present research was: What are the effects of potassium availability on grapevine physiology, actual evapotranspiration, growth, and yield characteristics under short drought stress periods? Four main conclusions emerge from the four sub-questions that were formulated to answer the main research question.

The first sub-conclusion is that g_s behavior during plant dehydration had similar patterns among treatments in each trial. Consequently, g_s recovery was staggered between treatments, separated by one day; in the first trial, the treatments recovered successively in the following order: 5WD, 15WD, and 60WD, while in the second: 15WD, 5WD, and 60WD. Necrosis and chlorosis conditions presented in the leaves of the 5WD treatment could have a role in the g_s recovery in the second trial. The Ψ_{stem} behavior during plant dehydration in the first trial was similar among treatments. In contrast, in the second trial, 5WD treatment had higher values than 15WD and 60WD, while the pattern between 15WD and 60WD treatments was similar. The Ψ_{stem} variation during critical days of drought by supplemental irrigation was high, being more noticeable in 5WD. The Ψ_{stem} recovered on the first day of rehydration in both drought events in all treatments.

The second sub-conclusion is that plant dehydration based on ET_a was quicker in the second trial than the first one, mainly due to the plant's water requirements regarding the physiological stage (canopy size) and the weather conditions. Both drought events suffered a reduction in post-drought ET_a without recovering similar levels as the well-watered treatments, indicating reduced growth capacity of the drought-affected trees. The pruning of the trees after the drought trials stimulated a re-set in ET_a, which could influence the cumulative effects of drought stress at the plant level. Similarly, ET_a reduction was noticeable in the ET_{accum}, boosting differences between treatments: the highest ET_{accum} was 15WW, while the lowest was 5WD. At late season, the 60WD treatment reached similar levels in ET_{accum} as the 15WD treatment (and slightly higher levels of g_s), denoting an apparent late recovery. The ET_a rate patterns differed significantly between well-watered and water-deficit treatments during severe water stress days. Finally, K_{lys} coefficients are not fully applicable in commercial vineyards, presenting differences regarding K_c coefficients, mainly due to the K_c coefficients are site specific in terms of plant spacing, soil type, soil wetting and weather conditions. K_{lys} coefficients use should be restricted to similar conditions as the present study.

The third sub-conclusion is that the drought significantly impacts plant canopy development. The impact during severe water deficit days between treatments was statistically more significant when the drought was prolonged for consecutive days, as in the second trial. Furthermore, the drought visual assessment did not show significant differences between trees, so it did not represent a viable method to evaluate the drought effect on trees. Finally, potassium deficiency affected trees' canopy in the form of necrosis and chlorosis, worsening in the 5WD treatment by having the most unfavourable conditions in the experiment.

The fourth sub-conclusion is that short drought events did not affect the yield, water productivity, number of clusters, and brix degrees of the grape juice, possibly due to the duration and number of drought events. In contrast, it affected average berry and cluster weights and pH mainly between K-5 and K-60 treatments.

In general, the results obtained in the present research go against the proposed hypothesis since abundant potassium levels did not enable grapevines' tolerance to drought periods regarding plant physiological and productivity parameters.

The following ideas are recommended for future research on grapevines:

- Extend the periods of severe water deficit to generate statistically noticeable effects on dehydration and recovery regarding physiological parameters, plant growth, and yield components.
- Explore physiological responses, plant growth, and yield components with deficit irrigation treatments subjected to short drought periods.
- Measure the leaf area index at least every third day to monitor its behavior during plant dehydration and rehydration.
- Conduct tests with fruit load to define how the physiological parameters, plant growth, and yield components are affected in drought stress episodes.
- Integrate additional parameters to monitor tree water status, such as sap flow, leaf water potential, canopy temperature, quantum yield of photosystem II photochemistry, fraction of absorbed photosynthetically active radiation, soil moisture, photosynthetic parameters and diameter changes in the plant's trunk, branches, and fruits, among others.
- Explore the potential of sensors on-tree (e.g., dendrometers, sap flow, and/or water potential sensors) and on-soil (e.g., tensiometers or moisture probes) to monitor water stress in the plant.
- Study the physiological responses, plant growth, and yield components under different potassium treatments (e.g., K-10 and/or K-30) and drought events to contrast these results with the present research results.

REFERENCES

Agrometeo. (2023). Agrometeo, agricultural meteorology, measurements, and indicators. https://www.meteo.co.il/

Allen, R.G., Pereira, L.S., Raes, D., Smith, M. (1998) Crop evapotranspiration —guidelines for computing crop water requirements. FAO Irrigation and drainage paper 56. Food and Agriculture Organization, Rome.

Alston, J. M. & Sambucci, O. (2019). The grape genome. In *Grapes in the world economy* (pp. 1–24). essay, Cham: Springer International Publishing: Springer. https://doi.org/10.1007/978-3-030-18601-2_1

Alton, P. B. (2016). The sensitivity of models of gross primary productivity to meteorological and leaf area forcing: a comparison between a penman-monteith ecophysiological approach and the modis light-use efficiency algorithm. *Agricultural and Forest Meteorology*, *218-219*, 11–24. https://doi.org/10.1016/j.agrformet.2015.11.010

Baert, A., Villez, K., & Steppe, K. (2013). Automatic drought stress detection in grapevines without using conventional threshold values. *Plant and Soil*, *369*(1-2), 439–452.

Baluška, F., Mancuso, S. & Volkman, D. (2006). Communication in plants: neuronal aspects of plant life. Springer, Berlin.

Battie-Laclau, P., Laclau, J.-P., Domec, J.-C., Christina, M., Bouillet, J.-P., de Cassia Piccolo, M., de Moraes Gonçalves, J. L., Moreira, R. M. E., Krusche, A. V., Bouvet, J.-M., & Nouvellon, Y. (2014). Effects of potassium and sodium supply on drought-adaptive mechanisms in eucalyptus grandis plantations. *The New Phytologist*, *203*(2), 401–413. https://doi.org/10.1111/nph.12810

Belfiore, N., Nerva, L., Fasolini, R., Gaiotti, F., Lovat, L., & Chitarra, W. (2021). Leaf gas exchange and abscisic acid in leaves of glera grape variety during drought and recovery. *Theoretical and Experimental Plant Physiology*, *33*(3), 261–270. https://doi.org/10.1007/s40626-021-00211-3

Ben-Gal, A., & Shani, U. (2002). A highly conductive drainage extension to control the lower boundary condition of lysimeters. *Plant and Soil*, *239*(1), 9–17.

Ben-Gal, A., Kool, D., Agam, N., van Halsema, G. E., Yermiyahu, U., Yafe, A., Presnov, E., Erel, R., Majdop, A., Zipori, I., Segal, E., Rüger, S., Zimmermann, U., Cohen, Y., Alchanatis, V., & Dag, A. (2010). Whole-tree water balance and indicators for short-term drought stress in non-bearing ‘barnea’ olives. *Agricultural Water Management*, *98*(1), 124–133. https://doi.org/10.1016/j.agwat.2010.08.008

Bitew, A. M. (2015). *Strategies to adapt to climate change in the central rift valley of ethiopia: landscape impact assessment for on-farm adaptation*. Wageningen University. Retrieved 2023, from https://edepot.wur.nl/357885.

Blanco, V., & Kalcsits, L. (2021). Microtensiometers accurately measure stem water potential in woody perennials. *Plants (Basel, Switzerland)*, *10*(12). https://doi.org/10.3390/plants10122780

Buesa, I., Pérez D, Castel, J., Intrigliolo, D. S., & Castel, J. R. (2017). Effect of deficit irrigation on vine performance and grape composition of vitis vinifera l. cv. muscat of alexandria. *Australian Journal of Grape and Wine Research*, *23*(2), 251–259. https://doi.org/10.1111/ajgw.12280

Chaves, M. M., Zarrouk, O., Francisco, R., Costa, J. M., Santos, T., Regalado, A. P., Rodrigues, M. L., & Lopes, C. M. (2010). Grapevine under deficit irrigation: hints from physiological and molecular data. *Annals of Botany*, *105*(5), 661–76. https://doi.org/10.1093/aob/mcq030

Choné X., Van Leeuwen, C., Dubourdieu, D., & Gaudillère J.P. (2001). Stem water potential is a sensitive indicator of grapevine water status. *Annals of Botany*, *87*(4), 477–483. https://doi.org/10.1006/anbo.2000.1361

Cogato, A., Jewan, S.Y.Y., Wu, L., Marinello, F., Meggio, F., Sivilotti, P., Sozzi, M., Pagay, V. (2022). Water Stress Impacts on Grapevines (Vitis vinifera L.) in Hot Environments: Physiological and Spectral Responses. Agronomy, 12, 1819. https://doi.org/10.3390/agronomy12081819

Dai, A. (2013). Increasing drought under global warming in observations and models. *Nature Climate Change*, *3, 52-58*. https://doi.org/10.1038/nclimate18

Dong, Y., & Hansen, H. (2023). Development and design of an affordable field scale weighing lysimeter using a microcontroller system. *Smart Agricultural Technology*, *4*. https://doi.org/10.1016/j.atech.2022.100147

Fahad, S., Adnan, M., & Saud, S. (Eds.). (2023). Improvement of plant production in the era of climate change (First, Ser. Footprints of climate variability on plant diversity). CRC Press. https://doi.org/10.1201/9781003286417

Fang, H., Baret F., Plummer, S., & Schaepman-Strub, G. (2019). An overview of global leaf area index (LAI): methods, products, validation, and applications. *Reviews of Geophysics*, *57*(3), 739–799. https://doi.org/10.1029/2018RG000608

FAO. (2023). FAOSTAT. Crops and livestock products. Grapes. Recovered from: https://www.fao.org/faostat/en/#data/QCL/visualize

FAO-OIV. (2016). FAO-OIV Focus 2016. Table and dried grapes. Rome: Food and Agriculture Organization of the United Nations.

Ferreira, M.I., Valancogne, C., Daudet, F.A., Ameglio, T., Pacheco, C.A., Michaelsen, J. (1996). Evapotranspiration and crop-water relations in a peach orchard. In: Evapotranspiration and Irrigation Scheduling. Presented at the International Conference, American Society of Agricultural Engineers the Irrigation Association, pp. 3–6.

Fisher, D. K. (2012). Simple weighing lysimeters for measuring evapotranspiration and developing crop coefficients. *International Journal of Agricultural and Biological Engineering*, *5*(3). https://doi.org/10.3965/j.ijabe.20120503.00

Flexas, J., Bota, J., Escalona, J. M., Sampol, B., & Medrano, H. (2002). Effects of drought on photosynthesis in grapevines under field conditions: an evaluation of stomatal and mesophyll limitations. *Functional Plant Biology: 29*(4), 461–471. https://doi.org/10.1071/PP01119

Fraga, H. (2019). *Viticulture and winemaking under climate change*. MDPI - Multidisciplinary Digital Publishing Institute. Retrieved 2023, from https://mdpi.com/books/pdfview/book/1905.

Franks, P. J., Cowan, I. R., & Farquhar, G. D. (1997). The apparent feedforward response of stomata to air vapour pressure deficit: information revealed by different experimental procedures with two rainforest trees. *Plant, Cell & Environment*, *20*(1), 142–145. https://doi.org/10.1046/j.1365-3040.1997.d01-14.x

Gambetta, G. A., Herrera, J. C., Dayer, S., Feng, Q., Hochberg, U., & Castellarin, S. D. (2020). The physiology of drought stress in grapevine: towards an integrative definition of drought tolerance. *Journal of Experimental Botany*, *71*(16), 4658–4676. https://doi.org/10.1093/jxb/eraa245

Gerzon, E., Biton, I., Yaniv, Y., Zemach, H., Ben-Ari, G., Netzer, Y., Schwartz, A., & Fait, A. (2015). Grapevine anatomy as a possible determinant of isohydric or anisohydric behavior. *American Journal of Enology and Viticulture*, *66*(3), 340–347. https://doi.org/10.5344/ajev.2015.14090

Ghaderi, N., Talai, A. R., Ebadi, A., & Lessani, H. (2011). The physiological response of three iranian grape cultivars to progressive drought stress. *Journal of Agricultural Science and Technology*, *13*(4), 601–610.

Giménez C., Gallardo M. & Thompson R.B. (2013). Plant–Water Relations. Earth Systems and Environmental Sciences, Elsevier. https://doi.org/10.1016/B978-0-12-409548-9.05257-X

Grossiord, C., Buckley, T. N., Cernusak, L. A., Novick, K. A., Poulter, B., Siegwolf, R. T. W., Sperry, J. S., & McDowell, N. G. (2020). Plant responses to rising vapor pressure deficit. *New Phytologist*, *226*(6), 1550–1566. https://doi.org/10.1111/nph.16485

Gupta, A. S., & Berkowitz, G. A. (1987). Osmotic adjustment, symplast volume, and nonstomatally mediated water stress inhibition of photosynthesis in wheat. *Plant Physiology*, *85*(4), 1040–1047

Herrera, J. C., Savi, T., Mattocks, J., De Berardinis, F., Scheffknecht, S., Hietz, P., Rosner, S., & Forneck, A. (2021). Container volume affects drought experiments in grapevines: insights on xylem anatomy and time of dehydration. *Physiologia Plantarum*, *173*(4), 2181–2190. https://doi.org/10.1111/ppl.13567

Hochberg, U. (2020). Facilitating protocols while maintaining accuracy in grapevine pressure chamber measurements- comments on levin 2019. *Agricultural Water Management*, *227*, 105836.

Hochberg, U., Degu, A., Gendler, T., Fait, A., & Rachmilevitch, S. (2015). The variability in the xylem architecture of grapevine petiole and its contribution to hydraulic differences. *Functional Plant Biology:* *42*(4), 357–365. https://doi.org/10.1071/FP14167

Hochberg, U., Herrera, J. C., Degu, A., Castellarin, S. D., Peterlunger, E., Alberti, G., & Lazarovitch, N. (2017). Evaporative demand determines the relative transpirational sensitivity of deficit-irrigated grapevines. *Irrigation Science*, *35*(1), 1–9. https://doi.org/10.1007/s00271-016-0518-4

Hochberg, U., Perry, A., Rachmilevitch, S., Ben-Gal, A., & Sperling, O. (2023). Instantaneous and lasting effects of drought on grapevine water use. *Agricultural and Forest Meteorology*, *338*. https://doi.org/10.1016/j.agrformet.2023.109521

Intergovernmental Panel on Climate Change. (2022). *Climate change 2022: Impacts, Adaptation and Vulnerability*. WMO, IPCC Secretariat. Retrieved 2023, from https://www.ipcc.ch/report/ar6/wg2/.

Intrigliolo, D. S., & Castel, J. R. (2007). Evaluation of grapevine water status from trunk diameter variations. *Irrigation Science*, *26*(1), 49–59. https://doi.org/10.1007/s00271-007-0071-2

James, A., Mahinda, A., Mwamahonje, A., Rweyemamu, E. W., Mrema, E., Aloys, K., Swai, E., Mpore, F. J., & Massawe, C. (2023). A review on the influence of fertilizers application on grape yield and quality in the tropics. *Journal of Plant Nutrition*, *46*(12), 2936–2957. https://doi.org/10.1080/01904167.2022.2160761

Keller, M. (2010). Managing grapevines to optimise fruit development in a challenging environment: a climate change primer for viticulturists. *Australian Journal of Grape and Wine Research*, *16*, 56–69. https://doi.org/10.1111/j.1755-0238.2009.00077.x

Keller, M. (2020). The science of grapevines (3rd ed.). Academic Press.

Kool, D., Kustas, W. P., Ben-Gal, A., Lazarovitch, N., Heitman, J. L., Sauer, T. J., & Agam, N. (2016). Energy and evapotranspiration partitioning in a desert vineyard. *Agricultural and Forest Meteorology*, *218-219*, 277–287. https://doi.org/10.1016/j.agrformet.2016.01.002

Lauer, H. C. (2012). *The effect of deficit irrigation on grape quality characteristics: an analysis of current literature* (dissertation). University of California, Davis.

Lovisolo, C., Perrone, I., Hartung, W., & Schubert, A. (2008). An abscisic acid-related reduced transpiration promotes gradual embolism repair when grapevines are rehydrated after drought. *The New Phytologist*, *180*(3), 642–651. https://doi.org/10.1111/j.1469-8137.2008.02592.x

Marschner, P. (2011). Marschner's mineral nutrition of higher plants (3rd ed.). Academic Press Imprint.

Montgomery, D. C., & Runger, G. C. (2018). *Applied statistics and probability for engineers* (Seventh edition (EMEA edition). Wiley.

Munitz, S., Netzer, Y., & Schwartz, A. (2017). Sustained and regulated deficit irrigation of field-grown merlot grapevines. *Australian Journal of Grape and Wine Research*, *23*(1), 87–94. https://doi.org/10.1111/ajgw.1224

Naor, A. (2000). Midday stem water potential as a plant water stress indicator for irrigation scheduling in fruit trees. *Acta Horticulturae*, *537*(537), 447–454.

Netzer, Y., Munitz, S., Shtein, I., & Schwartz, A. (2019). Structural memory in grapevines: early season water availability affects late season drought stress severity. *European Journal of Agronomy*, *105*, 96–103. https://doi.org/10.1016/j.eja.2019.02.008

Nieves-Cordones, M., Al Shiblawi, F. R., Sentenac H. (2016). *Roles and transport of sodium and potassium in plants*. The alkali metal ions: their role for life, Springer International Publishing, 291–324. https://doi.org/10.1007/978-3-319-21756-7_9

Ochoa, C. G., Fernald, A. G., Guldan, S. J., & Shukla, M. K. (2007). Deep percolation and its effects on shallow groundwater level rise following flood irrigation. *Transactions of the Asabe*, *50*(1), 73–81.

Ochoa-Sánchez A., Crespo P., Carrillo-Rojas G., Sucozhañay A. & Célleri R. (2019). Actual evapotranspiration in the high andean grasslands: a comparison of measurement and estimation methods. *Frontiers in Earth Science*, *7*. https://doi.org/10.3389/feart.2019.00055

Ohana-Levi, N., Mintz, D. F., Hagag, N., Stern, Y., Munitz, S., Friedman-Levi, Y., Shacham, N., Grünzweig, J. M., & Netzer, Y. (2022). Grapevine responses to site-specific spatiotemporal factors in a mediterranean climate. *Agricultural Water Management*, *259*. https://doi.org/10.1016/j.agwat.2021.107226

Paulson, R. W. (1991). *National water summary 1988-89: Hydrologic events and floods and droughts*. *U.S. Geological Survey*, *Water Supply Paper 2375, p. 99-104.*

Payero J.O, & Irmak, S. (2008). Construction, installation, and performance of two repacked weighing lysimeters. *Irrigation Science*, *26*(2), 191–202. https://doi.org/10.1007/s00271-007-0085-9

Potchter, O., & Ben-Shalom, I. (2013). Urban warming and global warming: combined effect on thermal discomfort in the desert city of Beer Sheva, Israel. *Journal of Arid Environments*, *98*, 113–122. https://doi.org/10.1016/j.jaridenv.2013.08.006

Premachandra, G., Saneoka, H., & Ogata, S. (1991). Cell membrane stability and leaf water relations as affected by potassium nutrition of water-stressed maize. *Journal of Experimental Botany*, *42*(239), 739–745.

Romero, P., Martinez-Cutillas, A., & Fernandez-Fernandez, J. I. (2010). Physiological thresholds for efficient regulated deficit-irrigation management in winegrapes grown under semiarid conditions. *American Journal of Enology and Viticulture*, *61*(3), 300–312.

Running, S. W. (1976). Environmental control of leaf water conductance in conifers. *Canadian Journal of Forest Research*, *6*(1), 104–112. https://doi.org/10.1139/x76-013

Salisbury, F.B. & Ross, C.W. (1992). Plant physiology. 4th edition. Wadsworth Publishing Company, Belmont (CA), USA.

Scott, P. (2008). *Physiology and behaviour of plants*. John Wiley & Sons.

Sepúlveda N. (2021). *Evaluation of actual evapotranspiration rates from the operational simplified surface energy balance (ssebop) model in florida and parts of alabama and georgia, 2000-17* (Ser. Scientific investigations report, 2021-5072). U.S. Department of the Interior, U.S. Geological Survey.

Sepúlveda, G., & Kliewer, W. M. (1986). Effect of high temperature on grapevines (vitis vinifera l.). ii. distribution of soluble sugars. *American Journal of Enology and Viticulture*, *37*(1), 20–25. https://doi.org/10.5344/ajev.1986.37.1.20

Smart, R. E. (1974). Aspects of water relations of the grapevine (vitis vinifera). *American Journal of Enology and Viticulture*, *25*(2), 84–91. https://doi.org/10.5344/ajev.1974.25.2.84

Smart, R. E., Dick, J. K., Gravett, I. M., & Fischer, B. M. (1990). Canopy management to improve grape yield and wine quality - principles and practices. *South African Journal of Enology and Viticulture*, *11*(1), 3–17

Smith, G., Figueiredo, E., & Van Wyk, B. (2019). *Kalanchoe (crassulaceae) in southern africa : classification, biology, and cultivation*. Physiology and Anatomy. Chapter 8. Academic Press, Elsevier. 93-104.

van Halsema, G. E., & Vincent, L. (2012). Efficiency and productivity terms for water management: a matter of contextual relativism versus general absolutism. *Agricultural Water Management*, *108*, 9–15. https://doi.org/10.1016/j.agwat.2011.05.016

Williams L. E. (2000). Grapevine water relations. In: Christensen LP (ed) Raisin production manual, vol publication 3393. University of California, Agricultural and Natural Resources, Oakland, pp 121-126.

Wraith, J. M., Baker, J. M., & Blake, T. K. (1995). Water uptake resumption following soil drought: a comparison among four barley genotypes. *Journal of Experimental Botany*, *46*(288), 873–880.

Wu, X., Shi, J., Zuo, Q., Zhang, M., Xue, X., Wang, L., Zhang, T., & Ben-Gal, A. (2021). Parameterization of the water stress reduction function based on soil–plant water relations. *Irrigation Science*, *39*(1), 101–122. https://doi.org/10.1007/s00271-020-00689-w

APPENDIX

APPENDIX 1. OVERVIEW OF THE EXPERIMENTAL SETUP

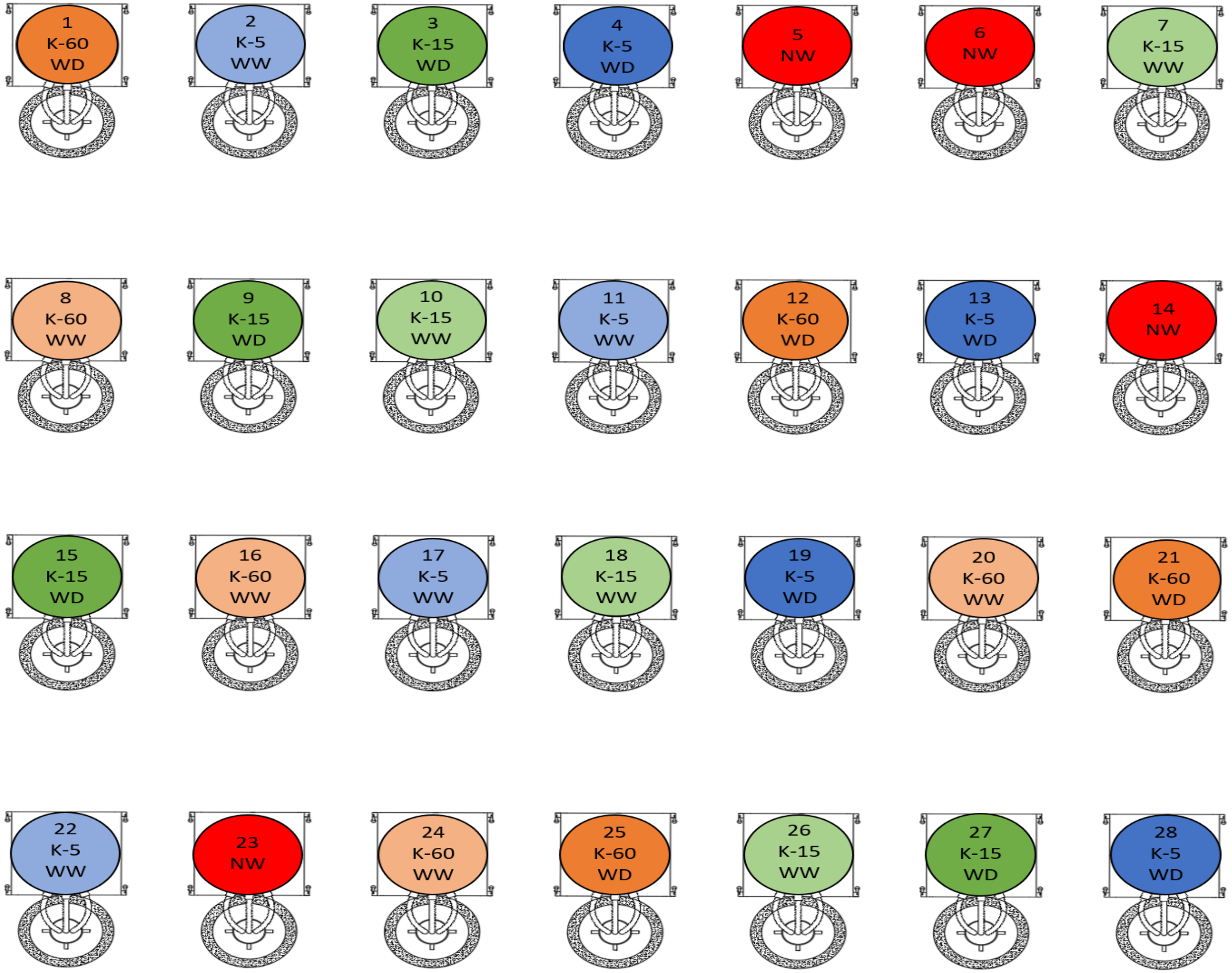

Figure 28. Overview of the experimental setup. K-5 defines 5 mg K^+ L^{-1}, K-15 describes 15 mg K^+ L^{-1} and K-60 expresses 60 mg K^+ L^{-1}. WW stands for well-watered, WD for water-deficit, and NW describes lysimeters not integrated in the research analyses.

APPENDIX 2. LYSIMETER SCHEMES

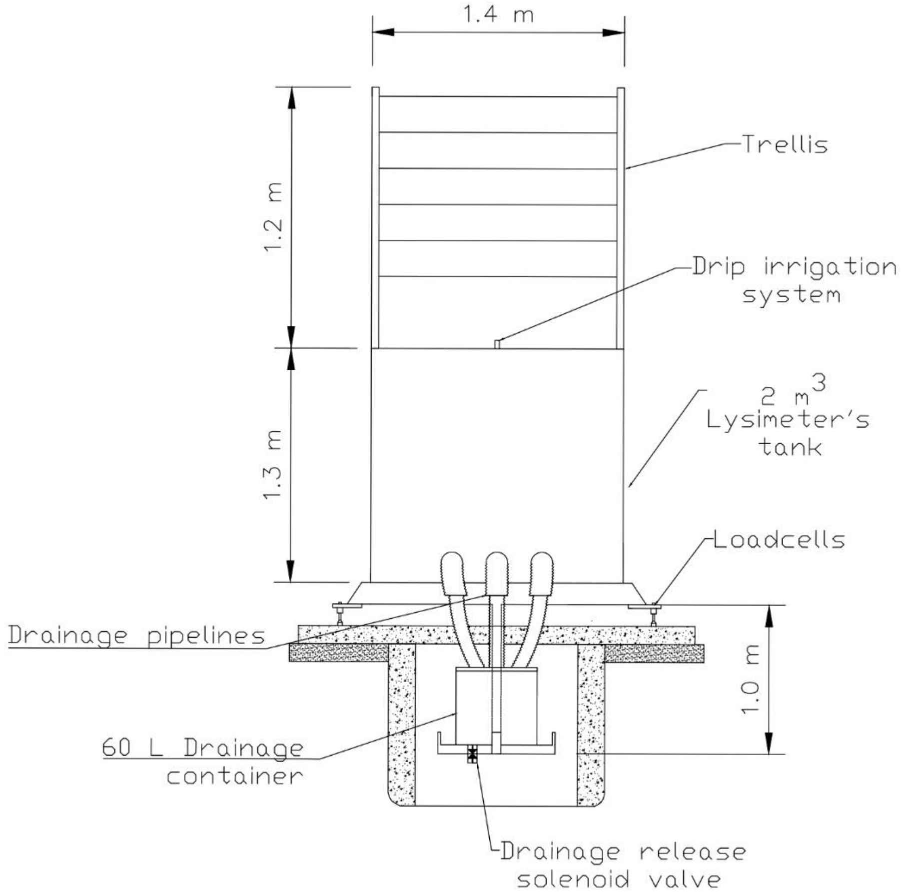

Figure 29. Front view scheme of the lysimeter used in the research (own elaboration).

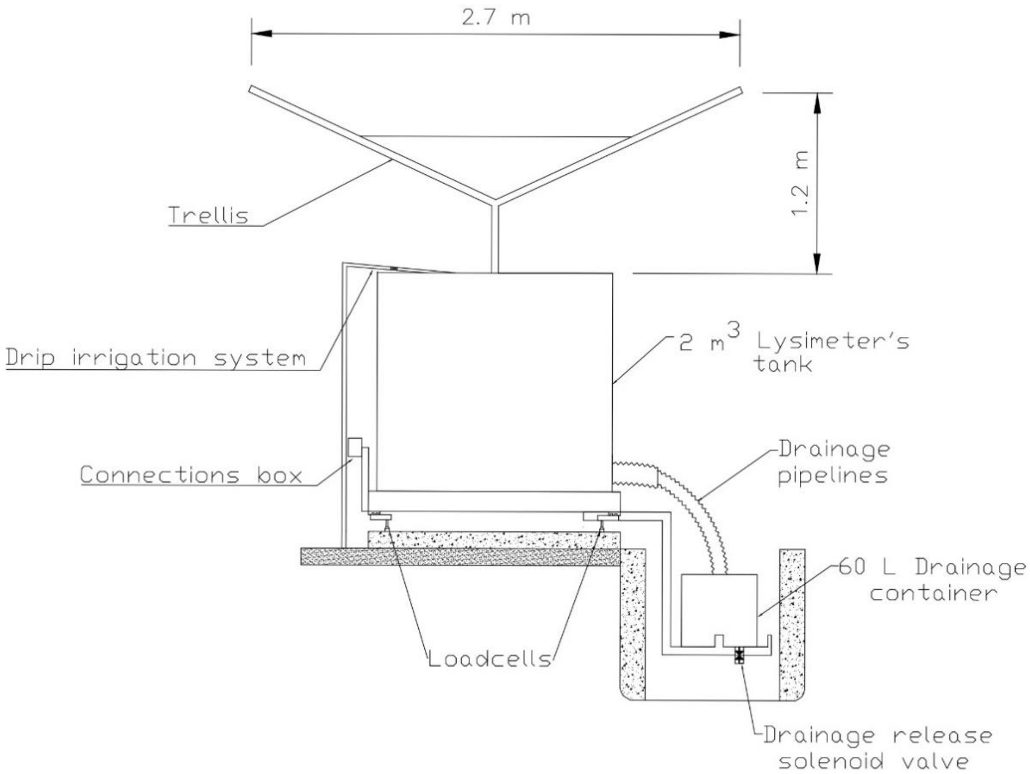

Figure 30. Side view scheme of the lysimeter used in the research (own elaboration).

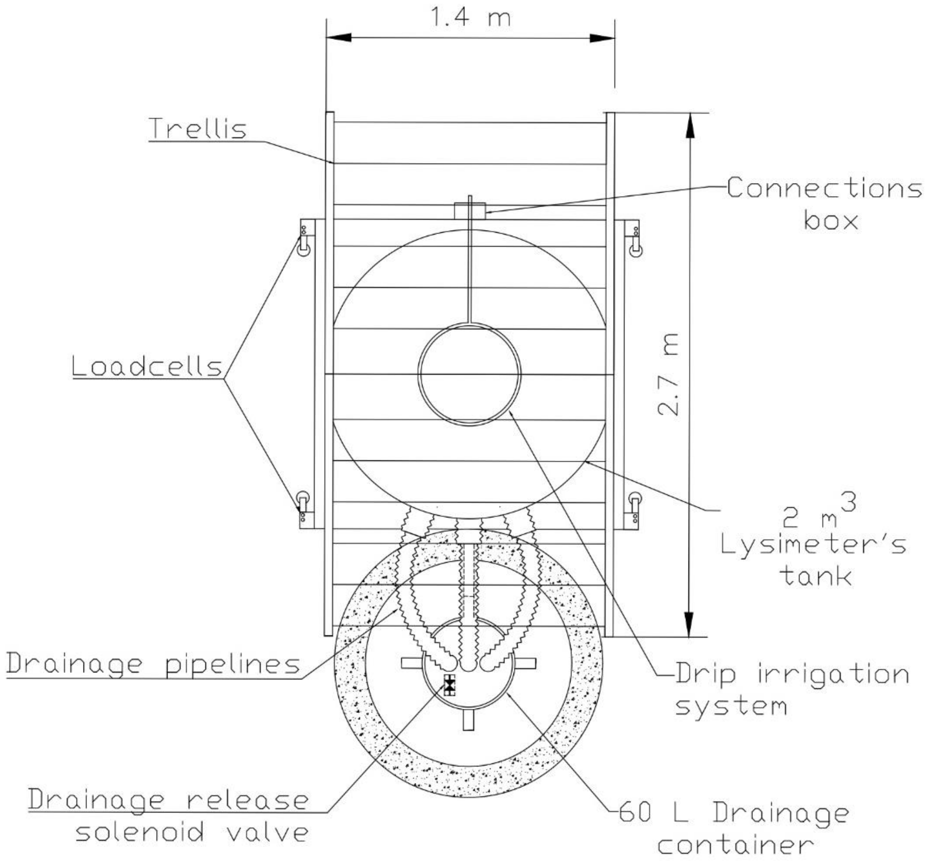

Figure 31. Top view scheme of the lysimeter used in the research (own elaboration).

APPENDIX 3. AGROCHEMICALS USED DURING GROWING SEASON

Table 6. Agrochemicals used during growing season.

Date	Product name	Cubic centimeters (cm^3) in 100 liters of water	Purpose
2/3/2023	Dormex	4000	Phytoregulator to break dormancy and stimulate bud sprouting
2/3/2023	BB5	100	Foliar fertilizer N-P (3-18%)
16/03/2023	Amistar	50	Fungicide
29/03/2023	Tracer	80	Insecticide
29/03/2023	Mancodi	250	Fungicide
16/04/2023	Amistar	50	Fungicide
16/04/2023	Vertigo	80	Fungicide
27/04/2023	Sufa	700	Fungicide
27/04/2023	Talstar	100	Insecticide
10/05/2023	Aplord	150	Fungicide
10/05/2023	Amistar	50	Fungicide
14/05/2023	Giberlon	40	Fruit growing
14/05/2023	Triton	25	Fruit growing
24/05/2023	Sufa	700	Fungicide
24/05/2023	Mancodi	250	Fungicide
6/06/2023	Amistar	50	Fungicide
6/06/2023	Tracer	80	Insecticide
22/06/2023	Acrobat	200	Fungicide
22/06/2023	Vertigo	80	Fungicide
4/07/2023	Aplord	150	Fungicide
4/07/2023	Tracer	80	Insecticide

APPENDIX 4. DATA COLLECTION OF STOMATAL CONDUCTANCE

Table 7. Data collection of stomatal conductance. Yellow cells represent drought days and blue cells depict plant recovery days.

Treatment	60D	5W	15D	5D	15W	60W	15D	15W	5W	60D	5D	15D	60W	5W	15W	5D	60W	60D	5W	60W	60D	15W	15D	5D
Date/Lysimeter	1	2	3	4	7	8	9	10	11	12	13	15	16	17	18	19	20	21	22	24	25	26	27	28
24/04/2023	0.4179	0.5459	0.4749	0.5869	0.5154	0.2227	0.4519	0.2569	0.3436	0.3079	0.2675	0.3455	0.4551	0.2644	0.5090	0.2797	0.2477	0.2841	0.3059	0.2372	0.2809	0.2499	0.2527	0.1940
27/04/2023	0.1685	0.2205	0.5437	0.2103	0.3223	0.3087	0.3486	0.2370	0.2355	0.1595	0.2151	0.1488	0.1685	0.2925	0.3788	0.2977	0.2262	0.2659	0.3045	0.2380	0.1811	0.2112	0.2874	0.2350
30/04/2023	0.3474	0.2045	0.2082	0.2776	0.2912	0.1921	0.3055	0.2170	0.2470	0.2655	0.2525	0.1672	0.2557	0.2421	0.2735	0.3213	0.2450	0.2968	0.2640	0.2752	0.2733	0.2656	0.2685	0.2085
01/05/2023	0.2781	0.2851	0.2111	0.3113	0.2285	0.2531	0.2577	0.1841	0.2424	0.2809	0.1982	0.2283	0.2423	0.2427	0.2725	0.2868	0.2911	0.1665	0.2905	0.2543	0.2772	0.2218	0.2916	0.2068
02/05/2023	0.2512	0.3155	0.2559	0.2438	0.2616	0.3027	0.2728	0.2643	0.2628	0.2746	0.2201	0.1989	0.2538	0.2519	0.2684	0.2441	0.2615	0.2611	0.2672	0.2423	0.2539	0.2500	0.2045	0.2066
03/05/2023	0.2997	0.3048	0.2126	0.2425	0.2850	0.3015	0.2431	0.2930	0.3094	0.2086	0.1904	0.2096	0.3220	0.2742	0.2537	0.2681	0.2552	0.2376	0.3389	0.2687	0.2612	0.2981	0.2305	0.2371
04/05/2023	0.2983	0.3077	0.1828	0.1986	0.3335	0.2848	0.2411	0.3052	0.3133	0.2028	0.2141	0.2027	0.2939	0.2998	0.3332	0.2160	0.3314	0.2171	0.3096	0.2889	0.2468	0.2910	0.2589	0.2007
05/05/2023	0.0772	0.2684	0.0884	0.1012	0.2188	0.2250	0.1728	0.3358	0.2307	0.1019	0.1125	0.1284	0.1428	0.2598	0.1873	0.1179	0.1947	0.1409	0.2379	0.2725	0.1973	0.2710	0.1334	0.0944
07/05/2023	0.1146	0.3558	0.1712	0.2097	0.4111	0.3889	0.3235	0.4145	0.3996	0.1406	0.2163	0.1557	0.3475	0.3575	0.3387	0.2486	0.3397	0.3324	0.3836	0.4163	0.1549	0.3887	0.1850	0.2373
08/05/2023	0.0897	0.2849	0.0775	0.1182	0.3686	0.2360	0.1426	0.2361	0.2806	0.0853	0.1799	0.0988	0.3072	0.3554	0.3581	0.1355	0.3092	0.1062	0.3084	0.3186	0.0987	0.3260	0.1355	0.1736
09/05/2023	0.0503	0.3075	0.0428	0.0800	0.3232	0.3246	0.0805	0.2988	0.3749	0.0433	0.0759	0.0601	0.3328	0.2968	0.3035	0.1282	0.3744	0.0662	0.3333	0.2827	0.0884	0.3306	0.0556	0.0788
10/05/2023	0.0231	0.3584	0.0259	0.0367	0.3831	0.2950	0.0290	0.3173	0.4305	0.0242	0.0400	0.0186	0.3014	0.3009	0.2959	0.0235	0.3401	0.0185	0.4032	0.3079	0.0300	0.3231	0.0191	0.0295
11/05/2023	0.0227	0.3336	0.0291	0.0276	0.4190	0.2833	0.0307	0.4132	0.3801	0.0153	0.0214	0.0135	0.4014	0.2645	0.3590	0.0166	0.3506	0.0211	0.3437	0.4215	0.0301	0.3190	0.0206	0.0221
12/05/2023	0.1969	0.4170	0.1672	0.1632	0.4434	0.3940	0.1673	0.4460	0.4493	0.1630	0.1609	0.1405	0.4365	0.3985	0.4330	0.1520	0.4163	0.1586	0.4007	0.4127	0.1993	0.4280	0.1434	0.1600
14/05/2023	0.2412	0.3679	0.3110	0.3087	0.3852	0.3456	0.2827	0.3935	0.3390	0.2378	0.3133	0.2517	0.3669	0.3986	0.4091	0.2951	0.3282	0.2250	0.3694	0.4137	0.2476	0.3647	0.3099	0.3145
15/05/2023	0.3550	0.3999	0.3862	0.4548	0.4347	0.3760	0.3882	0.4687	0.4531	0.3410	0.3910	0.3676	0.3923	0.4085	0.4616	0.4438	0.4326	0.3495	0.4330	0.4235	0.3910	0.4086	0.4350	0.4216
16/05/2023	0.3830	0.4745	0.5622	0.4781	0.5815	0.5466	0.5575	0.6012	0.5501	0.3906	0.4245	0.5368	0.4335	0.4221	0.4828	0.5352	0.4588	0.3990	0.5115	0.5206	0.3791	0.4456	0.5003	0.4577
17/05/2023	0.4545	0.5200	0.4786	0.4857	0.5137	0.5509	0.5026	0.5000	0.5280	0.5131	0.5153	0.4944	0.4692	0.5005	0.5542	0.5534	0.5218	0.5270	0.5356	0.4772	0.5012	0.4684	0.5022	0.4762
18/05/2023	0.4971	0.5079	0.5483	0.4785	0.4420	0.5102	0.4995	0.4711	0.5228	0.4639	0.5241	0.5200	0.4801	0.5609	0.5021	0.5095	0.5283	0.5056	0.4874	0.5286	0.4835	0.5089	0.4945	0.5083
22/05/2023	0.2313	0.2570	0.2414	0.2303	0.2328	0.1957	0.2533	0.2249	0.2386	0.2089	0.2358	0.2278	0.2594	0.2175	0.2320	0.2432	0.2599	0.2700	0.2642	0.2505	0.2750	0.2940	0.2728	0.2816
31/05/2023	0.5017	0.5102	0.4664	0.4433	0.5233	0.5057	0.4895	0.5044	0.4537	0.4873	0.4444	0.5382	0.5335	0.4563	0.4833	0.4709	0.4582	0.5363	0.4911	0.4776	0.5240	0.5541	0.4719	0.4894
08/06/2023	0.4687	0.4685	0.4928	0.5031	0.5347	0.5416	0.4775	0.4761	0.4726	0.5217	0.5281	0.5120	0.5379	0.5333	0.5127	0.4861	0.4789	0.4558	0.5228	0.4632	0.5395	0.4634	0.4851	0.4810
11/06/2023	0.3260	0.5082	0.3462	0.3096	0.4742	0.5036	0.3069	0.4528	0.4979	0.3233	0.2881	0.2823	0.5017	0.4931	0.4927	0.2901	0.5411	0.2726	0.5120	0.4953	0.3031	0.5226	0.2901	0.3041
12/06/2023	0.0596	0.4856	0.0920	0.0965	0.5173	0.5565	0.1089	0.4955	0.4999	0.0688	0.0835	0.0907	0.5431	0.5137	0.4858	0.0945	0.5201	0.0736	0.5038	0.4730	0.0518	0.4778	0.0870	0.0933
14/06/2023	0.0094	0.5631	0.0106	0.0103	0.5207	0.5979	0.0090	0.5284	0.4975	0.0086	0.0089	0.0119	0.5973	0.5190	0.4899	0.0094	0.5574	0.0116	0.4995	0.5637	0.0097	0.5743	0.0109	0.0064
15/06/2023	0.0122	0.5190	0.0155	0.0112	0.5462	0.6109	0.0118	0.5028	0.4779	0.0092	0.0094	0.0087	0.5895	0.5561	0.5573	0.0068	0.6273	0.0083	0.5031	0.6310	0.0086	0.5458	0.0125	0.0074
16/06/2023	0.0092	0.4825	0.0155	0.0148	0.6065	0.6558	0.0121	0.5601	0.5113	0.0097	0.0117	0.0112	0.6259	0.5643	0.5836	0.0121	0.6158	0.0132	0.4597	0.5814	0.0119	0.5921	0.0114	0.0092
18/06/2023	0.0365	0.4557	0.0367	0.0355	0.4946	0.5662	0.0386	0.4792	0.4672	0.0369	0.0321	0.0326	0.6302	0.4480	0.4937	0.0341	0.5508	0.0304	0.4778	0.5508	0.0336	0.5148	0.0293	0.0390
19/06/2023	0.1089	0.4081	0.0937	0.1014	0.4889	0.5938	0.1183	0.5174	0.4156	0.1236	0.0705	0.0954	0.5404	0.4434	0.4888	0.0715	0.6083	0.0993	0.4212	0.5903	0.1149	0.4500	0.0863	0.1068
20/06/2023	0.3061	0.4706	0.2910	0.2721	0.4625	0.5368	0.2756	0.4477	0.4123	0.2791	0.2565	0.2970	0.5307	0.4370	0.4573	0.2671	0.5487	0.2949	0.4202	0.5469	0.3220	0.4653	0.2665	0.3085
21/06/2023	0.4397	0.4971	0.5106	0.4346	0.4773	0.6337	0.5576	0.5399	0.4458	0.5039	0.3549	0.5535	0.5689	0.4710	0.5254	0.3862	0.5698	0.4209	0.4879	0.6270	0.4439	0.5168	0.4613	0.4196
22/06/2023	0.4280	0.5402	0.5575	0.5262	0.5195	0.6330	0.5292	0.5342	0.5302	0.4352	0.4824	0.5166	0.5793	0.4896	0.4930	0.5237	0.6294	0.4281	0.4508	0.5935	0.4489	0.4864	0.4876	0.5188
23/06/2023	0.5654	0.5376	0.6172	0.4701	0.5767	0.6063	0.5760	0.6005	0.5235	0.5743	0.5346	0.5784	0.5730	0.4833	0.6051	0.4934	0.5963	0.6289	0.5214	0.5757	0.5754	0.5822	0.5892	0.4724
27/06/2023	0.6384	0.5474	0.5821	0.5206	0.5897	0.6044	0.6120	0.5984	0.5227	0.5711	0.4858	0.6141	0.6161	0.5088	0.5754	0.5319	0.5627	0.6145	0.4965	0.6001	0.5725	0.5978	0.5719	0.5421

APPENDIX 5. DATA COLLECTION OF STEM WATER POTENTIAL

Table 8. Data collection of stem water potential. Yellow cells represent drought days and blue cells depict plant recovery days.

Treatment	60D	5W	15D	5D	15W	60W	15D	15W	5W	60D	5D	15D	60W	5W	15W	5D	60W	60D	5W	60W	60D	15W	15D	5D
imeter	1	2	3	4	7	8	9	10	11	12	13	15	16	17	18	19	20	21	22	24	25	26	27	28
24/04/2023	-0.40	-0.39	-0.55	-0.38	-0.38	-0.49	-0.51	-0.41	-0.45	-0.43	-0.48	-0.39	-0.51	-0.35	-0.48	-0.46	-0.42	-0.44	-0.51	-0.53	-0.42	-0.42	-0.39	-0.41
30/04/2023	-0.47	-0.41	-0.33	-0.55	-0.49	-0.42	-0.37	-0.51	-0.57	-0.45	-0.48	-0.58	-0.53	-0.49	-0.37	-0.53	-0.54	-0.39	-0.46	-0.53	-0.39	-0.40	-0.45	-0.43
01/05/2023	-0.43	-0.44	-0.57	-0.46	-0.47	-0.46	-0.41	-0.37	-0.46	-0.50	-0.52	-0.56	-0.44	-0.55	-0.41	-0.46	-0.45	-0.51	-0.40	-0.49	-0.55	-0.51	-0.40	-0.41
02/05/2023	-0.40	-0.37	-0.55	-0.60	-0.54	-0.45	-0.50	-0.36	-0.46	-0.43	-0.56	-0.51	-0.57	-0.51	-0.48	-0.44	-0.45	-0.52	-0.48	-0.37	-0.44	-0.53	-0.45	-0.47
03/05/2023	-0.45	-0.41	-0.56	-0.47	-0.43	-0.44	-0.43	-0.37	-0.36	-0.50	-0.52	-0.45	-0.42	-0.38	-0.41	-0.51	-0.33	-0.43	-0.40	-0.42	-0.41	-0.43	-0.60	-0.51
04/05/2023	-0.60	-0.53	-0.54	-0.70	-0.46	-0.61	-0.57	-0.49	-0.44	-0.66	-0.51	-0.53	-0.56	-0.47	-0.55	-0.64	-0.57	-0.59	-0.47	-0.38	-0.56	-0.60	-0.52	-0.69
05/05/2023	-0.63	-0.47	-0.68	-0.73	-0.61	-0.60	-0.63	-0.58	-0.50	-0.75	-0.74	-0.69	-0.57	-0.57	-0.59	-0.76	-0.60	-0.72	-0.52	-0.59	-0.74	-0.62	-0.60	-0.85
07/05/2023	-0.63	-0.42	-0.60	-0.64	-0.45	-0.38	-0.58	-0.40	-0.45	-0.64	-0.56	-0.61	-0.35	-0.40	-0.70	-0.63	-0.42	-0.63	-0.44	-0.40	-0.71	-0.52	-0.75	-0.62
08/05/2023	-0.87	-0.41	-0.91	-0.67	-0.44	-0.48	-0.70	-0.37	-0.40	-0.87	-0.73	-0.74	-0.41	-0.35	-0.42	-0.68	-0.50	-0.69	-0.46	-0.41	-0.77	-0.45	-0.83	-0.82
09/05/2023	-1.14	-0.73	-1.05	-1.02	-0.71	-0.55	-0.92	-0.54	-0.74	-0.98	-0.89	-0.96	-0.51	-0.72	-0.61	-0.93	-0.70	-1.04	-0.55	-0.54	-0.92	-0.54	-1.14	-1.03
10/05/2023	-1.15	-0.69	-1.07	-1.14	-0.51	-0.48	-0.96	-0.51	-0.65	-1.10	-0.93	-0.96	-0.63	-0.62	-0.44	-1.02	-0.50	-1.09	-0.61	-0.58	-1.15	-0.49	-1.10	-1.06
11/05/2023	-1.19	-0.55	-1.05	-1.08	-0.57	-0.60	-0.95	-0.58	-0.65	-1.03	-0.92	-1.04	-0.70	-0.53	-0.62	-0.97	-0.48	-1.10	-0.65	-0.67	-1.15	-0.67	-1.18	-1.05
12/05/2023	-0.62	-0.57	-0.65	-0.60	-0.58	-0.54	-0.56	-0.54	-0.57	-0.56	-0.55	-0.50	-0.55	-0.60	-0.61	-0.55	-0.48	-0.52	-0.61	-0.59	-0.55	-0.64	-0.58	-0.59
14/05/2023	-0.55	-0.47	-0.40	-0.47	-0.45	-0.46	-0.60	-0.39	-0.52	-0.48	-0.50	-0.48	-0.47	-0.57	-0.39	-0.60	-0.53	-0.47	-0.44	-0.53	-0.52	-0.56	-0.49	-0.54
15/05/2023	-0.41	-0.47	-0.48	-0.53	-0.45	-0.45	-0.51	-0.47	-0.45	-0.55	-0.50	-0.56	-0.48	-0.52	-0.67	-0.58	-0.51	-0.53	-0.43	-0.68	-0.64	-0.45	-0.56	-0.53
16/05/2023	-0.50	-0.42	-0.46	-0.53	-0.39	-0.37	-0.41	-0.44	-0.46	-0.42	-0.46	-0.42	-0.37	-0.42	-0.42	-0.60	-0.42	-0.51	-0.43	-0.44	-0.48	-0.35	-0.51	-0.56
17/05/2023	-0.62	-0.59	-0.70	-0.68	-0.75	-0.78	-0.77	-0.73	-0.73	-0.68	-0.57	-0.76	-0.80	-0.65	-0.72	-0.63	-0.61	-0.70	-0.59	-0.74	-0.62	-0.71	-0.78	-0.80
18/05/2023	-0.60	-0.38	-0.51	-0.44	-0.43	-0.47	-0.53	-0.55	-0.46	-0.54	-0.60	-0.45	-0.40	-0.54	-0.56	-0.54	-0.62	-0.58	-0.39	-0.50	-0.47	-0.55	-0.51	-0.48
22/05/2023	-0.56	-0.49	-0.60	-0.68	-0.63	-0.64	-0.71	-0.59	-0.55	-0.71	-0.65	-0.50	-0.67	-0.55	-0.62	-0.65	-0.58	-0.54	-0.62	-0.61	-0.66	-0.54	-0.55	-0.68
31/05/2023	-0.69	-0.45	-0.67	-0.59	-0.49	-0.54	-0.46	-0.47	-0.55	-0.65	-0.51	-0.55	-0.50	-0.71	-0.59	-0.54	-0.66	-0.68	-0.63	-0.62	-0.58	-0.57	-0.54	-0.51
08/06/2023	-0.45	-0.60	-0.66	-0.55	-0.64	-0.53	-0.52	-0.58	-0.62	-0.65	-0.64	-0.63	-0.59	-0.55	-0.60	-0.57	-0.60	-0.63	-0.67	-0.57	-0.49	-0.52	-0.50	-0.66
11/06/2023	-0.85	-0.67	-0.72	-0.70	-0.49	-0.55	-0.89	-0.60	-0.57	-0.81	-0.68	-0.85	-0.71	-0.59	-0.63	-0.73	-0.52	-0.87	-0.48	-0.65	-0.83	-0.66	-0.72	-0.76
12/06/2023	-0.95	-0.53	-0.95	-0.79	-0.59	-0.54	-0.97	-0.42	-0.50	-0.97	-0.73	-1.10	-0.51	-0.58	-0.57	-0.62	-0.47	-0.94	-0.33	-0.55	-0.91	-0.53	-0.93	-0.77
13/06/2023	-1.02	-0.51	-1.11	-0.88	-0.45	-0.39	-1.05	-0.40	-0.43	-0.98	-0.60	-0.99	-0.58	-0.42	-0.46	-0.65	-0.41	-0.95	-0.49	-0.48	-1.15	-0.46	-0.87	-0.86
14/06/2023	-1.07	-0.65	-1.15	-0.83	-0.55	-0.68	-1.02	-0.60	-0.59	-1.23	-1.06	-0.99	-0.47	-0.82	-0.66	-0.88	-0.57	-1.01	-0.58	-0.69	-1.00	-0.52	-0.97	-0.89
15/06/2023	-0.73	-0.49	-0.68	-0.65	-0.51	-0.52	-0.72	-0.49	-0.50	-0.77	-0.62	-0.67	-0.64	-0.67	-0.65	-0.71	-0.67	-0.81	-0.55	-0.64	-0.77	-0.58	-0.81	-0.87
16/06/2023	-1.14	-0.69	-1.06	-1.06	-0.73	-0.68	-1.32	-0.67	-0.70	-1.06	-1.07	-1.12	-0.65	-0.75	-0.74	-0.97	-0.87	-1.17	-0.67	-0.75	-1.21	-0.78	-1.04	-1.12
18/06/2023	-0.95	-0.46	-1.00	-0.90	-0.50	-0.51	-0.92	-0.42	-0.50	-0.90	-0.64	-0.73	-0.45	-0.42	-0.42	-0.79	-0.53	-0.82	-0.46	-0.48	-0.97	-0.39	-0.80	-0.95
19/06/2023	-0.66	-0.49	-0.55	-0.67	-0.49	-0.54	-0.59	-0.55	-0.52	-0.70	-0.48	-0.50	-0.54	-0.58	-0.61	-0.46	-0.55	-0.64	-0.65	-0.59	-0.58	-0.65	-0.64	-0.62
20/06/2023	-0.58	-0.47	-0.58	-0.55	-0.44	-0.53	-0.62	-0.58	-0.48	-0.58	-0.51	-0.62	-0.46	-0.51	-0.54	-0.60	-0.57	-0.60	-0.56	-0.50	-0.53	-0.46	-0.61	-0.58
21/06/2023	-0.82	-0.75	-0.83	-0.68	-0.74	-0.63	-0.80	-0.53	-0.61	-0.79	-0.76	-0.69	-0.65	-0.40	-0.72	-0.71	-0.55	-0.71	-0.61	-0.67	-0.56	-0.77	-0.76	-0.65
22/06/2023	-0.65	-0.48	-0.51	-0.50	-0.51	-0.60	-0.42	-0.52	-0.37	-0.58	-0.46	-0.55	-0.53	-0.54	-0.45	-0.49	-0.55	-0.55	-0.53	-0.62	-0.65	-0.61	-0.57	-0.54
23/06/2023	-0.69	-0.56	-0.64	-0.60	-0.54	-0.60	-0.66	-0.62	-0.64	-0.66	-0.59	-0.61	-0.50	-0.66	-0.68	-0.66	-0.58	-0.67	-0.60	-0.58	-0.62	-0.55	-0.54	-0.59
27/06/2023	-0.60	-0.51	-0.61	-0.52	-0.78	-0.73	-0.66	-0.65	-0.63	-0.72	-0.79	-0.74	-0.78	-0.82	-0.75	-0.74	-0.80	-0.69	-0.78	-0.71	-0.83	-0.74	-0.73	-0.81

APPENDIX 6. WATER BALANCE COMPONENTS DURING GROWING SEASON

IRRIGATION

Table 9. Daily irrigation during the growing season. Yellow cells represent drought days, blue cells depict plant recovery days, and the blue cell the harvest.

Treatment	60D	5W	5D	15W	60W	15D	15W	5W	60D	5D	15D	60W	5W	15W	5D	60W	60D	5W	60W	60D	15W	15D	5D
Date/Lysimeter	1	2	4	7	8	9	10	11	12	13	15	16	17	18	19	20	21	22	24	25	26	27	28
20/04/2023	15.96	17.38	16.67	18.93	21.79	20.65	19.15	21.56	19.78	19.14	19.99	19.25	15.66	16.97	20.06	20.46	18.29	18.20	14.33	19.11	20.67	18.25	20.69
21/04/2023	15.33	17.61	16.78	19.56	19.83	20.14	20.12	22.53	19.92	19.94	19.93	20.38	17.20	18.06	21.63	21.36	18.38	19.12	17.04	19.89	20.50	18.18	21.42
22/04/2023	15.50	17.59	16.91	19.61	21.82	20.09	20.48	21.98	19.85	20.14	19.14	20.20	17.41	17.87	21.88	21.44	18.27	18.99	16.78	19.46	20.47	17.90	21.62
23/04/2023	15.29	18.19	16.89	19.14	19.20	19.80	19.76	22.10	20.31	19.85	19.20	20.26	16.77	17.70	21.40	21.18	18.17	19.02	16.32	18.92	19.94	17.85	21.26
24/04/2023	15.70	17.79	17.01	19.82	21.10	20.86	20.22	22.04	19.81	20.04	20.54	20.59	17.36	18.52	22.40	22.67	18.74	19.06	18.26	20.72	20.72	18.58	20.70
25/04/2023	18.93	22.53	21.51	24.55	26.50	25.58	25.18	27.41	25.20	25.39	25.03	25.63	22.03	23.19	27.38	27.48	23.15	23.99	22.82	25.33	25.29	22.80	27.27
26/04/2023	19.37	22.27	21.19	23.69	25.96	25.15	24.13	28.02	25.27	25.17	24.11	25.48	21.21	21.78	26.85	26.30	22.69	23.84	21.08	23.45	25.15	22.49	27.47
27/04/2023	19.12	22.07	20.82	24.23	22.34	25.04	24.79	27.03	24.73	24.79	24.22	24.95	21.36	23.08	26.60	26.59	22.72	23.49	21.22	24.33	24.81	22.30	26.95
28/04/2023	0.00	24.35	0.00	30.17	33.09	0.00	30.91	30.99	0.00	0.00	0.00	32.80	22.13	28.63	0.00	34.31	0.00	29.54	26.20	0.00	30.97	0.00	0.00
29/04/2023	0.00	23.54	0.00	30.54	32.61	0.00	31.27	31.13	0.00	0.00	0.00	33.05	23.32	28.96	0.00	34.65	0.00	30.38	27.70	0.00	31.40	0.00	0.00
30/04/2023	0.00	24.28	0.00	30.34	32.60	0.00	30.83	31.05	0.00	0.00	0.00	33.06	23.15	28.98	0.00	34.96	0.00	29.17	27.32	0.00	31.21	0.00	0.00
01/05/2023	0.00	24.30	0.00	31.95	32.80	0.00	32.14	31.56	0.00	0.00	0.00	33.42	23.61	29.29	0.00	34.23	0.00	29.53	27.39	0.00	31.19	0.00	0.00
02/05/2023	0.00	24.06	0.00	31.54	32.66	0.00	30.93	30.27	0.00	0.00	0.00	33.13	22.82	28.24	0.00	34.31	0.00	28.39	27.77	0.00	31.20	0.00	0.00
03/05/2023	0.00	28.17	0.00	35.81	38.20	0.00	35.33	36.25	0.00	0.00	0.00	38.11	27.22	31.57	0.00	39.58	0.00	33.05	31.39	0.00	35.40	0.00	0.00
04/05/2023	0.00	28.14	0.00	35.43	36.47	0.00	35.00	35.12	0.00	0.00	0.00	36.94	26.17	31.23	0.00	35.95	0.00	30.60	28.04	0.00	34.26	0.00	0.00
05/05/2023	8.97	34.14	11.89	42.40	43.65	13.90	41.75	46.15	12.71	13.39	11.22	44.11	35.26	40.21	15.04	46.68	9.83	42.80	37.63	12.83	43.07	12.60	15.52
06/05/2023	11.77	37.74	11.82	43.21	44.10	13.87	42.58	47.65	12.93	13.77	11.00	44.47	36.90	40.97	15.41	46.29	10.22	44.37	37.44	13.69	42.87	11.41	11.97
07/05/2023	11.23	37.60	11.86	42.89	43.38	11.68	42.24	47.47	12.53	13.16	10.51	43.62	35.83	39.60	14.48	43.51	8.14	45.10	34.33	11.91	42.40	11.69	12.27
08/05/2023	0.00	31.40	0.00	36.02	35.49	0.00	35.80	35.67	0.00	0.00	0.00	35.40	27.11	33.00	0.00	36.19	0.00	31.42	29.48	0.00	35.99	0.00	0.00
09/05/2023	5.00	31.92	0.00	36.47	35.63	0.00	35.73	36.02	0.00	0.00	0.00	35.78	27.79	33.19	0.00	36.85	0.00	31.95	29.46	0.00	35.65	5.00	0.00
10/05/2023	10.00	37.41	10.00	41.14	40.49	10.00	40.80	41.93	10.00	10.00	10.00	41.09	32.03	37.65	10.00	42.66	10.00	38.26	34.93	10.00	40.75	10.00	10.00
11/05/2023	0.00	42.03	0.00	45.28	44.91	0.00	44.51	46.89	0.00	0.00	0.00	45.71	35.94	41.56	0.00	46.55	0.00	43.27	38.08	0.00	44.93	0.00	0.00
12/05/2023	112.50	90.11	103.72	96.42	93.64	124.25	94.36	100.32	120.38	106.69	116.21	89.13	75.04	89.25	127.41	96.44	98.98	94.96	77.33	118.15	96.35	116.83	122.95
13/05/2023	55.38	58.37	50.19	62.98	58.30	63.20	62.25	65.05	58.01	49.90	61.06	58.63	50.56	58.27	62.78	60.30	50.19	59.49	47.93	57.94	62.04	58.59	63.54
14/05/2023	54.24	47.81	41.92	59.00	57.65	58.50	58.52	54.27	57.49	41.70	57.27	57.60	41.68	53.86	52.60	58.95	48.94	47.48	46.88	56.30	57.92	55.43	50.77
15/05/2023	62.64	57.98	50.54	68.07	66.96	66.85	67.63	65.63	66.44	49.78	65.81	67.48	50.38	62.47	61.78	67.29	56.74	57.94	54.25	64.73	65.85	61.41	64.06
16/05/2023	73.00	61.34	58.67	78.51	78.06	77.15	78.17	75.07	78.17	57.37	75.41	79.38	57.93	73.18	71.68	78.91	65.23	66.18	63.25	75.61	76.13	69.76	72.96
17/05/2023	73.48	61.27	58.85	78.61	78.15	79.86	77.79	76.04	77.57	58.31	76.39	78.94	56.85	72.73	73.86	80.55	65.57	69.14	63.99	77.29	78.00	68.04	75.24
18/05/2023	62.56	49.42	46.17	68.07	66.89	67.21	66.49	64.80	66.33	45.11	66.34	66.58	44.23	61.46	61.68	68.34	55.42	59.85	52.86	65.92	66.95	60.60	63.48
19/05/2023	61.67	49.30	46.19	68.38	66.31	67.39	66.83	65.60	65.55	45.32	66.64	66.60	45.65	62.28	62.43	67.73	55.03	59.48	53.93	64.43	66.39	62.15	63.25
20/05/2023	61.45	49.16	45.96	67.36	65.75	67.24	66.41	64.33	65.05	44.87	65.87	65.86	45.50	62.21	62.52	67.66	54.88	58.95	53.57	64.43	66.18	62.31	62.94
21/05/2023	60.17	48.91	45.89	67.27	64.79	66.41	66.12	63.70	63.82	44.75	65.70	64.90	45.16	61.43	61.61	65.72	54.02	58.43	51.61	62.66	64.95	62.43	62.64
22/05/2023	57.17	64.36	60.39	84.09	81.09	84.64	82.45	84.71	79.57	58.77	82.92	81.25	58.88	77.97	81.82	83.28	67.49	76.06	65.90	79.43	82.37	77.72	81.14
23/05/2023	50.73	55.74	52.41	74.68	71.21	74.97	73.19	72.79	70.17	50.92	73.61	71.75	51.22	68.90	70.48	73.24	59.51	65.64	58.40	69.88	72.82	68.88	70.37
24/05/2023	44.28	47.12	44.42	65.26	61.34	65.30	63.92	60.86	60.78	43.06	64.30	62.25	43.55	59.84	59.15	63.20	51.54	55.22	50.89	60.33	63.28	60.04	59.60
25/05/2023	52.84	56.06	52.48	74.41	72.95	73.34	73.42	72.53	72.41	50.33	72.47	73.62	51.17	67.53	68.66	73.24	60.80	64.79	56.97	74.44	71.36	67.32	70.15
26/05/2023	52.74	56.45	53.19	76.24	72.11	76.11	74.48	72.12	71.42	51.75	74.87	73.25	52.93	70.06	71.01	74.90	61.17	66.70	60.82	71.46	74.00	70.54	70.84
27/05/2023	61.56	70.76	66.30	87.65	85.35	87.08	88.20	91.70	84.69	62.52	88.56	86.59	63.17	81.75	85.59	85.20	71.94	79.76	65.96	82.55	86.04	81.91	86.21
28/05/2023	50.59	55.84	52.10	73.26	68.76	75.72	73.68	72.82	68.43	50.27	73.50	69.64	52.20	67.97	69.35	71.74	57.91	64.96	55.63	69.51	74.07	68.71	68.29
29/05/2023	46.19	52.59	49.27	65.58	62.21	66.24	64.60	68.60	61.32	48.10	65.13	63.49	49.04	60.62	65.30	64.76	52.64	59.87	51.81	61.62	64.71	60.73	65.06
30/05/2023	47.69	52.18	48.33	65.92	60.43	66.77	64.96	66.95	60.24	47.09	65.21	60.45	47.85	49.17	63.77	62.96	52.64	61.65	62.51	59.59	64.17	60.23	65.45
31/05/2023	48.42	52.41	49.12	66.86	62.14	67.01	66.24	68.72	61.65	47.99	65.93	59.95	48.35	48.74	64.86	64.05	56.02	63.21	62.71	61.14	65.51	61.71	66.37

Table 9. Daily irrigation during the growing season. Yellow cells represent drought days, blue cells depict plant recovery days, and the blue cell the harvest (continuation).

01/06/2023	53.49	56.30	51.96	65.21	69.28	65.75	65.00	72.38	68.13	50.02	64.79	67.03	51.21	46.97	68.50	70.38	62.66	65.35	70.02	67.43	63.83	60.08	69.97
02/06/2023	80.58	77.04	77.27	75.38	80.54	75.17	77.93	77.19	80.03	77.75	73.64	77.63	74.81	72.54	76.08	81.76	75.26	76.00	82.91	80.88	75.41	72.52	75.52
03/06/2023	80.58	77.04	77.27	75.38	80.54	75.17	77.93	77.19	80.03	77.75	73.64	77.63	74.81	72.54	76.08	81.76	75.26	76.00	82.91	80.88	75.41	72.52	75.52
04/06/2023	60.44	52.03	50.98	51.22	59.64	50.93	53.46	52.03	59.81	52.54	50.08	57.35	51.12	48.51	52.29	60.20	55.41	51.29	60.95	59.08	51.17	48.75	52.08
05/06/2023	82.63	82.09	80.54	80.43	82.15	79.83	81.03	83.95	82.34	83.35	78.31	81.27	80.55	76.14	81.70	82.32	76.08	81.21	82.90	79.94	80.31	76.12	82.33
06/06/2023	95.52	73.08	89.30	72.25	75.21	88.20	72.74	74.11	94.47	92.15	86.60	72.76	71.04	67.28	90.51	74.44	84.71	71.80	74.13	92.18	70.64	84.92	92.18
07/06/2023	81.87	81.59	79.80	80.57	82.02	78.83	81.17	82.97	82.42	83.13	79.29	79.39	80.16	76.39	81.06	82.47	75.18	80.47	84.37	81.58	80.02	75.90	81.70
08/06/2023	81.37	80.57	78.64	79.80	81.06	78.87	80.71	81.76	81.56	82.48	77.52	78.61	79.85	75.78	80.88	82.18	75.44	78.03	83.16	80.96	79.91	75.40	80.92
09/06/2023	0.00	71.09	0.00	72.79	80.62	0.00	82.41	72.30	0.00	0.00	0.00	78.74	71.82	70.19	0.00	80.95	0.00	68.18	79.82	0.00	72.54	0.00	0.00
10/06/2023	0.00	72.12	0.00	75.62	82.51	0.00	75.98	73.27	0.00	0.00	0.00	79.10	70.73	70.82	0.00	83.11	0.00	71.42	74.26	0.00	75.59	0.00	0.00
11/06/2023	0.00	56.74	0.00	61.50	67.01	0.00	61.72	57.28	0.00	0.00	0.00	64.97	56.15	57.68	0.00	68.24	0.00	55.83	62.22	0.00	61.71	0.00	0.00
12/06/2023	0.00	56.33	0.00	60.81	66.43	0.00	61.81	57.49	0.00	0.00	0.00	64.30	55.34	57.52	0.00	67.02	0.00	55.46	60.62	0.00	60.88	0.00	0.00
13/06/2023	0.00	56.11	0.00	60.63	66.17	0.00	61.15	56.99	0.00	0.00	0.00	63.96	55.52	57.00	0.00	66.79	0.00	55.12	60.16	0.00	59.46	0.00	0.00
14/06/2023	0.00	55.36	0.00	60.53	65.64	0.00	61.50	56.27	0.00	0.00	0.00	60.59	53.81	56.80	0.00	66.29	0.00	53.63	59.22	0.00	60.97	0.00	0.00
15/06/2023	30.67	74.29	28.65	71.69	75.98	28.28	72.92	74.54	30.43	29.27	25.76	70.89	72.41	67.21	29.29	75.85	27.52	70.34	68.32	30.02	71.05	26.80	30.08
16/06/2023	0.00	74.66	0.00	72.87	79.27	0.00	73.41	76.48	0.00	0.00	0.00	67.35	72.13	67.07	0.00	79.59	0.00	71.78	71.46	0.00	71.85	0.00	0.00
17/06/2023	16.94	63.80	15.80	61.09	65.07	14.67	63.28	64.99	16.38	15.54	13.87	56.69	62.99	57.80	15.78	64.68	13.52	59.02	58.87	15.06	61.30	14.34	15.77
18/06/2023	18.46	65.31	16.71	63.63	66.74	16.79	64.37	66.07	17.61	17.10	13.86	61.75	64.01	59.69	17.53	67.09	14.75	63.22	60.84	17.98	63.10	15.53	18.09
19/06/2023	114.59	90.91	112.32	88.11	89.97	110.82	89.88	91.84	114.12	115.56	95.24	79.95	88.05	82.46	114.55	88.73	102.70	86.18	81.50	112.47	87.19	106.10	114.73
20/06/2023	112.41	88.94	110.75	87.10	87.96	109.28	89.24	90.55	111.51	114.09	94.73	98.03	87.28	81.44	112.07	86.21	102.62	83.57	78.03	110.19	86.34	105.48	112.88
21/06/2023	76.64	66.62	65.70	74.54	75.63	73.74	75.79	67.60	76.85	68.53	63.92	72.38	65.33	69.41	66.67	74.69	71.60	63.35	66.83	75.31	73.58	70.60	67.37
22/06/2023	78.06	67.76	66.24	75.97	77.37	74.20	76.16	68.57	77.75	69.61	63.34	69.45	65.90	68.38	66.85	77.04	73.75	64.64	66.44	76.38	75.47	71.85	68.49
23/06/2023	83.38	68.87	67.63	81.40	82.72	79.24	81.58	69.66	83.37	70.95	67.56	75.01	67.21	71.75	67.33	81.93	77.99	65.49	69.94	77.39	80.75	77.14	70.05
24/06/2023	82.14	67.33	65.97	79.72	81.08	78.39	80.36	68.53	82.29	69.34	66.80	75.00	65.39	73.35	67.01	79.89	75.35	63.46	70.82	80.33	78.86	74.90	67.71
25/06/2023	81.63	70.84	70.22	79.39	80.47	78.75	79.81	72.74	81.54	74.04	66.56	77.19	70.15	73.29	72.09	80.06	76.17	66.95	71.71	80.07	78.89	74.64	72.54
26/06/2023	81.31	71.36	70.38	78.87	80.08	78.31	79.39	72.38	81.67	74.02	66.66	76.35	69.73	73.75	71.92	80.14	76.32	67.55	72.63	79.93	78.91	74.77	72.10
27/06/2023	80.74	71.06	69.94	78.84	79.76	78.42	79.17	71.63	81.11	73.79	65.99	77.79	69.60	73.01	71.98	79.65	75.56	67.75	72.77	79.50	78.78	74.57	72.22
28/06/2023	80.65	70.45	69.74	78.64	79.58	78.66	78.87	72.59	81.25	73.67	66.26	77.14	69.55	73.90	71.97	79.91	76.13	66.31	73.79	79.89	78.91	75.35	72.12
29/06/2023	78.22	69.66	68.92	76.83	77.51	76.56	77.97	71.63	78.87	72.25	65.29	72.47	68.30	72.30	70.55	75.77	71.93	65.65	69.40	76.58	76.32	73.31	70.37
30/06/2023	81.24	70.25	69.69	78.16	79.97	78.10	78.58	72.26	81.68	73.82	65.66	83.21	69.47	72.42	71.84	79.50	74.77	67.20	72.34	79.59	78.28	74.82	71.10
01/07/2023	78.13	69.33	68.88	76.95	77.33	77.00	77.68	71.10	78.94	71.97	64.99	80.56	67.60	71.63	70.66	75.73	71.67	63.81	66.92	76.60	76.74	73.87	69.37
02/07/2023	57.24	52.46	52.15	56.10	56.54	55.99	56.29	53.63	57.76	54.46	47.01	55.15	51.38	52.32	52.87	55.77	52.60	48.28	49.52	56.07	55.21	52.89	52.84
03/07/2023	64.46	59.14	58.46	62.16	64.39	63.10	61.89	60.05	65.04	61.59	51.59	62.61	57.90	56.68	60.32	63.40	60.38	55.31	57.69	63.35	62.16	59.48	59.68
04/07/2023	65.02	59.53	58.83	62.75	64.76	62.10	62.20	60.86	66.21	61.66	52.20	59.72	58.05	56.79	60.73	64.40	60.68	56.16	58.91	64.00	62.39	59.40	59.72
05/07/2023	62.96	58.32	57.65	61.21	63.43	60.21	61.24	60.33	64.23	60.35	51.49	61.19	56.09	55.00	57.90	60.33	58.21	53.69	53.21	61.93	60.29	58.03	58.58
06/07/2023	64.35	59.08	58.53	62.33	64.38	61.55	61.64	60.67	65.26	61.24	52.43	59.47	57.78	57.28	60.01	62.69	60.30	54.35	57.20	63.21	60.90	58.26	59.72
07/07/2023	64.24	59.07	58.47	61.91	64.46	61.41	61.64	60.29	65.40	61.43	52.03	66.81	57.66	57.44	60.14	63.43	60.57	52.69	56.29	63.21	61.38	59.08	59.92
08/07/2023	64.42	59.66	58.63	62.35	64.59	61.94	61.65	61.21	65.09	61.67	52.19	66.81	58.32	57.71	60.46	64.22	60.97	52.54	57.48	63.82	62.14	59.04	60.38
09/07/2023	63.87	58.90	58.42	61.84	64.11	61.38	61.17	59.94	65.27	61.28	51.35	62.91	57.19	56.57	59.86	62.80	59.29	51.90	55.18	63.02	61.34	58.73	59.36
10/07/2023	63.41	58.35	57.83	61.60	64.04	61.16	60.71	59.79	64.92	61.44	51.31	56.51	56.32	56.04	58.88	59.35	58.96	51.04	53.75	61.92	60.58	58.17	59.26
11/07/2023	64.03	60.03	58.57	62.26	64.49	61.39	61.61	60.60	65.33	57.22	51.79	61.46	57.42	56.53	59.94	60.53	59.57	51.91	55.36	62.44	60.80	59.07	58.15
12/07/2023	82.76	72.75	72.00	79.44	82.92	79.11	79.17	74.80	83.86	70.84	66.33	80.57	70.30	72.98	74.01	78.44	76.61	64.74	73.21	81.18	78.36	75.94	73.42
13/07/2023	81.89	72.23	71.67	78.70	82.36	78.35	79.41	74.08	83.27	69.12	66.17	78.36	69.37	72.36	72.88	75.72	75.43	63.32	69.17	79.61	77.85	74.89	72.16

DRAINAGE

Table 10. Daily drainage during the growing season. Yellow cells represent drought days, blue cells depict plant recovery days, and the blue cell the harvest.

Treatment	60D	5W	5D	15W	60W	15D	15W	5W	60D	5D	15D	60W	5W	15W	5D	60W	60D	5W	60W	60D	15W	15D	5D
Date/Lysimeter	1	2	4	7	8	9	10	11	12	13	15	16	17	18	19	20	21	22	24	25	26	27	28
20/04/2023	4.44	5.27	6.59	2.87	4.45	2.35	3.96	5.96	3.68	4.40	3.59	5.18	3.34	2.67	3.53	3.92	3.83	4.86	1.23	3.35	1.97	3.10	3.10
21/04/2023	4.44	4.82	5.31	2.97	3.52	2.77	4.04	5.71	3.65	3.71	3.91	5.21	2.98	2.96	3.42	4.22	3.85	4.50	1.31	3.45	1.91	3.24	2.40
22/04/2023	4.07	4.32	4.69	2.86	4.70	2.77	4.02	5.58	3.75	3.60	3.94	5.00	2.65	2.75	3.70	4.21	3.73	4.18	1.06	3.36	1.83	3.12	2.42
23/04/2023	4.08	4.16	4.33	3.12	5.09	3.84	4.05	5.65	3.60	4.08	4.09	5.48	3.03	3.56	3.58	4.39	3.72	4.28	0.39	3.47	1.76	3.43	4.33
24/04/2023	3.55	4.41	4.55	3.40	5.91	3.22	4.51	6.41	3.78	3.46	4.26	6.03	3.28	3.61	3.95	4.68	3.53	4.70	1.23	3.25	2.09	3.28	1.88
25/04/2023	2.89	4.13	4.49	3.46	4.76	3.62	4.72	6.57	3.52	3.46	3.91	5.60	2.86	3.67	3.57	4.54	3.44	4.52	0.71	3.89	1.98	3.20	2.32
26/04/2023	2.43	5.28	4.69	3.57	6.19	3.53	4.86	6.61	3.52	3.65	4.16	6.14	3.61	3.54	4.56	5.03	3.27	5.16	1.59	3.87	2.30	3.19	1.68
27/04/2023	2.14	4.97	4.65	2.76	4.80	1.64	4.38	6.35	3.32	4.00	3.53	5.80	3.28	2.19	3.73	4.23	2.97	4.87	1.20	3.44	1.70	2.27	3.62
28/04/2023	1.46	4.17	3.91	3.40	5.98	0.83	4.43	6.01	2.48	2.50	2.67	6.68	2.83	4.61	2.73	6.12	2.34	3.83	1.36	3.08	1.16	0.64	0.86
29/04/2023	0.50	5.08	2.62	6.63	12.28	0.00	9.13	9.18	1.31	2.97	0.87	13.38	4.33	8.20	1.75	11.15	1.03	4.87	1.45	1.29	2.55	0.30	4.52
30/04/2023	0.33	6.91	1.68	7.06	12.39	0.00	10.72	8.73	1.01	1.62	0.66	12.52	4.41	7.42	1.32	10.65	0.83	5.16	2.61	1.14	3.04	0.00	1.86
01/05/2023	0.00	7.46	1.14	10.21	13.20	0.00	11.65	9.58	0.35	1.35	0.45	13.01	4.63	6.95	0.95	11.20	0.24	5.82	2.65	0.38	3.64	0.00	1.95
02/05/2023	0.00	7.91	0.53	10.46	12.91	0.00	11.42	9.21	0.32	0.37	0.00	12.60	4.29	6.73	0.36	10.53	0.00	6.82	3.13	0.00	3.96	0.00	0.23
03/05/2023	0.00	9.53	0.19	14.09	17.09	0.00	17.45	14.43	0.00	0.00	0.00	16.95	7.24	10.87	0.00	14.65	0.00	7.38	4.68	0.00	6.25	0.00	0.00
04/05/2023	0.00	9.83	0.00	13.65	14.22	0.00	12.47	14.24	0.00	0.00	0.00	17.16	9.82	9.53	0.00	16.70	0.00	13.02	7.62	0.00	10.64	0.00	0.00
05/05/2023	0.00	6.61	0.00	11.27	12.29	0.00	9.99	13.25	0.00	0.00	0.00	15.65	9.07	7.40	0.00	16.48	0.00	9.36	6.10	0.00	7.33	0.00	0.00
06/05/2023	0.00	7.14	0.00	9.22	11.97	0.00	8.30	11.68	0.00	0.00	0.00	15.50	7.49	7.88	0.00	15.99	0.00	9.30	4.99	0.00	6.43	0.00	0.00
07/05/2023	0.20	8.56	0.00	9.49	13.26	0.00	9.46	13.33	0.00	0.00	0.00	16.59	7.25	10.59	0.00	17.38	0.00	11.91	4.76	0.00	6.71	0.00	0.00
08/05/2023	0.00	9.62	0.00	10.08	12.65	0.00	9.81	11.95	0.00	0.00	0.00	15.15	7.03	9.91	0.00	14.52	0.00	9.87	5.10	0.00	6.61	0.00	0.00
09/05/2023	0.00	9.87	0.00	11.03	12.85	0.00	11.91	12.41	0.00	0.00	0.00	14.94	6.58	9.67	0.00	13.58	0.00	10.61	5.77	0.00	7.26	0.00	0.00
10/05/2023	0.00	9.73	0.00	11.90	12.95	0.00	13.39	13.21	0.00	0.00	0.00	15.73	6.70	9.59	0.00	13.55	0.00	9.29	5.63	0.00	7.47	0.00	0.00
11/05/2023	0.00	10.27	0.00	12.57	13.16	0.00	12.36	13.14	0.00	0.00	0.00	15.83	6.88	8.43	0.00	13.31	0.00	10.78	5.61	0.00	8.24	0.00	0.00
12/05/2023	0.00	34.34	0.00	40.31	42.70	0.00	43.67	44.51	0.00	0.00	0.00	34.27	25.06	37.21	0.00	44.10	0.00	33.45	16.01	0.00	25.73	0.00	0.00
13/05/2023	0.00	28.42	0.00	32.41	29.07	0.00	29.90	32.18	0.00	0.00	0.00	32.13	22.31	26.17	0.00	31.46	0.00	30.76	15.27	0.00	27.58	0.00	0.00
14/05/2023	7.59	19.29	0.06	25.57	24.80	1.07	24.78	21.46	0.08	0.00	0.00	27.55	15.08	20.11	0.20	25.63	0.00	21.31	11.99	22.70	22.16	5.23	4.16
15/05/2023	16.76	20.16	0.17	28.36	29.82	18.65	28.97	25.73	15.02	0.00	14.35	33.04	14.93	24.62	7.96	31.11	1.01	19.83	13.92	34.25	23.18	5.21	15.84
16/05/2023	31.46	25.90	17.77	34.55	37.18	28.67	34.35	30.95	35.15	4.59	33.71	40.57	18.58	29.10	23.46	37.71	14.91	24.38	16.09	44.31	26.64	14.35	35.01
17/05/2023	30.63	22.66	21.94	27.28	30.43	24.92	27.00	24.93	34.07	9.23	31.78	35.17	15.85	21.50	24.17	32.67	17.50	20.38	13.81	40.32	21.72	23.52	34.00
18/05/2023	26.67	16.16	17.04	19.93	23.23	20.51	18.06	16.39	30.19	8.67	29.23	28.06	9.76	13.85	19.97	24.83	14.51	14.55	10.80	35.32	17.07	19.73	27.76
19/05/2023	27.77	17.54	16.57	24.82	27.58	26.04	24.51	23.60	31.48	9.68	33.07	31.08	9.25	20.68	23.20	28.67	16.68	16.72	10.78	35.16	20.19	23.60	29.13
20/05/2023	29.04	19.47	18.16	27.27	29.29	28.10	26.63	25.02	32.64	11.99	35.01	32.16	10.60	21.73	26.79	29.21	18.25	20.00	11.73	36.23	22.89	25.43	31.44
21/05/2023	28.15	18.75	18.79	25.57	26.80	27.08	23.82	23.78	30.70	14.88	33.84	29.75	11.81	19.61	26.99	26.83	17.51	21.65	12.84	36.23	21.89	24.35	33.04
22/05/2023	11.34	21.63	21.36	24.10	29.49	29.04	25.96	27.43	32.26	17.19	37.01	32.65	12.06	20.10	32.41	28.12	17.78	21.64	10.53	37.90	18.36	30.29	37.59
23/05/2023	7.16	13.45	14.66	14.70	17.36	18.25	15.65	14.82	21.97	10.33	26.22	22.03	7.04	10.97	26.85	17.91	11.81	12.53	6.02	27.85	10.70	20.94	26.92
24/05/2023	2.99	5.26	7.97	5.31	5.23	7.46	5.34	2.22	11.68	3.47	15.44	11.42	2.02	1.84	21.28	7.71	5.85	3.42	1.50	17.81	3.03	11.59	16.25
25/05/2023	2.47	5.40	7.62	5.58	9.44	13.62	8.73	5.07	16.55	3.24	18.65	17.31	1.52	4.06	15.90	12.12	5.37	2.55	0.73	19.03	2.88	13.85	17.14
26/05/2023	2.69	6.76	9.00	8.98	13.98	19.53	14.54	14.87	21.93	4.80	23.72	22.07	1.82	8.31	20.20	18.09	8.83	3.54	4.79	26.37	7.47	20.00	21.85
27/05/2023	4.60	13.32	14.30	16.01	22.36	30.46	26.60	28.84	31.82	9.03	37.14	31.83	3.89	16.20	31.47	28.56	14.43	9.04	6.90	35.91	14.69	30.19	33.40
28/05/2023	9.66	18.67	18.79	21.43	26.95	33.49	26.28	27.34	32.32	15.99	39.46	32.17	8.38	22.83	32.07	30.21	16.70	18.88	10.98	34.88	23.85	31.75	36.97
29/05/2023	11.21	18.45	18.70	23.18	25.97	29.42	26.86	27.25	27.64	17.74	31.87	27.02	10.56	18.31	29.62	27.78	22.82	21.20	11.74	29.60	24.58	26.79	35.14
30/05/2023	10.11	16.96	16.76	24.56	24.39	25.36	27.11	27.16	22.98	17.41	27.57	21.87	12.75	7.30	27.11	26.06	19.14	23.52	12.50	24.32	22.42	23.49	33.31
31/05/2023	7.19	12.92	13.68	18.95	19.49	19.60	20.43	20.48	17.33	15.11	22.82	16.34	10.50	1.88	23.17	19.97	14.44	20.21	9.72	18.81	18.21	17.93	29.51

Table 10. Daily drainage during the growing season. Yellow cells represent drought days, blue cells depict plant recovery days, and the blue cell the harvest (continuation).

01/06/2023	5.32	9.57	11.43	13.38	20.25	17.38	15.04	19.63	14.94	13.68	17.47	16.22	9.29	1.22	21.45	20.62	6.42	18.58	9.87	17.23	14.35	13.27	27.29
02/06/2023	8.55	13.58	13.80	9.56	23.01	10.29	19.11	14.93	14.61	23.93	15.65	18.57	16.04	1.01	19.38	20.88	5.42	17.60	6.00	17.76	10.65	9.92	24.33
03/06/2023	5.09	7.87	10.14	5.04	9.51	0.98	5.05	6.49	5.67	18.06	7.17	6.24	9.69	0.00	10.36	8.86	2.50	8.55	2.79	7.57	4.95	4.91	13.25
04/06/2023	22.88	24.58	19.43	11.43	36.11	21.74	30.35	20.27	25.45	41.60	23.16	34.23	29.33	6.86	26.03	36.24	8.61	18.14	10.95	28.90	14.50	16.26	20.24
05/06/2023	26.33	31.01	32.70	20.49	34.94	25.98	33.00	27.87	30.11	45.71	27.06	32.68	35.67	14.40	32.96	35.92	15.45	28.57	14.82	31.85	22.01	25.14	27.37
06/06/2023	38.97	31.58	44.62	24.38	33.72	35.82	31.66	28.62	44.50	45.54	38.30	30.84	35.12	16.52	37.09	34.36	25.26	31.17	16.13	44.33	25.94	39.69	45.27
07/06/2023	34.47	37.16	42.98	26.80	39.83	33.73	39.19	34.90	39.73	45.67	36.15	36.43	42.80	23.99	36.18	40.13	23.24	37.64	17.84	40.24	31.03	33.85	43.31
08/06/2023	30.36	34.66	36.17	24.29	36.27	28.18	41.29	31.98	35.05	44.29	31.88	33.14	33.68	21.67	34.20	36.92	17.53	34.40	17.55	33.35	29.63	28.72	37.23
09/06/2023	11.16	35.34	16.00	26.30	41.11	5.74	34.72	33.05	11.45	14.17	11.01	39.12	40.85	23.73	13.55	40.28	7.51	33.15	40.17	11.09	30.70	9.45	19.47
10/06/2023	1.17	23.50	2.65	17.53	34.18	0.11	26.39	22.00	0.97	2.47	0.63	30.54	28.27	13.61	2.42	32.99	1.18	25.35	16.01	0.49	24.55	1.47	5.45
11/06/2023	0.00	14.28	0.26	11.29	23.17	0.00	16.13	12.75	0.12	0.44	0.32	19.58	17.83	5.26	0.22	22.05	0.00	15.31	8.77	0.00	16.36	0.00	0.60
12/06/2023	0.00	7.04	0.00	5.47	14.61	0.00	10.17	7.17	0.00	0.00	0.00	11.16	12.89	1.09	0.00	13.68	0.00	8.16	5.26	0.00	8.75	0.00	0.00
13/06/2023	0.00	4.68	0.00	2.86	14.09	0.00	9.25	5.23	0.00	0.00	0.00	10.39	10.42	0.15	0.00	15.08	0.00	6.11	4.11	0.00	7.15	0.00	0.00
14/06/2023	0.00	10.73	0.00	4.22	27.12	0.00	24.96	14.32	0.00	0.00	0.00	30.47	22.42	7.99	0.00	24.90	0.00	9.83	9.79	0.00	12.25	0.00	0.00
15/06/2023	0.00	14.69	0.00	5.73	23.43	0.00	21.11	18.89	0.00	0.00	0.00	21.53	26.57	6.79	0.00	22.67	0.00	14.30	9.86	0.00	13.97	0.00	0.00
16/06/2023	0.00	16.61	0.00	6.03	23.91	0.00	21.50	19.86	0.00	0.00	0.00	22.18	28.00	6.24	0.00	23.17	0.00	18.03	9.47	0.00	15.43	0.00	0.00
17/06/2023	0.00	8.48	0.00	4.25	9.95	0.00	7.69	9.48	0.00	0.00	0.00	9.10	17.37	0.07	0.00	9.12	0.00	9.66	3.82	0.00	7.35	0.00	0.00
18/06/2023	0.00	4.76	0.00	0.98	7.62	0.00	5.69	6.67	0.00	0.00	0.00	6.70	15.00	0.18	0.00	7.87	0.00	5.53	2.17	0.00	3.90	0.00	0.00
19/06/2023	0.00	13.34	0.00	1.07	20.80	0.00	24.40	22.67	0.00	0.00	0.00	6.70	34.08	0.88	0.00	21.07	0.00	12.65	4.88	0.00	9.46	0.00	0.00
20/06/2023	5.04	28.58	0.36	3.44	30.57	0.00	35.21	35.66	0.00	5.59	0.00	29.54	42.67	10.71	0.31	33.60	0.00	28.60	12.92	21.22	24.45	0.00	1.12
21/06/2023	18.22	23.11	23.56	11.22	26.44	7.15	29.05	26.20	11.86	27.59	4.98	26.26	33.68	13.36	11.77	27.10	0.00	24.59	12.95	29.58	26.24	13.93	16.90
22/06/2023	19.17	12.63	25.13	9.24	17.89	16.34	21.43	15.59	22.18	33.53	12.30	19.72	24.63	7.33	19.40	20.83	7.44	14.37	9.28	28.01	20.51	20.92	21.11
23/06/2023	20.28	8.37	22.17	6.72	17.88	20.75	24.80	13.27	28.82	35.52	15.12	22.89	23.05	7.80	21.50	22.48	14.72	9.22	8.73	29.26	18.89	25.85	20.19
24/06/2023	19.81	5.28	20.68	5.54	14.43	21.54	19.63	10.14	29.56	34.20	15.20	18.51	20.15	5.71	21.45	20.70	14.04	6.57	7.28	28.85	17.29	25.40	18.64
25/06/2023	18.20	3.80	20.05	3.56	11.18	19.31	16.98	9.67	27.57	35.29	14.09	15.78	20.71	4.16	23.31	18.14	12.95	4.92	6.36	27.09	14.98	22.92	17.82
26/06/2023	17.06	2.66	18.99	2.13	7.64	17.09	14.03	9.10	25.49	34.90	12.49	12.76	18.83	1.20	23.05	14.87	10.77	3.30	4.40	24.88	12.19	19.49	16.96
27/06/2023	17.20	1.84	18.95	1.26	6.56	16.35	13.77	8.73	24.93	35.03	11.75	12.73	19.65	0.53	23.63	13.82	10.14	2.51	4.46	24.36	11.36	18.96	16.16
28/06/2023	17.50	1.42	19.13	0.81	5.76	16.67	14.31	8.22	25.41	35.65	11.73	13.42	20.77	0.53	24.03	14.46	10.22	2.48	3.75	23.79	11.03	19.26	16.45
29/06/2023	19.84	1.56	21.03	0.95	6.31	19.75	19.19	10.44	28.15	38.54	14.17	9.22	22.98	0.37	26.59	16.70	11.46	2.57	4.64	25.88	13.54	21.91	18.18
30/06/2023	25.75	5.50	26.37	4.31	19.36	27.34	30.25	22.99	36.69	45.45	20.31	20.70	30.37	11.35	33.60	31.01	18.57	7.17	11.73	33.61	24.21	31.20	22.68
01/07/2023	26.46	16.89	29.10	24.63	30.29	31.66	37.35	31.80	40.20	45.31	22.51	29.18	31.71	22.69	33.50	34.91	22.25	19.37	15.98	39.94	31.39	36.00	32.63
02/07/2023	17.80	15.49	24.04	22.12	18.70	21.25	20.85	21.50	28.05	33.00	15.76	16.74	20.95	12.72	25.01	20.32	14.20	19.42	11.19	30.17	25.30	24.96	28.81
03/07/2023	14.50	14.33	21.71	19.39	18.50	21.20	23.59	22.83	25.07	33.58	13.63	17.78	21.69	12.01	23.91	19.92	13.62	18.07	9.46	26.36	20.95	22.85	26.78
04/07/2023	11.76	12.26	20.38	17.07	15.69	18.87	18.60	20.40	22.97	31.76	12.29	17.75	20.46	8.13	22.17	17.98	12.23	14.88	8.36	24.31	18.42	19.18	24.60
05/07/2023	10.42	10.89	18.44	15.52	14.30	18.67	18.55	17.36	21.96	30.44	11.72	18.12	18.65	7.08	20.94	16.92	10.92	13.27	6.05	23.27	16.37	19.41	22.74
06/07/2023	12.43	12.94	19.55	17.90	17.97	21.29	22.88	20.96	24.84	34.25	13.43	23.40	22.99	11.74	24.36	23.82	12.52	13.83	8.42	25.18	18.82	21.94	23.18
07/07/2023	14.89	14.60	21.70	20.83	20.83	23.47	24.65	23.44	27.32	36.83	15.07	28.87	25.22	14.38	23.52	27.97	13.78	15.71	10.89	28.15	22.20	25.01	25.06
08/07/2023	16.00	16.31	23.34	22.86	21.93	23.82	26.52	24.43	28.28	37.35	15.61	16.46	26.84	15.57	12.64	16.18	14.65	16.59	10.99	29.04	24.60	26.30	25.76
09/07/2023	16.07	17.48	23.74	23.00	21.06	23.47	27.15	23.28	27.99	36.66	15.02	16.05	26.87	14.40	28.38	15.71	13.89	16.70	11.03	28.67	24.15	25.80	25.38
10/07/2023	15.50	16.21	22.39	21.87	19.40	23.62	25.97	21.41	27.68	35.94	14.37	14.85	26.46	13.48	27.43	14.69	13.43	15.50	10.30	28.13	23.51	24.62	24.27
11/07/2023	14.92	15.56	21.93	21.50	19.11	22.41	24.97	22.59	26.60	0.72	13.42	14.93	27.34	12.85	25.77	14.43	12.75	14.72	10.75	27.61	22.72	23.53	23.55
12/07/2023	18.62	16.18	23.77	24.15	25.39	28.31	34.90	25.42	33.53	1.02	16.67	28.93	32.53	17.55	28.41	18.91	15.47	15.56	14.67	33.85	26.63	29.15	24.19
13/07/2023	22.40	16.78	25.15	27.85	27.75	30.43	36.99	26.20	38.14	0.95	18.78	35.10	35.09	19.26	31.54	21.38	17.90	16.03	17.63	37.76	30.63	32.95	25.32

CHANGE IN STORAGE

Table 11. Daily change in storage during the growing season. Yellow cells represent drought days, blue cells depict plant recovery days, and the blue cell the harvest.

Treatment	60D	5W	5D	15W	60W	15D	15W	5W	60D	5D	15D	60W	5W	15W	5D	60W	60D	5W	60W	60D	15W	15D	5D
Date/Lysimeter	1	2	4	7	8	9	10	11	12	13	15	16	17	18	19	20	21	22	24	25	26	27	28
20/04/2023	3.70	0.85	0.47	3.67	3.43	4.25	2.67	1.75	3.10	2.51	7.39	1.76	1.89	3.16	4.30	6.75	3.53	1.50	6.06	3.80	5.18	2.07	2.77
21/04/2023	-0.48	0.73	-0.87	1.17	0.92	4.04	0.59	0.90	0.75	0.70	2.04	0.68	0.45	1.58	1.41	1.93	0.23	0.69	1.55	0.42	1.33	-0.12	1.56
22/04/2023	-2.71	-0.39	-0.77	0.14	-0.10	0.01	0.39	0.29	-0.07	-0.26	0.65	-0.38	-0.34	-0.23	-0.16	0.05	-0.93	-0.15	-1.51	0.00	0.26	-2.01	0.16
23/04/2023	0.46	-0.07	2.33	2.96	3.65	1.79	3.25	3.50	3.40	2.53	2.15	2.95	2.77	2.40	3.62	2.54	1.65	2.07	3.47	1.10	3.23	-0.22	1.63
24/04/2023	-4.79	-3.14	-3.72	-4.35	-5.85	-4.06	-4.67	-4.26	-5.17	-3.86	-3.39	-4.29	-3.73	-4.46	-3.53	-3.62	-4.17	-3.71	-2.46	-2.54	-3.92	-6.61	-4.31
25/04/2023	-1.00	1.71	1.44	1.62	3.80	1.48	1.48	1.91	1.36	2.00	2.81	2.34	2.15	1.68	1.91	2.95	1.00	1.92	3.09	2.64	1.71	-1.46	2.67
26/04/2023	-1.89	-1.86	-1.77	-2.35	-3.35	-3.02	-2.22	-2.09	-2.85	-2.12	-1.64	-1.24	-2.25	-1.68	-2.00	-1.71	-2.08	-2.07	-1.37	-1.51	-3.13	-5.74	-2.60
27/04/2023	-10.18	-3.87	-6.24	-5.57	-4.83	-7.49	-5.38	-5.89	-6.87	-6.95	-6.14	-4.62	-5.56	-4.20	-6.71	-5.36	-8.00	-5.11	-6.04	-6.93	-7.15	-10.44	-7.90
28/04/2023	-19.49	4.51	-18.66	7.36	9.46	-19.77	8.47	5.96	-20.49	-20.63	-20.40	8.67	2.63	5.12	-23.04	8.40	-19.56	6.38	8.11	-18.70	8.49	-20.31	-20.19
29/04/2023	-17.88	4.68	-16.11	5.95	5.19	-15.81	6.35	4.80	-18.19	-18.62	-16.43	3.77	4.45	2.39	-19.08	4.61	-17.00	6.51	10.49	-14.92	9.10	-16.05	-20.69
30/04/2023	-17.11	2.65	-16.07	3.06	4.17	-16.12	2.21	2.58	-17.98	-17.30	-16.77	2.80	2.26	0.87	-20.28	3.74	-16.79	4.52	6.58	-15.28	6.11	-17.41	-15.56
01/05/2023	-20.27	1.37	-17.77	2.65	0.31	-20.71	1.51	1.82	-21.03	-19.91	-20.27	0.30	2.31	1.07	-21.50	-0.61	-19.13	6.98	-0.97	-16.09	3.14	-18.32	-20.46
02/05/2023	-20.76	0.68	-19.05	0.88	-1.27	-21.26	0.56	0.37	-21.75	-20.02	-20.08	-1.67	1.75	-1.02	-22.46	-2.79	-18.87	-0.78	-3.67	-14.11	1.00	-19.53	-18.53
03/05/2023	-23.91	-2.64	-20.73	-2.31	-2.41	-24.02	-5.95	-4.60	-23.60	-21.50	-23.24	-1.89	-3.47	-3.43	-24.16	-3.67	-22.07	-0.76	-2.55	-18.72	-1.84	-22.29	-19.60
04/05/2023	-27.28	-2.77	-25.60	-10.05	-8.40	-30.72	-8.73	-9.71	-29.44	-28.23	-29.53	-5.61	-7.27	-3.64	-27.43	-4.34	-26.19	-13.72	-6.30	-21.85	-12.30	-28.10	-23.54
05/05/2023	-14.93	-9.32	-16.76	-11.49	-6.62	-23.89	-9.29	-9.84	-16.26	-19.24	-20.49	-5.66	-10.12	-7.00	-18.64	-6.61	-17.47	-8.86	-9.17	-10.86	-11.08	-20.12	-13.99
06/05/2023	-9.58	2.05	-9.70	1.68	1.69	-17.95	2.41	2.19	-9.62	-11.95	-12.79	1.49	0.36	2.37	-12.03	3.15	-11.96	3.71	2.72	-6.91	0.41	-11.38	-12.76
07/05/2023	-8.61	5.35	-6.51	5.82	4.19	-7.69	4.71	6.85	-6.74	-7.63	-7.62	4.13	4.97	4.65	-7.36	4.58	-9.10	7.10	5.49	-3.04	7.23	-8.98	-4.18
08/05/2023	-8.78	1.24	-11.51	6.06	3.55	-15.70	6.06	3.02	-9.92	-13.23	-14.83	1.02	0.37	1.82	-16.62	1.10	-13.12	0.34	1.03	-7.55	3.72	-13.80	-16.33
09/05/2023	-4.99	-2.27	-10.38	1.38	-1.71	-13.25	-1.54	-2.37	-9.06	-13.21	-12.21	-1.69	-2.37	-1.63	-13.50	-2.97	-11.54	-2.06	-2.46	-13.81	0.29	-5.38	-11.48
10/05/2023	-2.98	-4.87	1.17	-4.29	-4.01	-1.92	-4.73	-4.51	1.34	-0.66	-1.60	-4.49	-5.72	-4.38	-0.44	-4.76	0.15	-4.38	-3.87	0.29	-4.04	-1.31	-0.41
11/05/2023	-11.32	-7.81	-10.63	-7.89	-6.74	-13.74	-6.58	-7.85	-9.53	-10.81	-9.84	-4.26	-4.80	-5.55	-10.64	-6.32	-11.07	-10.78	-4.29	-7.69	-10.28	-11.24	-12.74
12/05/2023	94.01	20.69	88.93	20.00	16.45	102.17	12.97	16.18	102.16	92.16	98.12	17.49	19.07	14.25	110.15	17.13	82.09	26.81	18.90	97.77	30.37	101.09	107.95
13/05/2023	35.39	-0.57	32.45	-0.89	-1.45	42.19	0.71	0.72	39.09	31.28	41.67	-2.40	0.39	0.51	40.89	-1.24	30.32	-2.81	-0.16	36.76	-0.36	40.56	46.78
14/05/2023	22.88	-7.23	19.03	-3.83	-1.90	27.51	-2.15	-5.00	32.50	17.51	32.43	-2.86	-7.15	-2.54	23.09	-2.83	24.39	-9.52	-4.80	11.74	-5.38	25.20	21.80
15/05/2023	19.13	-0.16	24.52	-0.02	0.12	14.51	-1.01	-1.03	23.53	21.73	23.65	0.56	0.27	-0.67	22.14	-0.28	27.13	0.28	0.42	6.73	0.48	23.53	17.11
16/05/2023	3.77	-4.50	6.41	-7.88	-5.63	0.23	-7.40	-7.52	3.50	14.89	2.51	-3.73	-2.88	-6.10	5.39	-5.26	10.16	-8.02	-3.04	-2.36	-6.72	6.12	-2.52
17/05/2023	-0.26	-5.75	-0.53	-7.21	-4.92	-0.90	-7.07	-7.70	-0.03	5.94	-0.91	-3.82	-8.58	-8.36	-0.47	-4.44	0.60	-7.60	-2.32	-1.34	-5.54	-2.92	-3.90
18/05/2023	7.29	3.65	3.86	9.98	7.45	12.39	9.32	10.07	5.65	8.39	7.74	5.62	2.98	9.37	10.18	8.23	9.13	8.47	6.97	7.10	7.62	6.65	8.79
19/05/2023	6.80	6.05	7.53	9.90	6.52	10.26	7.27	7.22	6.36	10.97	6.22	5.48	6.87	6.23	9.52	5.37	7.82	10.18	6.11	6.23	8.25	6.30	9.91
20/05/2023	0.61	0.50	3.14	-2.73	-0.37	3.32	-0.17	-2.56	0.53	5.07	0.52	-0.81	1.47	-0.72	1.94	-0.68	1.19	1.07	0.88	0.13	0.00	0.32	3.35
21/05/2023	-7.76	-4.98	-3.81	-11.56	-7.35	-8.05	-7.08	-11.27	-6.82	-5.73	-7.52	-6.29	-6.84	-8.78	-8.58	-10.75	-6.60	-13.05	-13.47	-9.87	-13.04	-8.39	-7.28
22/05/2023	-1.32	-3.72	-0.32	-5.36	-4.41	-0.65	-8.95	-4.88	-2.15	-1.29	-2.41	-5.94	-6.47	-7.44	-2.23	-2.47	-2.21	-3.80	-3.04	-0.34	-3.72	0.20	-0.20
23/05/2023	-7.00	-7.18	-4.13	-9.83	-5.25	-1.83	-8.34	-4.93	-3.10	-3.89	-3.83	-7.69	-10.96	-9.61	-11.30	-6.67	-5.63	-7.42	-7.97	-4.15	-6.77	-2.37	-4.01
24/05/2023	-12.67	-10.63	-7.94	-14.30	-6.09	-3.01	-7.72	-4.98	-4.06	-6.48	-5.25	-9.43	-15.44	-11.77	-20.37	-10.88	-9.04	-11.04	-12.90	-7.97	-9.82	-4.95	-7.82
25/05/2023	5.83	6.47	7.91	8.64	10.74	11.39	9.78	14.88	11.91	9.03	8.52	8.16	6.74	9.67	8.52	12.36	11.83	8.68	15.37	13.75	13.48	10.97	14.16
26/05/2023	2.15	4.48	5.77	2.59	3.06	2.13	3.17	2.71	2.09	5.93	2.93	1.04	5.94	3.90	1.68	1.11	2.31	5.49	2.65	-0.04	4.72	0.82	6.82
27/05/2023	15.54	15.77	16.90	13.70	12.63	8.92	9.10	14.16	8.74	17.17	8.54	8.41	18.06	12.33	9.48	7.38	11.01	19.35	9.30	5.59	17.59	9.35	15.90
28/05/2023	9.17	2.59	4.37	9.25	5.52	3.81	5.97	6.00	0.78	7.07	-0.54	6.17	7.23	0.26	0.37	2.50	2.26	8.44	1.08	2.40	7.70	4.61	2.80
29/05/2023	2.40	0.80	0.81	7.06	5.73	1.90	7.67	-1.43	2.04	5.28	0.68	-2.39	0.69	4.50	3.50	6.55	0.21	-0.34	-2.78	-3.81	4.49	3.11	-2.92
30/05/2023	-8.85	-8.98	-9.82	-8.92	-7.51	-9.99	-7.57	-8.85	-8.90	-5.57	-8.32	-10.94	-5.85	-11.61	-7.21	-8.12	-9.26	-9.11	-6.64	-10.02	-8.22	-8.24	-8.65
31/05/2023	-7.78	-6.60	-7.42	-5.39	-2.58	-7.26	-1.70	-2.56	-5.22	-3.58	-4.44	-3.36	-1.37	-7.58	-2.74	-2.26	-9.07	-5.35	-2.72	-4.77	-5.45	-4.60	-5.52

Table 11. Daily change in storage during the growing season. Yellow cells represent drought days, blue cells depict plant recovery days, and the blue cell the harvest (continuation).

01/06/2023	-8.37	-7.86	-11.27	-15.32	-3.04	-16.71	-6.53	-9.43	-5.84	-6.81	-10.48	-4.46	-7.50	-21.08	-7.50	-8.97	-11.33	-11.81	-13.93	-7.55	-14.21	-13.62	-11.41
02/06/2023	9.78	9.99	13.29	-4.37	0.38	3.62	2.62	1.17	-2.68	15.86	3.35	1.10	15.57	3.71	6.86	2.38	-0.33	1.22	-0.20	0.29	3.83	4.38	-2.05
03/06/2023	35.04	24.63	23.98	23.40	33.32	30.84	27.03	26.21	34.94	25.66	23.53	31.59	24.74	22.41	23.56	35.88	25.03	26.32	31.14	34.77	27.94	26.59	22.99
04/06/2023	-9.52	-14.38	-6.67	-8.36	-17.26	-14.80	-17.25	-15.49	-9.89	-19.61	-16.91	-18.68	-14.33	-7.15	-13.53	-16.28	-3.12	-9.84	-4.29	-9.87	-7.73	-7.45	-8.36
05/06/2023	8.79	9.93	9.94	11.17	7.01	11.32	9.01	11.13	7.88	6.65	6.92	6.01	9.91	13.94	9.10	6.15	9.24	11.94	11.24	5.59	14.74	10.83	15.41
06/06/2023	11.80	3.16	7.91	4.16	5.06	12.89	4.38	5.55	8.60	4.12	5.75	3.30	5.41	5.69	6.45	4.07	9.33	3.93	3.33	7.98	4.78	7.51	10.51
07/06/2023	-6.71	-2.75	-8.43	-1.45	-3.65	-5.12	-4.37	-3.08	-6.98	-4.84	-10.93	-4.48	-3.10	-3.60	-6.74	-5.60	-8.84	-4.48	-4.22	-9.02	-1.91	-7.11	-7.54
08/06/2023	10.73	11.89	8.60	10.06	9.76	11.98	4.52	13.13	7.72	6.50	2.75	10.82	11.90	12.03	8.92	8.24	8.71	7.71	12.42	6.71	9.49	7.29	6.34
09/06/2023	-68.67	-17.91	-65.32	-19.47	-11.43	-62.00	-7.14	-15.44	-67.75	-55.61	-79.47	-12.44	-15.69	-17.29	-63.80	-13.72	-68.05	-15.95	-12.53	-67.68	-16.63	-67.60	-70.63
10/06/2023	-50.84	-1.83	-44.18	1.88	1.67	-45.18	2.96	0.04	-47.70	-37.13	#¡REF!	1.12	1.63	2.61	-44.34	4.09	-46.93	-1.07	3.69	-44.13	1.33	-47.80	-46.20
11/06/2023	-41.23	-12.88	-37.50	-13.47	-7.95	-41.90	-5.42	-9.99	-41.67	-36.59	-36.60	-7.80	-5.84	-7.21	-39.20	-6.20	-40.16	-11.21	-5.18	-27.77	-10.69	-41.55	-37.86
12/06/2023	-23.71	-13.76	-27.20	-18.84	-8.83	-30.51	-8.22	-11.57	-25.33	-36.16	-23.69	-7.83	-6.84	-12.95	-33.37	-7.94	-29.13	-13.44	-8.26	-17.05	-12.76	-25.48	-31.22
13/06/2023	-11.79	24.52	-11.84	23.41	26.31	-12.87	26.72	26.55	-11.21	-15.48	-9.63	24.54	24.03	25.70	-14.81	23.27	-11.76	22.98	24.03	-8.87	23.24	-12.19	-13.26
14/06/2023	-9.51	-9.48	-10.38	-4.95	-12.54	-11.39	-13.81	-9.32	-10.60	-16.70	-9.17	-18.45	-10.49	-10.28	-16.13	-10.49	-10.98	-4.34	-7.62	-7.61	-5.09	-9.78	-12.46
15/06/2023	14.26	4.78	12.14	5.30	1.00	10.90	1.30	5.52	13.83	12.43	11.05	-7.27	5.01	2.66	10.63	1.56	10.40	7.12	1.51	16.13	3.86	12.14	13.13
16/06/2023	-15.31	-7.32	-16.34	-11.40	-7.43	-15.35	-7.12	-6.74	-15.61	-17.18	-11.43	-27.53	-4.23	-8.82	-16.12	-6.44	-15.22	-8.48	-5.23	-14.41	-8.43	-13.68	-17.72
17/06/2023	-1.04	-18.05	-2.42	-31.30	-12.94	-3.33	-11.99	-12.13	-1.47	-3.07	-1.47	-11.19	-9.99	-20.43	-3.82	-11.91	-3.26	-16.05	-19.15	-1.57	-17.83	-2.52	-1.76
18/06/2023	-0.71	3.02	-1.91	-4.93	3.69	-2.25	5.88	6.19	-1.33	-1.70	-1.82	-4.16	7.42	-2.36	-2.27	5.13	-2.24	4.76	6.18	0.29	3.36	-1.45	-1.78
19/06/2023	81.87	22.37	85.19	20.89	14.30	80.44	13.94	17.57	84.14	94.68	71.00	16.86	13.11	21.61	88.20	15.38	77.77	23.66	20.89	84.16	24.43	80.76	85.52
20/06/2023	70.17	14.92	80.12	28.83	10.66	74.11	11.51	11.98	77.75	87.22	64.77	11.10	9.43	20.82	82.78	8.97	70.55	12.82	13.66	57.15	17.94	73.56	80.02
21/06/2023	6.05	-19.48	1.14	-8.50	-11.85	17.13	-9.35	-14.35	19.45	10.47	16.93	-10.94	-12.25	-9.90	14.64	-9.62	24.89	-18.49	-11.36	2.00	-11.61	13.89	6.72
22/06/2023	5.29	-14.23	-0.90	-6.67	-2.28	9.51	-0.39	-2.07	9.19	4.70	5.99	0.97	-1.87	-1.13	8.06	-0.08	14.79	-7.32	-2.56	3.38	-3.03	8.38	1.93
23/06/2023	4.74	-10.73	-1.14	-4.25	-3.70	5.70	-3.17	-3.38	3.80	0.78	2.55	-1.61	-3.11	-2.04	3.48	-0.45	3.28	-5.80	-0.67	2.54	-0.85	3.60	-1.13
24/06/2023	1.63	-11.39	-3.46	-8.32	-5.36	0.36	-2.37	-4.25	-0.41	-0.28	-0.89	-3.66	-3.02	-4.11	1.27	-2.48	-0.43	-6.69	-3.13	0.01	-3.40	-0.51	-3.44
25/06/2023	-0.06	-9.81	-1.41	-9.67	-8.15	-1.82	-4.37	-3.67	-2.87	0.73	-3.26	-2.58	-2.45	-7.29	1.16	-4.80	-3.00	-5.50	-4.12	-1.90	-5.41	-2.43	-1.93
26/06/2023	1.37	-4.98	1.31	-5.73	-2.99	0.94	-0.19	-0.92	1.01	1.99	-0.18	-2.49	1.00	-3.24	1.56	0.15	1.09	-2.28	-0.21	1.18	-1.16	1.57	0.82
27/06/2023	3.53	-3.51	2.04	-2.95	-1.40	2.71	1.70	0.86	1.80	2.38	1.16	-1.04	2.03	-1.92	2.56	1.73	1.48	-0.91	0.64	1.45	0.51	2.10	2.17
28/06/2023	2.88	-2.69	2.95	-1.10	-0.25	1.90	1.86	1.36	2.04	2.48	1.47	-3.32	1.38	-0.97	1.76	1.38	1.64	-1.89	1.70	2.02	1.74	2.01	2.58
29/06/2023	6.52	9.95	6.79	13.05	9.42	6.28	6.43	8.71	4.37	4.33	5.66	12.65	6.59	11.19	6.00	7.92	6.51	10.56	7.65	4.65	7.80	5.12	8.55
30/06/2023	6.20	22.84	7.04	35.03	19.32	12.22	11.23	13.14	6.84	1.97	6.10	13.93	3.52	20.20	0.98	7.91	11.65	23.68	14.57	12.11	14.15	9.15	16.44
01/07/2023	1.54	9.21	3.41	11.80	3.16	5.63	0.95	2.26	-0.25	0.03	0.53	15.96	-0.18	5.39	0.29	-0.54	1.52	8.66	1.80	1.54	4.85	1.83	5.08
02/07/2023	-8.71	-4.40	-5.64	-4.37	-5.44	-3.14	-1.34	-2.40	-7.59	-2.89	-5.85	-5.34	-2.53	-2.38	-5.01	-4.06	-5.96	-6.06	-6.52	-8.09	-9.14	-4.66	-6.61
03/07/2023	-4.62	-2.53	-2.08	-1.67	-2.73	-1.37	-4.33	-3.32	-2.69	-1.18	-2.68	-3.31	-2.45	-3.36	-1.80	-2.97	-4.12	-2.95	-4.23	-1.75	-4.20	-2.16	-3.71
04/07/2023	-5.71	-5.21	-4.77	-3.71	-4.72	-4.31	-2.67	-5.34	-3.75	-3.05	-3.23	-3.22	-3.29	-3.63	-2.56	-3.16	-4.95	-6.62	-1.77	-3.08	-5.79	-1.84	-7.17
05/07/2023	3.71	4.47	4.33	5.16	5.35	3.37	4.21	5.06	3.84	4.56	3.36	-1.79	3.44	4.27	2.89	3.67	3.24	4.08	1.95	4.57	4.97	3.98	2.10
06/07/2023	4.58	4.89	5.51	6.49	4.23	3.33	3.10	3.69	3.04	2.56	3.49	-0.54	3.56	4.16	3.73	-0.17	3.40	5.06	4.77	4.40	4.77	4.20	4.16
07/07/2023	3.63	3.97	4.14	4.81	3.15	2.42	2.74	1.50	2.14	1.17	1.60	1.60	2.00	1.91	2.06	0.85	2.78	1.81	0.81	2.24	2.75	1.89	3.11
08/07/2023	-0.35	0.51	0.34	0.72	-1.29	0.15	-0.37	-1.29	-1.38	-0.62	-1.24	-0.91	-0.24	-0.91	-3.01	-0.91	-1.03	-0.56	-0.53	-2.72	-0.01	-0.51	0.10
09/07/2023	-1.11	-0.79	-0.80	-0.81	-1.45	-0.45	-1.35	-0.99	-0.79	-1.17	-0.91	-0.85	-0.12	-0.90	0.33	-0.85	-1.70	-2.50	-0.25	-0.30	-1.23	-0.76	-1.62
10/07/2023	-14.51	-3.96	-5.16	-7.54	-14.78	-16.92	-28.87	-10.22	-23.03	-18.14	-12.37	-14.54	-20.42	-15.80	-14.78	-14.54	-15.26	-6.11	-14.29	-8.54	-15.58	-13.61	-4.65
11/07/2023	-4.57	-6.61	-4.86	-5.35	-5.33	-3.44	-2.08	-5.85	-2.92	-3.08	-3.19	-3.12	-2.82	-3.60	-3.71	-3.12	-4.84	-3.62	-0.91	-2.46	-2.93	-1.37	-7.14
12/07/2023	7.33	1.40	4.19	4.78	3.77	5.38	2.95	1.45	6.89	2.87	3.88	4.32	2.09	2.32	0.81	4.32	5.17	0.37	4.87	6.93	6.70	5.94	2.75
13/07/2023	0.90	-0.14	1.33	-2.52	-2.68	0.94	-0.65	-2.77	-0.88	-1.01	-1.23	-1.94	-0.03	-1.67	-1.33	-1.94	-2.60	-1.08	-1.20	-0.95	0.31	-0.66	-1.42

ACTUAL EVAPOTRANSPIRATION

Table 12. Daily actual evapotranspiration during the growing season. Yellow cells represent drought days, blue cells depict plant recovery days, and the blue cell the harvest.

Treatment	60D	5W	5D	15W	60W	15D	15W	5W	60D	5D	15D	60W	5W	15W	5D	60W	60D	5W	60W	60D	15W	15D	5D
Date/Lysimeter	1	2	4	7	8	9	10	11	12	13	15	16	17	18	19	20	21	22	24	25	26	27	28
20/04/2023	7.82	11.25	9.61	12.39	13.91	14.05	12.52	13.84	13.00	12.22	9.01	12.30	10.42	11.14	12.24	9.79	10.93	11.84	7.04	11.96	13.52	13.07	14.82
21/04/2023	11.38	12.07	12.34	15.42	15.39	13.34	15.50	15.92	15.52	15.54	13.97	14.49	13.78	13.52	16.80	15.21	14.30	13.92	14.17	16.02	17.26	15.07	17.47
22/04/2023	14.15	13.66	12.98	16.60	17.22	17.31	16.07	16.11	16.17	16.79	14.55	15.58	15.11	15.35	18.35	17.19	15.47	14.96	17.23	16.10	18.38	16.79	19.04
23/04/2023	10.75	14.10	10.22	13.06	10.45	14.16	12.47	12.96	13.30	13.24	12.97	11.83	10.97	11.75	14.20	14.25	12.80	12.67	12.47	14.36	14.95	14.64	15.30
24/04/2023	16.94	16.52	16.19	20.77	21.03	21.70	20.38	19.89	21.20	20.43	19.67	18.85	17.80	19.38	21.98	21.61	19.38	18.07	19.50	20.01	22.55	21.90	23.13
25/04/2023	17.03	16.69	15.59	19.47	17.94	20.49	18.97	18.93	20.32	19.92	18.32	17.69	17.02	17.84	21.90	19.99	18.72	17.55	19.02	18.80	21.60	21.07	22.28
26/04/2023	18.83	18.85	18.27	22.47	23.11	24.64	21.50	23.50	24.59	23.65	21.59	20.58	19.86	19.92	24.30	22.98	21.51	20.74	20.86	21.09	25.98	25.05	28.38
27/04/2023	27.16	20.98	22.41	27.04	22.37	30.89	25.78	26.57	28.28	27.74	26.82	23.77	23.64	25.08	29.58	27.72	27.75	23.73	26.06	27.82	30.26	30.47	31.23
28/04/2023	18.03	15.68	14.75	19.41	17.64	18.93	18.01	19.02	18.01	18.13	17.73	17.45	16.68	18.89	20.31	19.79	17.22	19.33	16.72	15.62	21.32	19.67	19.33
29/04/2023	17.38	13.78	13.49	17.97	15.14	15.81	15.79	17.14	16.87	15.66	15.57	15.90	14.53	18.37	17.32	18.89	15.96	18.99	15.76	13.64	19.76	15.75	16.16
30/04/2023	16.79	14.71	14.39	20.21	16.04	16.12	17.90	19.74	16.96	15.68	16.11	17.74	16.48	20.69	18.96	20.57	15.96	19.50	18.13	14.14	22.05	17.41	13.70
01/05/2023	20.27	15.47	16.63	19.09	19.29	20.71	18.99	20.16	20.67	18.57	19.83	20.11	16.67	21.27	20.55	23.64	18.89	16.73	25.71	15.71	24.42	18.32	18.51
02/05/2023	20.76	15.47	18.53	20.20	21.02	21.26	18.95	20.69	21.43	19.64	20.08	22.20	16.78	22.52	22.10	26.57	18.87	22.35	28.30	14.11	26.23	19.53	18.30
03/05/2023	23.91	21.29	20.54	24.03	23.52	24.02	23.82	26.43	23.60	21.50	23.24	23.05	23.45	24.12	24.16	28.59	22.07	26.43	29.26	18.72	30.99	22.29	19.60
04/05/2023	27.28	21.07	25.60	31.83	30.64	30.72	31.26	30.58	29.44	28.23	29.53	25.39	23.62	25.34	27.43	23.59	26.19	31.30	26.73	21.85	35.92	28.10	23.54
05/05/2023	23.90	36.85	28.65	42.62	37.97	37.80	41.05	42.74	28.97	32.62	31.72	34.12	36.31	39.81	33.68	36.81	27.30	42.30	40.69	23.69	46.83	32.72	29.52
06/05/2023	21.35	28.55	21.52	32.31	30.43	31.82	31.86	33.77	22.56	25.71	23.79	27.47	29.06	30.72	27.44	27.14	22.18	31.36	29.73	20.60	36.03	22.79	24.74
07/05/2023	19.65	23.69	18.37	27.59	25.93	19.37	28.07	27.30	19.27	20.79	18.13	22.90	23.61	24.35	21.84	21.55	17.25	26.10	24.08	14.95	28.47	20.67	16.45
08/05/2023	8.78	20.54	11.51	19.87	19.30	15.70	19.93	20.71	9.92	13.23	14.83	19.24	19.71	21.28	16.62	20.57	13.12	21.21	23.35	7.55	25.65	13.80	16.33
09/05/2023	9.99	24.32	10.38	24.07	24.49	13.25	25.36	25.98	9.06	13.21	12.21	22.53	23.57	25.15	13.50	26.25	11.54	23.40	26.14	13.81	28.10	10.38	11.48
10/05/2023	12.98	32.54	8.83	33.53	31.55	11.92	32.14	33.24	8.66	10.66	11.60	29.85	31.04	32.44	10.44	33.88	9.85	33.35	33.17	9.71	37.32	11.31	10.41
11/05/2023	11.32	39.57	10.63	40.60	38.49	13.74	38.73	41.60	9.53	10.81	9.84	34.14	33.86	38.68	10.64	39.57	11.07	43.27	36.77	7.69	46.97	11.24	12.74
12/05/2023	18.49	35.09	14.78	36.11	34.49	22.08	37.73	39.64	18.21	14.53	18.09	37.37	30.92	37.79	17.26	35.21	16.89	34.70	42.41	20.38	40.25	15.74	15.00
13/05/2023	19.99	30.52	17.74	31.46	30.69	21.01	31.64	32.15	18.92	18.62	19.40	28.90	27.86	31.59	21.88	30.08	19.87	31.54	32.82	21.18	34.82	18.03	16.77
14/05/2023	23.77	35.75	22.84	37.26	34.75	29.92	35.90	37.81	24.91	24.19	24.85	32.91	33.75	36.29	29.31	36.15	24.54	35.68	39.70	21.86	41.14	25.00	24.81
15/05/2023	26.75	37.98	25.85	39.73	37.02	33.69	39.66	40.93	27.89	28.05	27.82	33.88	35.17	38.52	31.68	36.46	28.61	37.83	39.91	23.75	42.20	32.67	31.10
16/05/2023	37.78	39.94	34.49	51.84	46.51	48.24	51.23	51.65	39.52	37.90	39.19	42.54	42.23	50.18	42.83	46.45	40.16	49.82	50.19	33.66	56.21	49.29	40.47
17/05/2023	43.10	44.36	37.43	58.55	52.64	55.85	57.86	58.81	43.53	43.14	45.53	47.59	49.57	59.59	50.16	52.32	47.47	56.36	52.51	38.31	61.82	47.44	45.14
18/05/2023	28.59	29.61	25.27	38.15	36.20	34.31	39.11	38.34	30.49	28.04	29.37	32.90	31.49	38.23	31.52	35.27	31.77	36.82	35.09	23.51	42.25	34.23	26.92
19/05/2023	27.09	25.71	22.09	33.65	32.22	31.10	35.05	34.78	27.71	24.67	27.34	30.04	29.52	35.37	29.71	33.69	30.53	32.57	37.04	23.04	37.94	32.25	24.21
20/05/2023	31.80	29.19	24.67	42.81	36.83	35.81	39.95	41.87	31.88	27.80	30.34	34.51	33.43	41.21	33.80	39.13	35.45	37.87	40.95	28.08	43.29	36.56	28.15
21/05/2023	39.78	35.14	30.91	53.25	45.35	47.38	49.38	51.19	39.93	35.60	39.38	41.45	40.18	50.60	43.19	49.63	43.12	49.82	52.24	36.30	56.10	46.47	36.89
22/05/2023	47.15	46.44	39.35	65.35	56.01	56.26	65.44	62.17	49.45	42.88	48.32	54.54	53.30	65.30	51.64	57.63	51.92	58.23	58.40	41.87	67.73	47.23	43.74
23/05/2023	50.56	49.47	41.87	69.81	59.11	58.55	65.87	62.89	51.31	44.47	51.21	57.40	55.13	67.54	54.94	62.00	53.33	60.53	60.34	46.18	68.90	50.31	47.46
24/05/2023	53.97	52.49	44.39	74.26	62.20	60.85	66.30	63.62	53.16	46.06	54.11	60.26	56.97	69.78	58.24	66.37	54.74	62.84	62.28	50.49	70.06	53.40	51.17
25/05/2023	44.54	44.18	36.95	60.19	52.77	48.32	54.91	52.58	43.95	38.06	45.30	48.15	42.90	53.81	44.24	48.76	43.60	53.56	40.87	41.66	54.99	42.50	38.84
26/05/2023	47.91	45.21	38.41	64.66	55.07	54.45	56.77	54.54	47.40	41.03	48.21	50.14	45.17	57.86	49.13	55.70	50.02	57.68	53.39	45.13	61.81	49.72	42.16
27/05/2023	41.41	41.67	35.10	57.94	50.36	47.70	52.51	48.69	44.13	36.32	42.88	46.36	41.23	53.22	44.65	49.27	46.50	51.37	49.76	41.05	53.76	42.37	36.91
28/05/2023	31.76	34.57	28.93	42.59	36.29	38.42	41.43	39.48	35.33	27.21	34.58	31.31	36.59	44.88	36.92	39.03	38.95	37.64	43.57	32.23	42.52	32.35	28.52
29/05/2023	32.58	33.33	29.76	35.35	30.52	36.35	30.07	42.77	31.64	25.08	32.58	38.86	37.79	37.81	32.18	30.42	29.61	39.00	42.86	35.82	35.64	30.83	32.84
30/05/2023	46.44	44.19	41.39	50.28	43.55	51.40	45.41	48.64	46.16	35.25	45.96	49.52	40.95	53.48	43.87	45.02	42.76	47.24	56.66	45.28	49.97	44.97	40.78
31/05/2023	49.01	46.09	42.87	53.30	45.23	54.67	47.52	50.79	49.54	36.47	47.55	46.97	39.22	54.44	44.44	46.34	50.64	48.35	55.71	47.09	52.75	48.37	42.38

Table 12. Daily actual evapotranspiration during the growing season. Yellow cells represent drought days, blue cells depict plant recovery days, and the blue cell the harvest (continuation).

01/06/2023	56.54	54.59	51.81	67.15	52.08	65.08	56.50	62.18	59.03	43.15	57.79	55.27	49.41	66.83	54.54	58.73	67.57	58.58	74.08	57.75	63.70	60.42	54.09
02/06/2023	62.25	53.47	50.18	70.19	57.14	61.26	56.20	61.09	68.10	37.97	54.64	57.96	43.20	67.82	49.83	58.50	70.17	57.18	77.11	62.82	60.93	58.22	53.25
03/06/2023	40.45	44.54	43.14	46.94	37.72	43.35	45.85	44.49	39.42	34.03	42.94	39.80	40.38	50.14	42.16	37.02	47.73	41.12	48.98	38.54	42.52	41.02	39.28
04/06/2023	47.08	41.83	38.21	48.15	40.80	43.99	40.36	47.25	44.26	30.55	43.83	41.81	36.12	48.79	39.78	40.24	49.93	42.99	54.29	40.05	44.40	39.93	40.20
05/06/2023	47.51	41.16	37.90	48.77	40.20	42.53	39.01	44.95	44.35	30.99	44.33	42.58	34.98	47.81	39.64	40.25	51.40	40.69	56.84	42.49	43.56	40.15	39.55
06/06/2023	44.75	38.34	36.76	43.70	36.43	39.48	36.71	39.95	41.38	42.49	42.55	38.62	30.50	45.07	46.96	36.01	50.12	36.70	54.67	39.86	39.92	37.72	36.41
07/06/2023	54.11	47.18	45.25	55.22	45.85	50.22	46.35	51.16	49.67	42.31	54.07	47.44	40.46	56.00	51.62	47.93	60.78	47.31	70.75	50.36	50.91	49.17	45.94
08/06/2023	40.28	34.01	33.88	45.45	35.04	38.72	34.90	36.66	38.79	31.68	42.89	34.64	34.27	42.08	37.76	37.02	49.21	35.91	53.20	40.91	40.79	39.39	37.35
09/06/2023	57.51	53.66	49.32	65.96	50.94	56.25	54.83	54.69	56.30	41.44	68.45	52.05	46.66	63.75	50.25	54.39	60.53	50.98	52.18	56.58	58.47	58.15	51.16
10/06/2023	49.67	50.45	41.53	56.21	46.66	45.07	46.62	51.23	46.73	34.66	49.22	47.44	40.84	54.61	41.92	46.03	45.75	47.14	54.56	43.63	49.70	46.33	40.75
11/06/2023	41.23	55.34	37.24	63.69	51.80	41.90	51.02	54.53	41.55	36.15	36.28	53.19	44.16	59.63	38.99	52.38	40.16	51.72	58.63	27.77	56.04	41.55	37.26
12/06/2023	23.71	63.04	27.20	74.19	60.65	30.51	59.87	61.90	25.33	36.16	23.69	60.98	49.29	69.38	33.37	61.28	29.13	60.74	63.62	17.05	64.88	25.48	31.22
13/06/2023	11.79	26.91	11.84	34.35	25.76	12.87	25.19	25.21	11.21	15.48	9.63	29.02	21.07	31.16	14.81	28.44	11.76	26.03	32.02	8.87	29.07	12.19	13.26
14/06/2023	9.51	54.11	10.38	61.27	51.05	11.39	50.35	51.27	10.60	16.70	9.17	48.57	41.89	59.09	16.13	51.87	10.98	48.13	57.05	7.61	53.81	9.78	12.46
15/06/2023	16.41	54.82	16.51	60.66	51.55	17.38	50.52	50.13	16.60	16.85	14.71	56.64	40.82	57.77	18.67	51.62	17.12	48.92	56.94	13.90	53.22	14.65	16.95
16/06/2023	15.31	65.37	16.34	78.25	62.78	15.35	59.03	63.36	15.61	17.18	11.43	72.70	48.36	69.65	16.12	62.86	15.22	62.23	67.22	14.41	64.85	13.68	17.72
17/06/2023	17.98	73.37	18.22	88.14	68.07	18.00	67.58	67.63	17.85	18.62	15.33	58.78	55.61	78.15	19.61	67.47	16.77	65.41	74.20	16.63	71.79	16.86	17.53
18/06/2023	19.17	57.53	18.63	67.59	55.43	19.04	52.79	53.20	18.94	18.80	15.68	59.21	41.59	61.86	19.80	54.09	16.99	52.94	52.50	17.69	55.84	16.98	19.87
19/06/2023	32.73	55.20	27.12	66.15	54.88	30.39	51.54	51.61	29.99	20.89	24.24	56.39	40.86	59.97	26.36	52.29	24.93	49.87	55.72	28.30	53.30	25.34	29.21
20/06/2023	37.20	45.43	30.27	54.83	46.72	35.16	42.52	42.91	33.76	21.28	29.96	57.39	35.18	49.91	28.98	43.64	32.07	42.15	51.45	31.82	43.95	31.92	31.74
21/06/2023	52.37	62.99	41.00	71.82	61.04	49.46	56.09	55.75	45.54	30.48	42.01	57.07	43.90	65.95	40.26	57.21	46.72	57.25	65.24	43.72	58.96	42.78	43.75
22/06/2023	53.60	69.36	42.01	73.40	61.76	48.36	55.12	55.06	46.39	31.39	45.06	48.76	43.14	62.18	39.40	56.29	51.52	57.60	59.72	44.98	58.00	42.55	45.45
23/06/2023	58.35	71.24	46.59	78.93	68.54	52.79	59.96	59.77	50.74	34.65	49.89	53.73	47.27	65.99	42.35	59.90	59.99	62.08	61.88	45.58	62.71	47.69	50.99
24/06/2023	60.70	73.44	48.76	82.50	72.01	56.50	63.10	62.65	53.14	35.42	52.49	60.14	48.26	71.76	44.28	61.66	61.74	63.58	66.68	51.47	64.97	50.01	52.51
25/06/2023	63.49	76.85	51.57	85.50	77.45	61.25	67.20	66.74	56.84	38.01	55.74	63.98	51.89	76.42	47.61	66.73	66.22	67.52	69.47	54.87	69.32	54.16	56.65
26/06/2023	62.88	73.68	50.08	82.46	75.43	60.28	65.55	64.21	55.17	37.12	54.35	66.08	49.91	75.80	47.32	65.12	64.46	66.53	68.44	53.87	67.88	53.71	54.32
27/06/2023	60.01	72.74	48.96	80.53	74.60	59.36	63.70	62.03	54.38	36.39	53.08	66.10	47.91	74.39	45.79	64.11	63.94	66.15	67.67	53.69	66.91	53.51	53.89
28/06/2023	60.27	71.72	47.65	78.93	74.08	60.08	62.71	63.02	53.80	35.54	53.06	67.04	47.41	74.33	46.18	64.07	64.26	65.71	68.34	54.07	66.15	54.07	53.09
29/06/2023	51.86	58.15	41.11	62.83	61.78	50.52	52.35	52.49	46.36	29.38	45.46	50.60	38.73	60.74	37.97	51.15	53.96	52.52	57.12	46.05	54.98	46.28	43.64
30/06/2023	49.30	41.91	36.28	38.82	41.29	38.55	37.10	36.12	38.16	26.40	39.25	48.58	35.58	40.87	37.26	40.58	44.55	36.35	46.04	33.88	39.92	34.48	31.99
01/07/2023	50.13	43.23	36.37	40.51	43.88	39.72	39.39	37.03	38.99	26.62	41.95	35.43	36.07	43.55	36.87	41.37	47.89	35.77	49.15	35.12	40.49	36.04	31.66
02/07/2023	48.14	41.37	33.75	38.35	43.28	37.88	36.78	34.53	37.30	24.35	37.10	43.75	32.95	41.97	32.87	39.51	44.36	34.92	44.84	33.99	39.05	32.59	30.64
03/07/2023	54.58	47.34	38.82	44.44	48.62	43.27	42.63	40.54	42.66	29.20	40.64	48.13	38.66	48.02	38.21	46.45	50.88	40.19	52.47	38.74	45.42	38.79	36.61
04/07/2023	58.98	52.49	43.21	49.39	53.79	47.54	46.27	45.80	46.98	32.95	43.14	45.19	40.88	52.29	41.13	49.58	53.40	47.90	52.32	42.77	49.75	42.05	42.30
05/07/2023	48.83	42.96	34.87	40.53	43.78	38.17	38.47	37.91	38.43	25.35	36.41	44.86	34.00	43.65	34.08	39.73	44.05	36.34	45.21	34.09	38.96	34.64	33.74
06/07/2023	47.34	41.25	33.47	37.94	42.17	36.93	35.66	36.02	37.39	24.44	35.52	36.62	31.23	41.38	31.91	39.05	44.38	35.46	44.01	33.62	37.30	32.12	32.39
07/07/2023	45.72	40.50	32.64	36.27	40.48	35.53	34.25	35.35	35.94	23.43	35.36	36.34	30.43	41.15	34.56	34.62	44.01	35.16	44.59	32.82	36.43	32.17	31.75
08/07/2023	48.78	42.84	34.96	38.77	43.95	37.97	35.51	38.07	38.20	24.94	37.82	51.26	31.72	43.05	50.83	48.96	47.34	36.51	47.03	37.50	37.56	33.26	34.52
09/07/2023	48.91	42.22	35.49	39.65	44.50	38.36	35.37	37.65	38.07	25.78	37.24	47.71	30.44	43.06	31.16	47.94	47.11	37.69	44.40	34.65	38.42	33.69	35.61
10/07/2023	45.38	42.45	34.43	37.74	42.27	35.67	33.88	36.78	36.54	27.78	34.01	37.60	27.54	39.89	30.20	37.88	42.20	34.87	39.68	31.25	35.20	30.48	34.32
11/07/2023	53.68	51.08	41.50	46.11	50.71	42.42	38.72	43.87	41.64	59.58	41.56	49.65	32.91	47.28	37.88	49.22	51.66	40.81	45.51	37.29	41.02	36.90	41.74
12/07/2023	56.82	55.18	44.04	50.51	53.76	45.42	41.32	47.94	43.44	66.95	45.79	47.32	35.68	53.11	44.78	55.20	55.97	48.81	53.67	40.40	45.04	40.86	46.48
13/07/2023	58.59	55.59	45.19	53.37	57.28	46.97	43.08	50.65	46.01	69.18	48.62	45.20	34.32	54.78	42.66	56.28	60.12	48.37	52.75	42.81	46.91	42.59	48.25

APPENDIX 7. DATA COLLECTION OF LEAF AREA INDEX BEFORE AND AFTER DROUGHT TRIALS

Table 13. Data collection of leaf area index before and after drought trials.

Treatment	April 25 (before 1st drought trial)	May 30 (between drought trials)	June 22 (after 2nd drought trial)	July 3 (end of the season)
5WD	2.39	3.40	4.31	3.27
	2.65	3.63	3.70	3.62
	2.75	3.87	4.44	4.08
	2.23	4.04	4.30	4.18
5WW	2.50	3.51	4.43	4.19
	2.44	4.12	4.92	4.05
	2.23	3.71	4.04	3.82
	2.24	3.63	4.81	3.71
15WD	3.00	3.98	4.44	3.92
	2.96	3.75	4.11	3.80
	2.53	4.06	4.00	3.69
	2.48	3.75	5.04	3.67
15WW	2.30	4.08	5.01	3.85
	2.75	3.97	4.63	3.87
	2.24	4.31	5.42	4.28
	2.57	3.95	5.16	3.82
60WD	2.73	3.90	4.91	4.24
	2.79	3.91	4.18	3.55
	2.55	3.92	4.40	4.05
	2.04	3.46	4.32	3.84
60WW	2.41	4.04	4.37	4.16
	2.27	3.90	5.00	3.97
	2.30	3.76	4.50	4.11
	2.15	3.69	5.62	4.01

APPENDIX 8. LAI ON CRITICAL DROUGHT DAYS

Table 14. LAI (m^2 m^{-2}) on critical drought days in both trials.

Treatment	LAI (m^2 m^{-2})	
	May 11 1st drought trial	June 15 2nd drought trial
5WD	2.06	3.65
	2.33	3.48
	3.12	3.9
	2.46	3.9
5WW	2.49	4.49
	3.27	4.68
	3.14	4.43
	2.9	4.43
15WD	2.53	3.55
	2.62	3.64
	2.6	3.64
	2.81	3.67
15WW	2.97	4.29
	3.28	4.17
	3.66	4.91
	3.01	4.67
60WD	2.52	3.3
	2.54	3.73
	3.02	3.8
	2.29	3.4
60WW	2.73	3.77
	3.01	4.66
	2.53	4.18
	3.29	4.53

APPENDIX 9. DROUGHT VISUAL ASSESSMENT

Table 15. Drought visual assessment during critical drought days. Score 5, "high drought effects" indicates that leaves have dropped and the existence of extreme curling leaves; score 2.5, "medium drought effects" expresses that leaves have not dropped and the presence of some curling leaves; and score 0, "no drought effects" points out that leaves have not dropped and the inexistence of curling leaves.

Lys. Number	Treatment	11/5/2023 1st drought	14-06-2022 2nd drought	15-06-2023 2nd drought	16-06-2023 2nd drought	18-06-2024 2nd drought
1	**60WD**	4	3.5	3	3.5	3.5
3	**15WD**	4	4	3	4	3.5
4	**5WD**	3	3.5	3	3.5	3
9	**15WD**	3	3	2.5	4	3
12	**60WD**	3	3.5	3	3.5	3
13	**5WD**	3	3.5	3	3	2.5
15	**15WD**	3	4	3	3.5	2.5
19	**5WD**	3	3.5	2.5	3	2.5
21	**60WD**	3	3.5	3	3.5	3
25	**60WD**	3	4	3	4	3
27	**15WD**	4	4	3	3.5	3
28	**5WD**	3	4	3	3.5	3.5
Average 60WD		3.1	3.6	3.0	3.6	3.1
Average 15WD		3.3	3.8	2.9	3.8	3.0
Average 5WD		2.8	3.6	2.9	3.3	2.9

APPENDIX 10. VISUAL EFFECTS OF POTASSIUM ON GRAPEVINE'S CANOPY

Figure 32. Drone images to visualize the effects of potassium on the canopy of the grapevines (Drone model Mavic Mini 2, brand DJI). Image A corresponds to June 22, while image B to July 6. Red titles are trees not integrated in the analysis of the present research.

APPENDIX 11. IMPACT OF POTASSIUM AVAILABILITY AND HEAT ON BERRIES

K-5 TREATMENTS

5WD TREATMENT

Figure 33. Impact of potassium availability and heat on berries, 5WD treatment in lysimeter 4.

Figure 34. Impact of potassium availability and heat on berries, 5WD treatment in lysimeter 13.

Figure 35. Impact of potassium availability and heat on berries, 5WD treatment in lysimeter 19.

Figure 36. Impact of potassium availability and heat on berries, 5WD treatment in lysimeter 28.

5WW TREATMENT

Figure 37. Impact of potassium availability and heat on berries, 5WW treatment in lysimeter 2.

Figure 38. Impact of potassium availability and heat on berries, 5WW treatment in lysimeter 11.

Figure 39. Impact of potassium availability and heat on berries, 5WW treatment in lysimeter 17.

Figure 40. Impact of potassium availability and heat on berries, 5WW treatment in lysimeter 22.

K15 TREATMENTS

15WD TREATMENT

Figure 41. Impact of potassium availability and heat on berries, 15WD treatment in lysimeter 27.

15WW TREATMENT

Figure 42. Impact of potassium availability and heat on berries, 15WW treatment in lysimeter 26.

K60 TREATMENTS

60WD TREATMENT

Figure 43. Impact of potassium availability and heat on berries, 60WD treatment in lysimeter 25.

60WW TREATMENT

Figure 44. Impact of potassium availability and heat on berries, 60WW treatment in lysimeter 24.

APPENDIX 12. DROUGHT EFFECTS ON HARVEST

Table 16. Data of yield, water productivity, number of clusters, average cluster and berry weight, brix degrees, and pH per treatment (n=4, except for 15WD where n=3).

Treatment	Yield per tree (kg)	Water productivity (kg m³)	Number of clusters per tree	Brix degress (°Bx)	Average cluster weight (kg)	Average berry weight (gr)	pH
5WW	3.64	1.09	11	13.0	0.331	4.76	3.38
	11.82	3.42	46	15.0	0.257	4.90	3.34
	22.74	7.95	83	16.1	0.274	4.94	3.48
	6.78	2.01	29	15.0	0.234	4.68	3.58
5WD	6.17	2.53	26	17.2	0.237	5.42	3.49
	15.86	7.03	68	13.1	0.233	4.34	3.37
	16.03	5.91	59	14.1	0.272	5.78	3.51
	5.32	2.04	21	11.0	0.253	5.14	3.46
15WW	9.53	2.47	32	16.2	0.298	5.31	3.72
	29.73	8.80	77	15.1	0.386	6.48	3.44
	18.47	4.96	40	16.0	0.462	5.86	3.64
	17.45	4.77	52	15.0	0.336	6.58	3.74
15WD	12.53	6.35	31	14.0	0.404	7.27	3.71
	18.79	5.64	60	15.0	0.313	6.28	3.75
	15.30	6.17	41	13.2	0.373	6.62	3.51
	16.69	ND	49	12.5	0.341	6.64	3.45
60WW	17.15	4.96	47	13.5	0.365	7.30	3.88
	18.60	5.58	41	17.2	0.454	5.49	3.7
	21.32	6.25	54	15.5	0.395	6.64	3.64
	18.07	4.86	53	15.2	0.341	6.87	3.76
60WD	17.05	5.85	33	15.5	0.517	7.75	3.76
	23.73	8.59	59	15.0	0.402	6.59	3.85
	18.60	6.24	57	12.5	0.326	6.43	3.62
	11.08	4.35	34	14.0	0.326	6.47	3.81